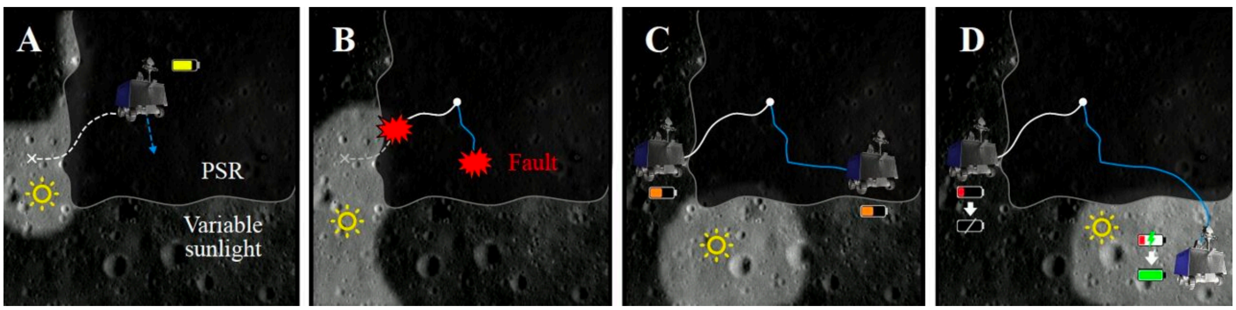
A new approach to reduce the risk of losing solar-powered rovers on the moon

August 20 2023, by Ingrid Fadelli



Conceptual overview of our approach. Most long-range traverse planning algorithms for solar-powered do not proactively account for possible navigation delays. Here, the dashed white path shows a plan that leads a rover inside a PSR to sunlight as quickly as possible, but it is not resilient against possible delays that will cause the rover to fall behind schedule and miss a critical solar charging event. On the other hand, a planning strategy that proactively accounts for delays (blue line) will take the rover on a potentially longer, but safer trajectory. Credit: Background image and VIPER rover render: NASA and Arizona State University.

NASA and other space agencies worldwide periodically send robots and automated vehicles into space to explore planets and other celestial objects in our solar system. These missions can greatly improve our understanding of the environment and resources in other parts of the solar system.

Researchers at the University of Toronto Institute for Aerospace Studies and NASA's Jet Propulsion Laboratory (JPL) recently carried out a study exploring recovery strategies that could improve the effectiveness and success of lunar explorations using solar-powered rovers. Their paper, pre-published on *arXiv*, introduces a new approach that could help solar-powered rovers to safely leave permanently shadowed regions on the moon.

"In recent years, several nations have expressed interest in exploring the lunar south pole, including the United States, China, India, Russia and others," Olivier Lamarre, the researcher who led the study, told Phys.org.

"Most of them are planning to use solar-powered rovers to explore areas that are constantly in the shade (called permanently shadowed regions, or PSRs), which we suspect might contain large quantities of water ice. As one can imagine, entering a PSR with a solar-powered rover is a risky endeavor! If the rover is delayed by faults, it may not be able to make it back to sunlight before running out of energy."

Solar-powered rovers can have numerous advantages in terms of power-efficiency, yet they are limited by their reliance on sunlight to operate. As some regions on the moon are permanently in the shadow, the rovers' reliance on sunlight can prevent them from safely exploring and then leaving these areas, causing them to run out of energy during their mission.

A key objective of the recent work by Lamarre and his colleagues was to quantify the probability of losing solar-powered rovers as they are exploring these shadowed areas on the moon. In addition, the team wished to devise an approach that could help to maximize the probability that the solar-powered rovers will safely complete their missions.

"First, we need to define what it means for a solar-powered rover to be 'safe' at the lunar south pole," Lamarre explained. "To do this, we pay attention to where the rover exits a PSR, at what time, and with how much energy left in its batteries. This gives an indication of whether the rover can hibernate in place before the next leg of its mission (and thus, remain 'safe' until then). Then, we compute an online traverse planning method that the rover can follow from any starting state (including inside of PSRs) to maximize its probability of survival."

The planning methodology outlined by Lamarre and his colleagues is referred to as a recovery policy, as it is essentially a fallback strategy that allows a rover to maximize the chance of reaching "safety" (i.e., regions where the sunlight will reach it, recharging its battery). In their paper, the researchers showed that calculating this recovery policy can be challenging in this context, as it requires several approximations that if vastly incorrect could affect the reliability of overall predictions.

"For example, time is a continuous dimension of our state space that needs to be discretized," Lamarre said.

"We need to make sure that this approximation/discretization does not dangerously skew the predictions on the probability of failure. At the lunar south pole, solar illumination is highly dynamic; nearby mountains and craters may cast large shadows on the surface. If the rover is a bit behind schedule compared to what the (approximate) policy assumes, it might miss a critical solar charging period. The same is true if it's a bit ahead of schedule compared to what the policy assumes."

As these time approximations greatly influence the reliability of recovery policies for the solar-powered rovers, Lamarre and his colleagues kept them highly conservative. This ultimately minimizes the risk of failure, while increasing the probability that the policy will remain safe during real-world missions.

"We think that this approach is useful in numerous ways," Lamarre said. "Firstly, it represents a step towards long-range autonomous mobility planning algorithms that proactively account for (or, 'reason' about) risk with solar-powered rovers. Additionally, our technique could become a useful tool for human operators as they formulate new rover missions at the lunar south pole (it could be used for landing site selection, global traverse planning and risk prediction, and more), or even support an ongoing mission through ground in the loop operation."

In the future, the recovery policy introduced by this team of researchers could be applied to real-world exploration missions on the moon, to reduce the risk of losing solar-powered rovers in shadowed regions. As the recent study was conducted in collaboration with NASA's JPL, the approach could soon be tested in various realistic lunar scenarios.

"So far, we tested our approach using orbital data of Cabeus Crater, but we're hoping to use NASA's custom solar illumination maps and apply our technique in many other areas at the lunar south pole that will, one day, be visited by robotic or crewed missions, such as Shackleton, Faustini, Nobile, Haworth and Shoemaker Craters," Lamarre added. "Also, we're currently working on a new generation of risk-predictive long-range navigation algorithms for the exploration of the lunar south pole with solar-powered rovers."

More information: Olivier Lamarre et al, Recovery Policies for Safe Exploration of Lunar Permanently Shadowed Regions by a Solar-Powered Rover, *arXiv* (2023). DOI: 10.48550/arxiv.2307.16786 rovers-moon.html