Utilization of LUNARSABER for Lunar Exploration. Vishnu Sanigepalli[1], Kris Zacny[1], Richard Margulieux[1], Zachary Begland[1], Kayla Klein[1], Lily Clay[1], Nicholas Naclerio[1], Kevin Hubbard[1], Grayson Glazer[1], Dean Bergman[1]. [1]Honeybee Robotics (2408 Lincoln Ave Altadena, CA 91001, vxsanigepalli@honeybeerobotics.com, kzacny@honeybeerobotics.com)

Introduction: LUNARSABER, Lunar Utility with Navigation with Advanced Remote Sensing and Autonomous Beaming for Energy Redistribution, is a tall deployable structure that integrates energy harvest and storage, communications, mesh network, PNT (Position, Navigation, and Timing), power transfer, and surveillance into a single infrastructure that can be scaled to provide commercial services to both public and private aerospace sectors. The architecture can seamlessly integrate into future lunar architectures with its ability to scale by size to fit the volume and mass constraints of the landing systems (i.e., single large scale LUNARSABER vs. multiple small LUNARSABERs on a single launch).

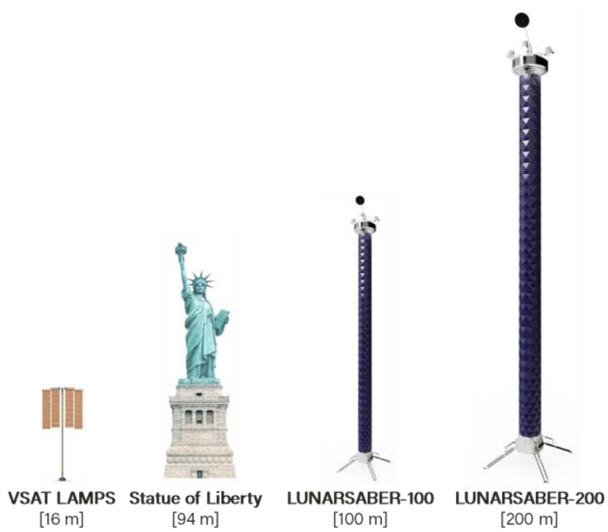

Fig. 1 LUNARSABER scalability

Configurations: There are two different scaling opportunities for LUNARSABER's architecture: form factor and production. As the deployment system increases in diameter and height, the power generation scales linearly. These two parameters (diameter/height) can be adjusted based on customer/mission requirements such as: power requirement, launch up-mass and down-mass, volume capability, and so on. LUNARSABER, shown in Fig 1, can also be customized for different needs: "fully loaded" LUNARSABER can be strategically positioned near crater rims, while LUNARSABER for PSRs can be deployed without solar panels and only be used for power transfer, PNT, communications, and asset monitoring.

Illumination and Viewshed: The system demonstrates an increase in performance after scaling the height. For Shackleton crater, when the deployed length exceeds 100 m, the square area of land with continuous illumination increases, and the periods in darkness drastically decrease. Most of the crater rim is illuminated for >80% of a lunar precession cycle, with some locations >95% (~18.6 years) [1]. If deployed at these locations, LUNARSABER would provide near continuous power for operations and lunar night survival capabilities. Although the power generation wouldn't be at full capacity as it would only illuminate the top of the solar panel assembly it would allow for a power redundancy for self-survival and the capacity to beam power to other assets. For the short periods in darkness, the batteries in the base of the system are sized appropriately to survive and provide power to other lunar assets. Since the illumination of these regions are deterministic and well-studied, mission architectures can be optimized to re-charge and store energy prior to these events. Placing a LUNARSABER on the rim of Shackleton crater provides nearly 100% line of sight to any payload within Shackleton crater, shown in Fig 2.

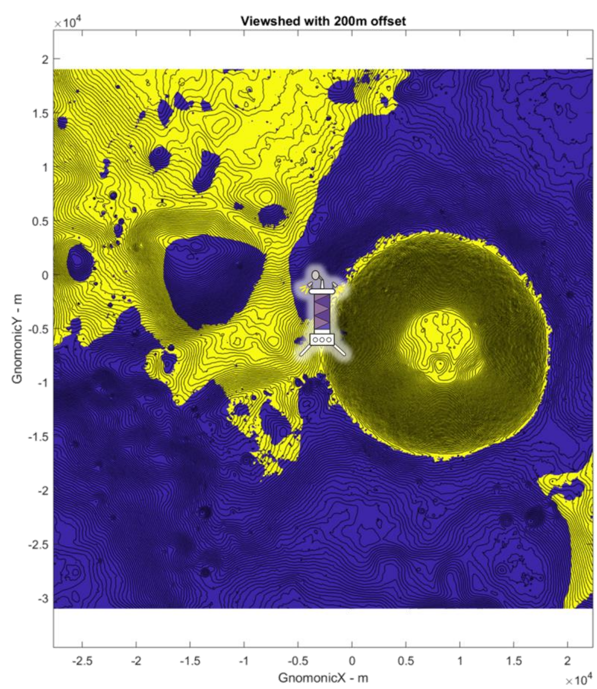

Fig. 2 Viewshed analysis of LUNARSABER with a deployment height of 200 meters placed on the rim of Shackleton Crater.

