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Acquisition reform: Real solutions

Shifting fortunes for commercial X-band

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Deep space 2023: The art of the possible

"The object of your mission is to explore the Missouri River, and such principal streams of it, as, by its course and communication with the waters of the Pacific Ocean...may offer the most direct and practicable water-communication across the continent, for the purposes of commerce."

—Thomas Jefferson to Meriwether Lewis, 1803.

President Jefferson's order to Meriwether Lewis inaugurating the Lewis and Clark expedition offers the nation a model for guiding its explorations of Earth-Moon space. The U.S. should make deep space not only an arena of scientific exploration, but also a fertile economic frontier where private enterprise and industry can thrive. The guiding mission for the U.S and NASA in the coming decade should be to explore Earth-Moon space and tap the resources found there—*for the purposes of commerce.*

"NASA's Strategic Direction," a National Research Council report issued in December, stated that the agency's progress toward achieving its long-term priorities is hampered by a lack of national consensus on its strategic goals and objectives. Another serious obstacle is the mismatch between its directed goals and the congressionally allocated budget. Because current law restricts NASA from reorganizing its personnel and infrastructure more efficiently, the agency cannot use its limited resources more wisely in pursuit of long-term goals. The panel suggested that the White House take the lead in developing a national consensus on space policy goals and provide a budget better suited to the directives it gives NASA.

Far from boosting NASA's resources, the Congress passed a budget in March cutting about a billion dollars through the rest of this fiscal year. Whatever the funding details for 2013 and 2014, neither the White House nor the Congress will make any major shifts in the agency's overall goals. A change in NASA fortunes requires a change in strategic direction.

The SpaceX Dragon was captured and berthed at the ISS by Expedition 34 using Canadarm II on March 3. Future commercial vehicles will be essential in supplying propellant and hardware to exploration outposts in Earth-Moon space.

How far in a decade?

On the current course, by 2023 NASA astronauts will still be working aboard the ISS, an outpost heading into its twilight years. Commercial transport firms will be handling resupply, and NASA will be leasing private spacecraft for the launch and return of its space station crews. ISS lifeboat services also will have gone commercial, shifting that duty to the U.S. for the first time since Russia's Soyuz assumed the role in 2000. NASA will announce a stream of interesting scientific discoveries from the ISS, but no scientific or technological breakthroughs will have reached the marketplace. In public perception, the ISS and its mission will still have a very low profile.

By 2023, NASA's Orion will have launched just three times, and only once with crew aboard. The heavy-lift Space Launch System (SLS) might have two missions under its belt, perhaps propelling the first Orion crew around the Moon in 2021. But these milestones assume flawless performance for Orion and SLS in their initial shakedowns. Budget projections for the 2020s envision NASA flying the SLS/Orion only once every couple of years. With progress and momentum so slow, and without the ability to equal even Apollo achievements, a future president and Congress could easily decide to end NASA's entire human space exploration enterprise.

NASA hopes its announced deep space goal, an expedition beyond the Moon to a near-Earth asteroid (NEA) by 2025, will finally revive its fortunes. However, progress toward that goal has been elusive: Orion and SLS are hardly on a fast track, and the agency's ideal targets for such expeditions have yet to be discovered.

NASA has not even allotted funds to conduct the half-billion-dollar survey mission, critical to finding a target for the administration's 2025 asteroid goal. As NASA's own Small Bodies Assessment Group reported in January, "Funding a NEO survey mission has the collateral benefits of identifying potential NEO targets for ISRU [in-situ resource utilization] and robotic science missions, as well as Potentially Hazardous Objects for planetary defense." Yet no funds to commence the needed space-based search (0.3% of the NASA budget over 10 years) can be found.

Neither the scientific discoveries to be made in deep space nor the prospect of losing leadership to China in that arena seem to energize U.S. policymakers. If science and foreign policy are insufficient prods, perhaps we should turn to another incentive, one that has sustained U.S. progress for more than two centuries: entrepreneurial commercial development.

