Designing a science program for sky-monitoring telescope based on the moon

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Projected L-CAM1 field of view from Schrodinger Basin on April 14, 2024. Credit: AstronetX

The SETI Institute teamed up with Louisiana State University (LSU) and

Mississippi State University (MSU) to help students design the science program for AstronetX PBC's first lunar-based camera (L-CAM 1). The scientific program planning is funded by a Gordon and Betty Moore Foundation grant to AstronetX. Additional funding for student participation is provided by the National Science Foundation (NSF) Research Experiences for Undergrads (REU) program at LSU.

L-CAM1 will capture images for research in astrophysics, planetary science and planetary defense. Dr. Franck Marchis, a senior planetary astronomer at the SETI Institute, leads the SETI Institute's involvement. In addition to Marchis, Dr. Tabetha Boyjian (LSU) leads the science team with Dr. Matthew Penny (LSU) and Dr. Angelle Tanner (MSU).

"To develop the best plan, our student team first needed to create simulations of the portion of lunar sky L-CAM1 will see during the mission's multiple lunar days as a way of determining visible astrophysical and astronomical targets. One of the unique benefits L-CAM1 will provide is the duration of uninterrupted time individual subjects can be observed," said Marchis. "A next step for the solar system portion of the L-CAM1 science program was determining the asteroid population in the main belt that will cross our field of view."

The students developed two science cases for the observing program, based on understanding the benefits and limitations of a lunar observatory:

- Improving the characterization of previously known exoplanets: Space-based observations allow high-precision measurements of parent star brightness changes when an orbiting exoplanet briefly passes in front of the star. The brightness changes can be a few percent for large exoplanets, down to less than 100 parts per million for rocky exoplanets similar in size to the Earth. Working continuously during a lunar day (~14 Earth days), L-CAM1 data

will have long, uninterrupted observing sequences of exoplanet transit events. These long observing sequences will allow scientists to target specific systems and capture new data that can be used to determine properties of both the exoplanets and their host stars.
- Asteroid observation and characterization: Approximately 200 asteroids will be observable by L-CAM1 during a multi-lunar day mission, including approximately one near-Earth asteroid (NEA) per month. The combination of lunar day length and the stable platform the lunar surface provides will enable precise astrometric (position) and photometric (brightness) observations for determining the physical properties and orbits of these small solar system bodies.

"Giving early-career students the chance to design a frontier, space-based science program that will operate on the lunar surface is a wonderful and unique opportunity to support the progression of tomorrow's leading astronomers and astrophysicists," said Boyajian, LSU Assistant Professor of Physics & Astronomy. "Planning a science program from scratch also presents a number of challenges that students often don't get exposure to this early in their careers."

Student Experience

Rendering of AstronetX L-CAM 1 Telescope. Credit: AstronetX

"Some of the specific data analysis was classifying targets by type and observability, including opportunities to continuously observe the light curves of near-Earth asteroids so we can characterize them in new ways," said Peter Santana, L-CAM1 Student Science Team member who worked at the SETI Institute as part of their REU program. "Where we're really limited by time, weather and other conditions when observing from Earth, we anticipate being able to observe some targets for up to 100 continuous hours. This is something that ground-based and low-Earth orbiting telescopes generally cannot do."

"Working on L-CAM has been a dream come true for me. I've been an astronomer since I was 13, and now I'm developing the science program for a lunar surface telescope," said Farzaneh Zohrabi, L-CAM1 student science team member studying at LSU. "A unique thing that we're planning to do with L-CAM makes precise measurements of nearby bright stars and their exoplanets. This is something that cannot easily be done using ground-based telescopes on Earth because of the atmosphere and saturation limits."

The long-duration and precise light curves of stars and asteroids may enable the detection of exomoons orbiting the exoplanets or moons orbiting their host asteroids. The light curves of transiting exoplanets captured by L-CAM can also detect a phenomenon called "transit timing variations," which occur due to the gravitational tug of additional objects orbiting the host star being observed. Scientists using L-CAM1 will similarly be able to study the light curves of near-Earth asteroids over longer durations to better characterize orbital parameters and rotational spin, contribute to advanced 3-D modeling and identify transiting asteroid moons.

"Because of my data science background, the initial challenge presented to me was to think about how we can map all the known exoplanets and their hosts in order to identify what will be observable from L-CAM1's landing site," said Carol Miu, L-CAM1 student science team member studying at Collin College. "I wrote a script that uses the Stellarium planetarium (stellarium.org) to determine what stars and known exoplanets will be in our planned field of view at specific times, and matched the results against NASA's exoplanet archive data to determine orbital periods and our list of candidate targets."

"My focus began with determining where we should be looking by using the Stellarium planetarium and other software to model the night sky. This enabled us to put together a list of candidate host stars and exoplanets for observation," said Connor Langevin, L-CAM1 student science team member studying at LSU. "More recently, I've started to identify the observability of near-Earth asteroids. This involves determining L-CAM's field of view at specific times and matching that with specific asteroids that will be viewable."

After selecting initial science targets, the team considered alternate mission schedule and landing locations for L-CAM1, requiring additional analysis to modify the list of targets. The team was able to step back and consider how programmatic changes or a multi-mission program can be efficiently designed while minimizing rework. The student team also had to develop a data acquisition strategy constrained by transmission limitations from the Moon to Earth for analysis.

"L-CAM has several advantages. The lack of atmosphere on the lunar surface, compared to ground-based telescopes for deep space science, will provide a higher level of precision, there will be longer continuous observation windows due to the two-week-long lunar day, and we will be able to observe areas closer to the sun than we can from Earth," said Dr. Jonas Klüter, L-CAM1 student science team member studying at LSU. "However, our observing and data strategy posed a challenge. Because data transmission from L-CAM to Earth is limited, we needed to determine how much data we require on stars and asteroids in order to fully characterize them. This includes exposure time, magnitude limits, and how many pixels are required to conduct the science."

Provided by SETI Institute