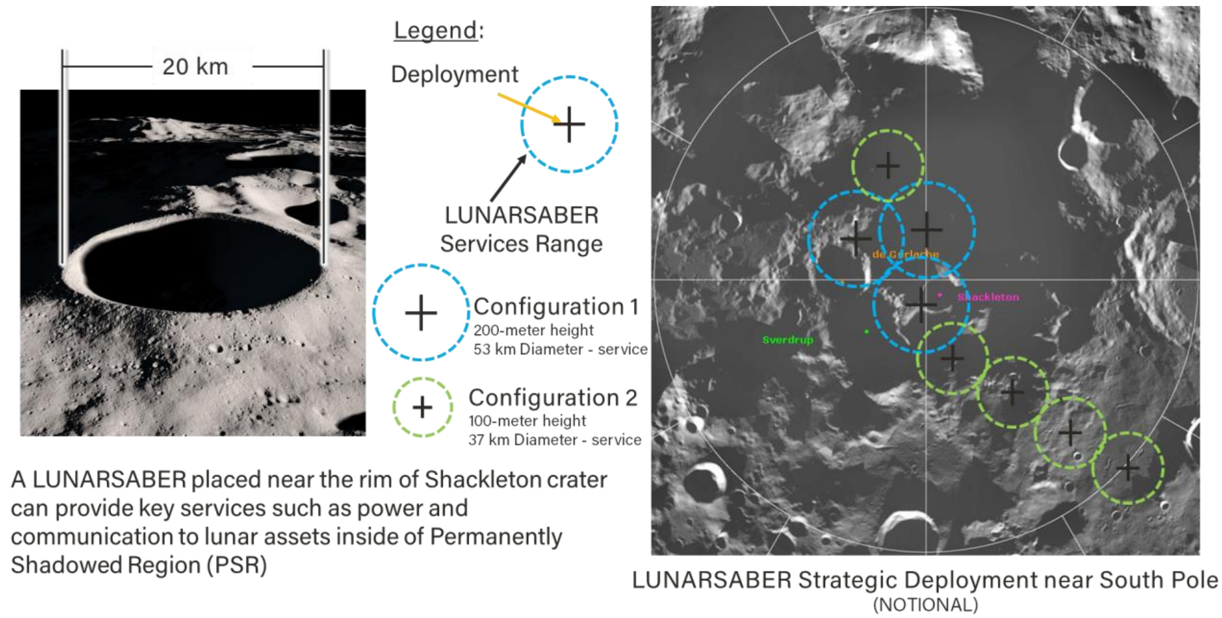

Fig. 3 LUNARSABER network that can be expanded near the Lunar South pole.

Lunar Services:

Lunar Network – instantly access data across lunar assets without line-of-sight

Data Storage – provide a data storage services for asset monitoring, science data, or decentralized lunar network

Power "checkpoints" – allow for lunar assets to transit across crater and regions without worrying about power and lunar nights

PNT services – high accuracy position state as the number of deployments scale

Space Traffic Control – future-forward to monitor and regulate space traffic while providing PNT services for more precision landing

Due to the limited view factors inside craters and PSRs, LUNARSABER provides continuous PNT services that traditional satellite-based architectures struggle to provide. The 360 FOV cameras and the actuated broad-beam lighting system allows critical asset monitoring to help Earth and Lunar Mission Control to oversee autonomous robotic systems and extravehicular activities.

As the number of deployments scale, shown in Fig 3, and are strategically placed, LUNARSABER communications systems evolves into a mesh communication network that allows any lunar asset to communicate with another without line-of-sight. A gimbaled communication antenna at the top of the structure also provides Direct-To-Earth (DTE) communications with Space Network (SN) or Deep Space Network (DSN) with higher % visibility based on the deployed location. This communication services can be extended with data storage capability and lunar network services at the base of each system to serve as a decentralized network to store, transmit, and provide mission data as required.

LUNARSABER focuses on providing multiple services, which help reduce the overall costs while maximizing the services rendered per mission. This solution focuses on providing essential infrastructure-as-a-service needed for lunar missions such as energy, comms, position knowledge, etc. In-situ services demand will be one of the primary driver to achieve economies of scale. As deployments of LUNSABER scale, the mesh network becomes efficient and seamlessly integrate with satellites communications, Deep Space Network, and Earth and Lunar mission controls.

References:

[1] Vanoutryve, Benjamin et al. (2010) "An analysis of illumination and communication conditions near lunar south pole based on Kaguya Data"