A deep-space mission to a near-Earth asteroid may reignite NASA's fortunes.

Reviving a mission

Fortunately for NASA and the nation, the agency is already empowered to help open up the deep space economic frontier. Congress, in the National Aeronautics and Space Act (as amended in 2010), declares: "*…the general welfare of the United States requires that the Administration seek and encourage, to the maximum extent possible, the fullest commercial use of space.*"

The Moon and nearby asteroids offer abundant raw materials, and the Sun provides nearly limitless energy to power industrial activity in space. The president, then, should direct NASA to expand the $300-billion global space sector by using its deep space programs to actively open the resources of Earth-Moon space to economic development.

The millions of NEAs are cosmic leftovers from the formation of the solar system, constantly streaming through Earth-Moon space. Asteroid 2012 DA14, for example, passed within Earth's geosynchronous satellite ring on February 15; at 45 m in diameter, its mass is about 130,000 metric tons. The NEA population harbors more than half a million objects as large as or larger than DA14, many on orbits accessible to NASA and private spacecraft. To date, we have discovered just 10,000, barely 1% of the total population.

Two asteroid mining companies, Planetary Resources and Deep Space Industries, have already announced their intentions to go after these natural sources of water, metals, and volatile organic compounds. They plan to find asteroidal water first and sell it to space agencies, later using NEA metals, organic compounds, and rare elements as feedstock for construction and industrial processes. The initial benefit derived from the asteroids (as from the Moon) is water for use as propellant, to replace hydrogen and oxygen launched at greater cost

The Pan-STARRS 1 telescope atop Haleakala, Maui, is part of NASA's ground-based near-Earth object search program. NASA's key first step toward locating and assessing asteroid resources should be to mount a comprehensive survey of the hundreds of thousands of smaller asteroids (about 50 m and up) in accessible, Earth-like orbits. Courtesy Rob Ratkowski.

NASA astronauts Kevin Ford (foreground), Expedition 34 commander, and Tom Marshburn, flight engineer, worked with the combustion integrated rack multiuser droplet combustion apparatus in the ISS Destiny laboratory on January 9. The ISS can host commercial/NASA tests of equipment and processors needed to exploit resources on the low-gravity surfaces of near-Earth asteroids.

from Earth. Even a 500-ton asteroid (about 7 m across) could harbor 100 tons of water, worth about $5 billion at today's launch prices.

Space resources, step by step

Both companies expect to take at least a decade to bootstrap their way to prospecting missions on distant asteroids. NASA can speed this progress appreciably.

As a matter of policy, the agency should put industrial use of space resources on a par with its science and technology goals as it plans to send astronauts to lunar distance and beyond. By fast-tracking physical access to in-space resources on both NEAs and the Moon, NASA can make these materials available not only to astronauts, but also to commercial industry.

Specifically, this means accelerating the search for water ice at the lunar poles, and returning samples and bulk asteroidal material for industrial assessment and testing. It's not enough just to invite industry to help NASA in these efforts; the agency should use its launch systems, or harness commercial partners to put companies in direct contact with space raw materials.

First, NASA can announce its intention to spur prospecting for space resources by starting a focused search for small asteroids using existing and off-the-shelf ground-based systems, such as the ATLAS search telescope just funded by the agency. It can evaluate this year and next the practicality of a robotic asteroid capture and return mission (see "Delivering on a promise to Columbia's explorers," March, page 14). NASA should initiate a low-cost mission to prospect for ice on the Moon using a commercially built rover and launcher.

In parallel, NASA should push ISS experiments testing asteroid surface systems and commercial resource processors aimed at exploiting water-bearing NEA regolith when available. Within five years, NASA should launch commercially built asteroid probes toward promising NEA targets, with the results guiding development of appropriate resource processors.

The shift to including commercial space activity as a NASA exploration goal, equal to science and exploration technology development, can happen quickly in a series of small but high-profile steps.

