ASTROBOTIC RESEARCH AND DEVELOPMENT: NEW TECHNOLOGY FOR LUNAR SCIENCE AND EXPLORATION. J. F. Kitchell[1], K. Snyder[1], E. Amoroso[1], and A. D. Horchler[1].
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Introduction: In March of 2016, Astrobotic created the Future Missions and Technology department, tasked with turning the company's current technologies into products and pursuing novel research contracts focused on space robotics applications. This focused effort builds upon the company's history of broad technology development for NASA through over 20 SBIR, STTR, and NIAC contracts. Here we present recent work on a range of space robotics technologies relevant to the lunar science and exploration communities and that will enable future missions to the Moon.

Terrain Relative Navigation for Precision Landing: In 2014, Astrobotic demonstrated visual terrain relative navigation (TRN) and LiDAR hazard detection to guide a rocket-propelled Masten Xombie to a safe landing (*https://youtu.be/kK-LwUcj2r8*). In 2017, the group has continued to refine our navigation system to minimize size, weight, power, and cost by leveraging space-tested COTS parts and hardware accelerated vision processing, for the purpose of providing precision navigation to a robotic lander. As NASA mission planners and Astrobotic's payload customers increasingly express interest in exploring the most challenging destinations on the Moon, Astrobotic sees a growing need for an affordable and effective TRN solution.

Navigation for Lunar Free-Flyers: Under a Phase II NASA STTR, Astrobotic is developing robust, GPS-denied navigation to allow free-flying robots to explore lunar skylights and lava tubes [1], [2]. The system fuses inertial measurements with stereo vision and 360° LiDAR scans for precision navigation, enabling free-flyers to safely and autonomously enter, map, sample, and exit from a cave or lava tube to a lander or roving base. Astrobotic will continue to develop these techniques to enable a multi-sortie lava tube mapping and sample collection mission incorporating a high degree of system autonomy.

Route Planning for Lunar Missions: In early 2017, Astrobotic, in collaboration with CMU, completed a Phase II NASA SBIR to develop software to plan safe rover missions at the poles of the Moon [3], e.g., Resource Prospector. The software extends mission durations, provides knowledge of safety margins, and maximizes science gain. Robust route planning optimization algorithms take into account time varying conditions, rover capabilities, risk specifications, and sequencing of science objectives. Astrobotic intends to further refine these tools to aid lunar mission planning and, eventually, volatile prospecting, infrastructure emplacement, and human settlement at the poles.

Lunar CubeRover: In May of 2017, Astrobotic was awarded a NASA SBIR to develop CubeRover, a concept for a 2-kg robot built to survive the harsh environment of the Moon while performing science aligned with NASA's lunar strategic knowledge gaps. The impetus behind CubeRover is to standardize and democratize surface mobility, analogous to the transformation CubeSats brought to the domain and economics of Low Earth Orbit. This will drive the space community to commoditize systems, components, and instruments. The first CubeRover will model blast ejecta and characterize terrain trafficability for small rovers.

Lunar Rendering: The Astrobotic Virtual Orbital Imager (AVOI) is a physically accurate lunar renderer to assist in precision landing, route planning, and landing site selection [4]. Using topography and ephemeris data, AVOI determines lighting and line-of-sight communication conditions at any date and location, and produces high-quality renderings and time-lapses. AVOI can be used for TRN by producing accurate georeferenced maps for a landing spacecraft.

References: [1] Snyder K. et al. (2017) ACM/IEEE *IPSN*. [2] Sofge E. (2015) *Popular Science*. [3] Cunningham C. et al. (2016) *LEAG*, Abstr. 5062. [4] Amoroso E. et al. (2016) *LEAG*, Abstr. 5037.

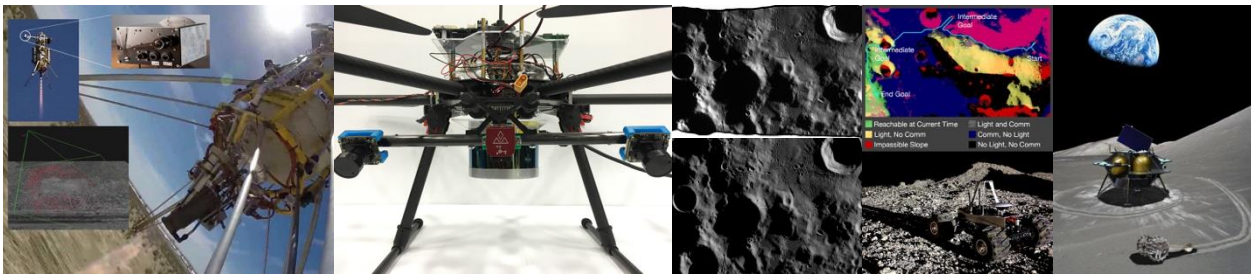

Figure 1. Astrobotic technologies: TRN demo, drone navigation, lunar rendering, route planning, CubeRover.