Apply Flexible Path to Near-Earth Objects

< DANIEL R. ADAMO >

Three months after U.S. President Barack Obama's human space exploration policy speech at Kennedy Space Center, many advocates of near-Earth object (NEO) exploration are regarding the administration's vision with mixed emotions akin to Dr. Frankenstein's at the birth of his creation.

On the upside, we have a presidential endorsement to send humans on a NEO mission in 2025. A NEO visit's implications with respect to defending our home planet, while extending a human presence well beyond it, are compelling.

These diverse worlds are convenient steppingstones to the moons of Mars, which themselves may be large NEOs captured from solar orbit. It's arguable that a subclass of NEOs offers better prospects for human colonization than either the Moon or Mars. In addition, some NEOs will hold the most humanly accessible resources for commercial and scientific interests in space.

On the downside, we may be dressing up for a party we can't attend if we insist on a date in 2025. Here's why we're probably on a path to disappointment if we pick any particular year for our first NEO visit in our current state of ignorance.

Due to human microgravity and radiation exposure vulnerabilities, initial NEO missions will likely be limited to 180 days or less for the round trip. Satisfying this limitation, without developing warp drive or sending a supertanker's propellant mass into space, requires we keep the mileage low. It means we can't fly humans to even the most accessible and Earth-like NEO orbit unless the NEO happens to approach Earth well within 15 million kilometers (about one-tenth the distance from Earth to the sun) during the mission's timeline.

Accessibility isn't the only attribute required of a viable NEO destination. In space exploration, size definitely matters. Thanks to congressional mandates issued in 1998 (discover 90 percent of all NEOs larger than 1 kilometer in diameter by 2008) and in 2005 (discover 90 percent of all NEOs larger than 140 meters in diameter by 2020), 7,235 NEOs had been catalogued as of July 28. Despite the best intent of Congress, however, the most accessible discoveries are less than 140 meters. The expense and risk of sending humans to a NEO smaller than the spacecraft they occupy is unjustifiable. Therefore, in addition to being accessible, viable NEO destinations must be larger than 50 meters in diameter. Objects near 50 meters are capable of penetrating Earth's atmosphere and laying waste to regions tens or hundreds of kilometers wide, lending further relevance to their robotic and human exploration. A larger NEO impacting Earth could threaten civilization altogether. Only by visiting these potential sources of devastating Earth impacts can we learn their physical properties in sufficient detail to develop the most effective means of diverting them.

How many large, humanly accessible NEOs approach Earth closely enough to permit a mission of less than 180 days around 2025? Although human accessibility currently depends on paper rocket designs and innumerable mission mode possibilities (how many launches, where launch elements are assembled in space, how much consumable mass is pre-emplaced where in space, etc.), today's answer is one — asteroid 1999 AO10, which is 29 to 116 meters. Like most interplanetary mission opportunities, the Earth departure season for 1999 AO10 is confined to but a few weeks in August or September 2025, and the round trip will require about 150 days. If this opportunity is missed, the next is to 2000 SG344 (19 to 76 meters, 100 days round trip) in 2029, followed by 1999 CG9 (16 to 64 meters, 160 days round trip) in 2033.

But accessibility and size alone are insufficient for a NEO to be a viable human exploration destination. Because they are members of a diverse and virtually unexplored population, any of the NEO destinations cited above could be hazardous to human visitors. Some may spin rapidly or irregularly, some may be accompanied by orbiting moonlets, some may have ill-defined surfaces akin to cosmic quicksand, and others may erupt like a geyser if disturbed.

Our level of ignorance regarding the nature of NEOs is indeed profound. In the two visits robotic spacecraft have paid to NEOs, knowledge of the destination before arrival was limited to a rough idea of size, shape and composition. Both visits were marked by repeated challenges and revelations. To pick a specific NEO launch year and destination for human exploration now is a recipe for disappointment, particularly when cost and schedule uncertainties associated with human interplanetary space transportation development are considered.

Yet some exploration strategies being inferred from the president's speech appear destined for disappointment. There are indications from NASA that a 2025 NEO mission is considered a single-shot demonstration, effectively a publicity stunt, whose success immediately clears the way for human Mars exploration. Highly placed NASA leaders consider the current list of 32 humanly accessible NEOs (with diameters at least 50 meters and mission opportunities from 2020 through 2050) to be sufficient for our exploration purposes.

The reality is we know far less about NEOs now than the U.S. Corps of Discovery knew about the Louisiana Purchase before departing Pittsburgh in 1803 bound for the Pacific Northwest. Our current best estimates indicate we've catalogued only 3 percent of all NEOs larger than 50 meters. Of all catalogued NEOs, 48 percent have such poorly determined orbits it isn't certain when they will next be

SEE *ADAMO* PAGE 21

ADAMO FROM PAGE 19

close enough to observe from Earth. Even if a "lost" NEO is observed again, it may be difficult to associate those observations with the original discovery.