One of the ambitious elements in this sequence is a robotic capture mission to 'bring an asteroid to us.' That enterprise will be far less expensive than a human mission to an asteroid (now sliding inexorably toward 2030).

Steps to integrate commercial activities in NASA's deep-space planning

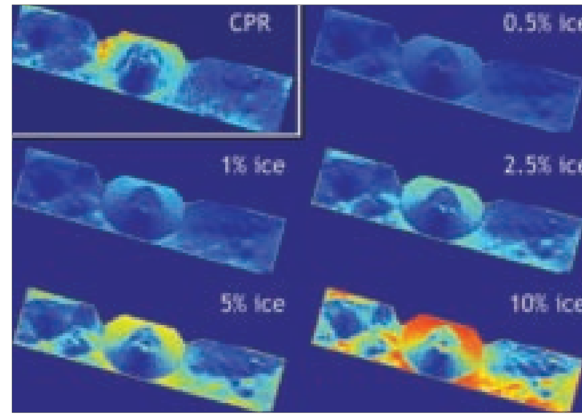
- *A search for small, accessible NEA targets using ground-based systems.*
- *ISS tests of NEA regolith collection and sampling, using simulated asteroid material.*
- *Launch of an infrared NEA discovery telescope to heliocentric orbit.*
- *Commercial ISS demonstration of water extraction from meteorite materials.*
- *NASA-commercial water ice robotic prospecting on the Moon.*
- *NASA launch of commercial probes to nearby asteroids.*
- *Launch of a NASA robotic mission to capture and return a roughly 7-m NEA to high lunar orbit.*
- *Solar electric propulsion delivers a small habitat to the Earth-Moon L2 Lagrange point.*
- *Using SLS, Orion visits the L2 habitat on the first crewed, deep-space mission.*
- *Commercial launch services deliver cargo and propellant to restock the L2 habitat.*
- *International outfitting of the L2 outpost for remote sensing of lunar resources.*
- *The first in-situ water production from lunar ice.*
- *The first lunar water samples boosted to L2 for return to Earth by Orion crews.*
- *A captured NEA placed in stable lunar orbit.*
- *L2 crews visit a captured NEA for sampling and processing demonstrations.*
- *International and commercial access (via telerobotics) to a 500-ton captured NEA.*
- *The first use of lunar-derived propellant in a launch from the Moon.*
- *The first commercial-scale extraction of asteroidal water in high lunar orbit.*
- *Competitive choice of space-derived water for propellant production: from the Moon or an NEA.*
- *Space-fueled lunar surface sorties.*
- *Space-fueled NEA expeditions.*
- *Use of lunar or NEA materials for industrial processes in Earth-Moon space.*

With a small asteroid in a stable lunar orbit, astronauts in the 2020s will have access to 500 tons of raw material, and with far less cost and complexity than putting humans on the Moon.

In fact, the U.S. should do both, but no one at NASA is proposing astronaut sorties to the Moon. That leaves small asteroid retrieval as the only means of giving robotic and human explorers access to bulk quantities of raw materials. A bonus is that asteroidal material avoids the considerable delta-V expended in getting into and out of the lunar gravity well.

These overlapping activities would begin in 2015 and culminate in deep-space asteroid expeditions in about 2030. Multiple robotic initiatives would be followed by astronaut involvement, with international and commercial participation providing telerobotic hardware, human habitats, life-support consumables, and processing machinery on the Moon and at a small captured asteroid. The payoff in the 2020s is a breakout from the 'only governments in deep space' model, where commercial firms develop the capability to supply in-space propellants and lower the overall cost of future exploration. Industry can determine what space products best match markets on or off the planet.

