A First Trip to the Farside of the Moon

An entirely unexplored world, with a surface area nearly twice that of the United States, lies in Earth's backyard just a few days travel away. NASA now has an opportunity to begin to explore the farside of the Moon with an affordable mission. It can use assets from both the human and robotic programs, and join together exploration and science to address fundamental questions about the origins of the Earth-Moon system and the first stars/galaxies in the early Universe.

The farside of the Moon has been mapped from orbit, but neither robots nor humans have ever landed there. Yet, it possesses one of the most interesting, oldest, and geologically-significant features in the inner solar system – the South Pole-Aitken Basin (SPA) – which may hold the key to understanding the role of large impacts on the evolution of both the Earth and Moon.

Because of the Moon's tidal locking with respect to the Earth, the farside always faces away from the Earth and is the only truly pristine radio-quiet location in the inner solar system. Thus, it is ideal for making low radio frequency observations of the first stars and galaxies, the Universe's Cosmic Dawn.

The lunar farside is dramatically different from the nearside, investigated by Apollo astronauts and by Soviet Lunokhod rovers forty years ago. The farside consists mainly of highlands with only 1% of its surface area possessing maria, the ancient impact basins now filled with volcanic lava. Maria regions dominate the appearance of the nearside. Why are these two faces of the Moon so different? This is but one of several unsolved scientific mysteries that suggests a more complex formation and history of the Moon than we previously thought.

NASA's Orion Multi-Purpose Crew Vehicle coupled with the Space Launch System (SLS) will offer an opportunity to explore the lunar farside for the first time in tandem with teleoperated landers/rovers at the end of this decade. A robotic lander and rover can be launched first on a slow trajectory to the Moon (similar to that used recently by GRAIL) followed by Orion launched on the heavy-lift SLS.

Orion would fly past the Moon for a gravity assist toward the Earth-Moon L2 Lagrange point, a gravitational balance point that is relatively stationary at about 65,000 km above the lunar farside. Orion would enter a halo or Lissajous orbit around the L2 point where both the Earth and the farside are in constant view. From their unique farside vantage point, the crew aboard Orion would teleoperate the rover to evaluate and gather geological samples from the SPA and deploy a low radio frequency antenna.

L2-Farside missions would offer a number of "firsts" for human exploration and science. They would be both the first missions by humans beyond the Moon, some 15% further into cis-lunar space than previously explored, and also the first in-situ explorations of the lunar farside. Another potential first could be participation of international partners in globally collaborative human expeditions beyond low Earth orbit.

These missions would be the first to investigate and potentially return samples from the oldest, largest, and deepest impact basin on the Moon. The smaller Schrödinger basin within SPA is a particularly promising landing site. Schrödinger is the second youngest impact basin on the Moon, is the best preserved, and its uplifted peak ring contains rock from some of the oldest episodes in lunar history that is easily accessible from the surface.

Returned rock samples could be used to test the lunar magma ocean hypothesis, determine the cadence of impacts during the basin-forming epoch, calculate the delivery of biogenic elements to Earth and any environmental consequences produced during that epoch which has been tentatively linked to the origin and evolution of life on Earth. For these and other reasons, the return to Earth of rock samples from the SPA was deemed to be one of the top planetary science priorities in the recent National Research Council's decadal survey *Vision and Voyages for Planetary Science in the Decade 2013-2022.*

L2-Farside missions could also deploy a unique polyimide film low radio frequency antenna or array in the proven radio-quiet and ionosphere-free zone of the farside. This radio antenna will be designed to detect highly redshifted signals arising from neutral hydrogen around the first stars and galaxies formed 100-200 million years after the Big Bang. These observations would be the first to measure how and when the first objects produced "first light" or Cosmic Dawn in the early Universe. Cosmic Dawn was selected as one of the top three science objectives in the NRC decadal survey *New Worlds, New Horizons in Astronomy and Astrophysics.*

Finally, this mission would be the first to demonstrate human "virtual presence" through teleoperation of rovers by astronauts in orbit to undertake complex scientific tasks on the surface of an extraterrestrial body. With a two-way speed of light latency between L2 and the farside of only 0.4 seconds, teleoperation from L2 will permit real-time control of the rover that will provide crucial operational experience for future, even more challenging destinations. This mission will validate realistic proof-of-concept exploration strategies that will be needed to explore locations where humans may not be able to visit in person, such as the -230 C shadowed craters at the lunar poles, which have recently been shown to contain water ice, as well as potential biologically-active sites on Mars.

L2-Farside missions would be far less expensive than Apollo-style sorties with human landers to the surface. Given NASA's flat notional budgets in coming years, L2-Farside missions executed in collaboration between the human and science programs are affordable missions within this decade. They address important exploration goals and the science objectives of two NRC decadal surveys in planetary science and in astrophysics. As a stepping stone to broader exploration of the solar system, these innovative, cost-effective missions are worthy of the great history and traditions of the U.S. space program.

Jack Burns is professor and director of the NASA Lunar Science Institute's (NLSI) Lunar University Network for Astrophysics Research (LUNAR) at the University of Colorado Boulder. David Kring is senior staff scientist and principal investigator of the NLSI's Center for Lunar Science and Exploration (CLSE) at the Lunar and Planetary Institute and Johnson Space Center. Joseph Lazio is principal research scientist at the Jet Propulsion Laboratory, California Institute of Technology and Deputy Director of LUNAR.