Earth-based radar tracking is capable of significantly refining a NEO orbit during a close approach. In the most favorable cases, radar can resolve shape, assess surface texture, determine rotation and detect orbiting companions. Unfortunately, radar observation opportunities are rather infrequent. Only 260 NEOs (3.6 percent of those catalogued) have been detected by radar, partly because facilities with this capability are underprioritized and underfunded with respect to NEO observation.

Spectral data, permitting gross composition to be inferred, are available for 323 NEOs (4.5 percent of those catalogued).

In summary, we know little more about a typical catalogued NEO beyond a rough estimate of size and an approximate orbit. Left unrefined, typical orbit fidelity is insufficient to reliably navigate a human vehicle toward NEO rendezvous under tight performance margins. Therefore, any human NEO exploration milestones we set now must not be cast in concrete. It's precisely because of our present ignorance that we must resist the temptation to identify specific human destinations in interplanetary space other than for conceptual "design reference mission" purposes.

This isn't our grandparents' space exploration strategy. That bygone race to the Moon more than 40 years ago was driven by international competition, while today's human aspirations in space seek international cooperation to enhance sustainability through programmatic depth and critical systems redundancies. What's required in the 21st century is a nimble, opportunistic and easily scalable exploration infrastructure ready to exploit new discoveries as they're made.

How do we dispel our NEO ignorance? To scout this unfamiliar territory, the first step is to send out our able robotic cavalry. These missions can include one-way NEO rendezvous visits and occasional round-trip sample returns. They will help identify any of the previously described hazards to human explorers, reduce navigation uncertainties, suggest otherwise unanticipated equipment required for a human visit, and assist explorers during and after that visit if longevity permits.

But these robotic scouts can target only destinations we've already catalogued. To find the hidden 97 percent of NEOs larger than 50 meters in less than 20 years, we need to survey interplanetary space from a perspective other than near-Earth. According to studies documented for NASA in 2003 and 2007 and for the National Research Council this year, the ideal perspective would be from a robotic infrared telescope of meter-class aperture stationed in a Venus-like solar orbit for five to 10 years.

If we remain shackled to Earth in our NEO survey efforts, many of the objects we seek will be lost in the sun's glare during much of the brief and infrequent interval they're close enough to observe. Operating near the orbit of Venus, a telescope detects NEOs by looking outward from the sun. Furthermore, observing from an orbit with significantly shorter period than virtually all NEOs permits the telescope to "lap" them and attain this ideal outward viewing geometry more frequently than Earthbound instruments. Consequently, the proposed survey telescope is able to significantly accelerate our NEO discovery rate and assist in maintaining orbit accuracy for all NEOs. Observing at multiple infrared wavelengths, this telescope would provide high-confidence size estimates and composition data as survey byproducts.

Without a NEO survey telescope stationed well inside Earth's orbit, even the most optimal Earth-based instruments expected to become operational this decade will leave our list of NEOs potentially accessible for exploration incomplete before 2030. In an Earthbound NEO survey scenario, some otherwise viable destinations will be discovered with insufficient notice to prepare a human visit. Others, with orbits interior to Earth's, may never be discovered. As described previously, viable human mission opportunities will typically be separated by intervals of several years until a more comprehensive NEO survey is completed. Since no survey is currently tasked with detecting NEOs down to 50 meters, adding a robotic telescope near the orbit of Venus to our tool kit could prove critical to discovery of compelling exploration destinations.

Stakeholders in NEO exploration and utilization span multiple NASA organizations. In recognition of these common aims, an integrated NASA-wide NEO exploration effort could be initiated by evaluating pertinent mission objectives within the Exploration Systems Mission Directorate, Science Mission Directorate and Space Operations Mission Directorate. Such an evaluation would identify resources to be pooled and coordinated in effective fulfillment of NEO exploration's full potential.

Finally, a disciplined "no stunts" exploration campaign mindset must become pervasive within NASA leadership. This would recognize NEOs as a diverse and strategic population worthy of sustained human and robotic exploration. To do otherwise in our rush to reach the "Pacific Ocean" at Mars, we may neglect the inner solar system's "heartland" of NEOs.

Dan Adamo is an independent astrodynamics consultant with research interests in space mission design throughout our solar system. From 1990 until 2008, he supported 60 space shuttle missions from NASA Mission Control's Flight Dynamics Officer Console. He welcomes feedback at adamod@earthlink.net.