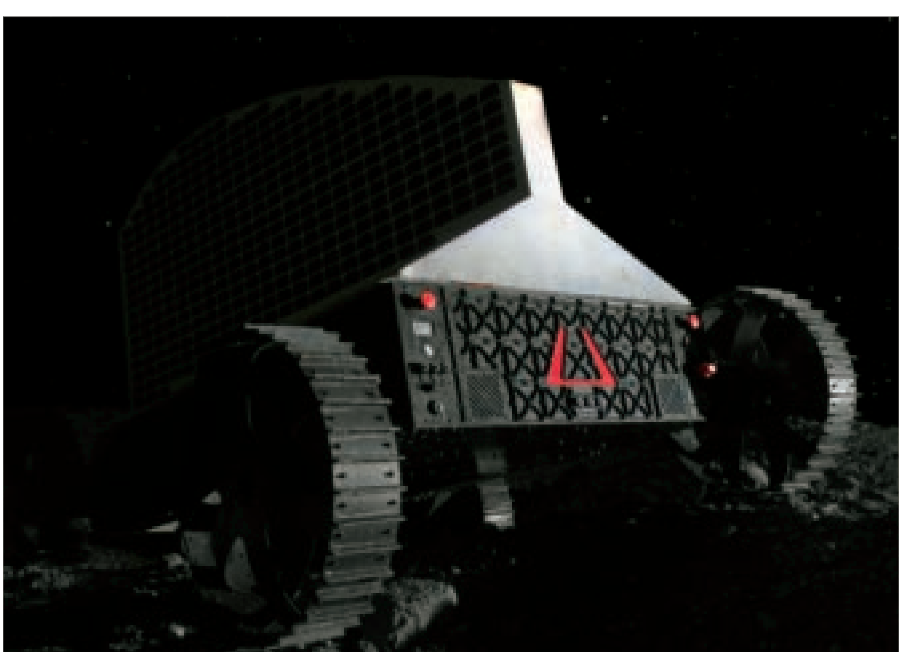
NASA should invite its ISS international partners to participate in this commercial push, too. In exchange for hardware and transportation services, the partners would gain physical access to lunar and asteroidal materials for assessment and process demonstration. Collectively, they can contribute launch services, habitats, propulsion modules, logistics flights, robotic rovers, and regolith samplers and processors. What happens after that is a matter of self-interest and competition: Those who contribute to the effort will get to pursue follow-on partnerships in pursuit of these resources (there are plenty of asteroids to go around).



Radar data indicates that the walls of Shackleton crater may hold ice. Actual observations (CPR) by LRO's mini-RF instrument are compared to calculated radar values for 0.5% to 10% ice. Credit: NASA.

Opening an economic frontier

The addition of a commercial element to NASA's deep space plans is well out of NASA's comfort zone. Jump-starting a space-supplied industrial frontier isn't a straightforward engineering challenge, like Apollo. But the shift is firmly based on the NASA charter, and a willing president and Congress can pivot to commercial exploration with the expectation of widespread support.


Commercially designed lunar ice prospectors, like this Polaris robotic rover from Astrobotic Technology, a spinoff of Carnegie Mellon University, can help NASA accelerate the search for valuable resources in Earth-Moon space. Courtesy Astrobotic Technology.

The alternative would be a continuation of the budget-constrained, sluggish pace toward a few astronaut deep-space sorties in the 2020s. Results will be meager, with nearby asteroids still out of reach, the Martian surface more so. Budgets will keep shrinking. A move to gain access to space resources will draw commercial innovation, public buy-in, private investment, and a rush to find methods of exploiting the raw materials and energy NASA first makes available.

The president's budget appeared after this column went to press, but it is unlikely that he issued new orders to NASA: No Orion sorties to EM L2, no outpost stationed above the far side of the Moon, no fast-paced, space-based search for accessible asteroid targets. Our exploration outlook for 2023 is stagnant, with a significant likelihood that we will abandon deep space to more energetic competitors. Could a goal of discovering material and industrial wealth in space turn those prospects around? We won't know until we try, as Jefferson and Lewis did.

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