

**Lunar Outpost COSMOS Surface Mission ConOps Planning Tool: Maximizing Science Return Through Rapid Data Fusion** A.J. Gerner<sup>1</sup>, J.A. Cyrus<sup>1</sup>, F. Meyen<sup>1</sup>, and J.B. Cyrus<sup>1</sup>, <sup>1</sup>Lunar Outpost, Inc. (17700 S. Golden Rd., Ste 102, Golden, CO 80401, [AJ@LunarOutpost.com](mailto:AJ@LunarOutpost.com) )

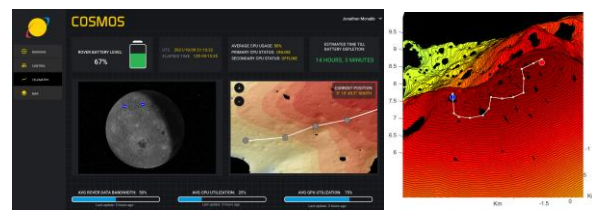
**Introduction:** Lunar Outpost is preparing to land small rovers on the Moon in 2022 and 2024; these rovers, dubbed the Mobile Autonomous Prospecting Platforms (MAPPs), have an overall length less than 50 cm and are designed to survive for a single lunar day. While the Lunar Reconnaissance Orbiter Camera (LROC) system has been used to generate detailed Digital Terrain Models (DTMs) of potential MAPP landing sites, the DTMs are typically produced at a resolution of 2-5 meters-per-pixel (mpp). Thus, hazards and obstacles of a scale that will impact MAPP rover path planning cannot be adequately resolved in the LROC DTMs. Compared to NASA Mars rover missions, the short duration of MAPP's missions dictate that decisions to alter the driving path waypoints must be made quickly and efficiently.

Many CLPS landers used to deliver MAPP to the lunar surface propose to acquire much higher-resolution digital elevation data of a relatively wide swath as they descend to the landing site. MAPP rovers also create high-resolution navigation maps of a narrow swath as they drive along the lunar surface. Lunar Outpost has developed the COSMOS lunar surface ConOps planning software, to allow the rover traverses to incorporate this high-resolution surface data and rapidly regenerate waypoints that account for a wide range of mission parameters and science objectives, maximizing MAPP's driving time and science data return.

**COSMOS:** The Lunar Outpost COSMOS system provides an iterative workflow for very rapid mission simulation and environmental data fusion, based on sensor data returned from the lunar surface in near-real-time.

The MAPP rover mission ConOps require consideration of a number of parameters when determining the optimal traverse away from the landing site. RF communications propagation, solar illumination vector, electrical power balance, thermal conditions, terrain slope and roughness, projected rover attitude in roll and pitch, and mission-specific science instrument requirements all must be evaluated when selecting MAPP waypoints. COSMOS gives the MAPP operators the ability to pull in updated, high-resolution DTMs as they become available, automate path planning based on the aforementioned criteria, rapidly assess many potential traverses to find the optimal solution, and simulate MAPP's performance using a "digital twin" rover with identical kinematics and characteristics before uplinking new waypoints to the lunar rover.

During the Planning Phase, before mission launch, a baseline traverse and waypoint set is plotted on a 3-dimensional DTM of the proposed landing site (*Fig. 1*), and the baseline waypoint set is loaded into MAPP's flight computer. As the lander descends to the lunar surface, a new, higher-resolution DTM is downlinked to mission control and uploaded into the COSMOS software, allowing the traverse to be "fine tuned" according to the discovery of new obstacles or science targets. The updated waypoints are uploaded to MAPP during post-landing commissioning, and the rover begins automated waypoint driving and obstacle avoidance between the waypoints nearest the lander, while simultaneously creating its own navigation maps onboard. Throughout the mission, navigation data from the stereoscopic navigation cameras, 360-degree panoramas, LIDAR data, and Vision-Based Navigation data are downlinked during periods of communication, and COSMOS is used to continuously fuse the new data into the mission ConOps. This iterative workflow, coupled with MAPP's onboard positioning and navigation algorithms, provides rover positioning accuracy of less than 10 cm over a 2 km rover traverse.



*Figure 1: Left: COSMOS interface and simulation environment; Right: 3D DTM with MAPP waypoints & traverse plotted.*

The COSMOS software also features a web-based interface for rover operators, allowing remote science teams to command the MAPP carrying their science instrument payload, identify science sites from freshly-downlinked mission imagery, and flag locations of interest for additional investigation. This allows the science team unparalleled control over MAPP's traverse, and maximizes the amount of science data return on short-duration surface missions. The flexibility of the COSMOS simulation environment also allows the tool to be extensible to other rover and surface vehicle dynamics, allowing for integrated mission planning between multiple vehicles, landers, and surface assets.