LSII Extreme Access

LSIC Focus Group Meeting

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Extreme Access

Objective

- Enable **humans** and **robots** to efficiently access, navigate, and explore extreme lunar surface or subsurface environments.

Considerations

- An environment is “extreme” due to **various factors**
- Extreme access may require handling **one (or more) factors**
- Extreme access may involve **a combination** of mission design, mission risk tolerance, mission operations, and technology
- Extreme access may be a **functional capability** at the subsystem or system level
- Extreme access may require the **integration** of multiple technologies

Extreme Factors

Terrain
- Composition (granular, friable, etc)
- Geometric hazards (positive & negative scale, distribution, etc)
- Slope, roughness, etc.

Dust
- Abrasiveness, electrostatic, etc.

Thermal
- High/low extremes
- Cycling, gradient, etc.

Radiation
- Total dose
- Flux

Visibility
- Sun (for solar illumination)
- Sky (for thermal radiation, navigation, etc)

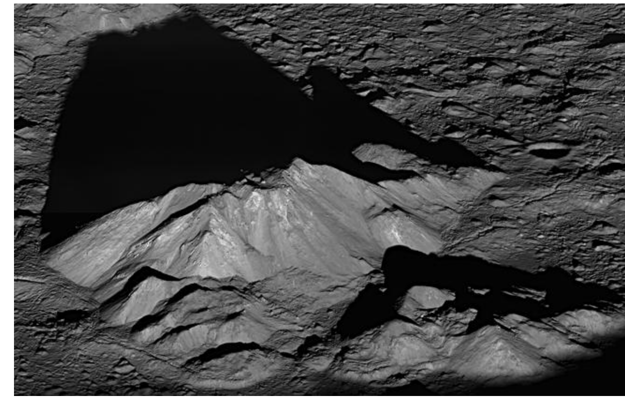
Extreme Access Missions

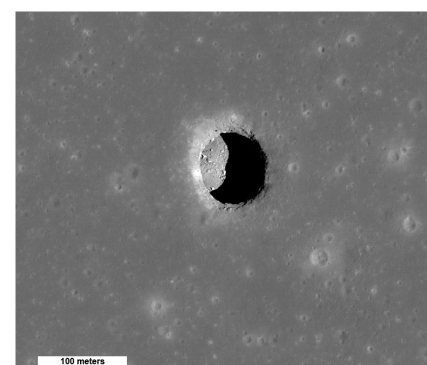
Missions

- Sample return from South Pole Aitken Basin
- Volatile prospecting (in PSRs)
- ISRU: oxygen reduction, volatile recovery
- Exploration of subsurface voids
- Long duration and long range traverse (e.g., New Frontiers “Intrepid”)

Targets

- Steep and deep craters, gullies, scarps, canyons, crevasses, vents, pits, lava tubes
- Areas dominated by “fluffy” or highly porous regolith, soft friable terrains
- Locations with largely unknown terra-mechanical properties at the scale of platform
- Permanently shadowed regions





Technology Challenges

Mobility

- Enable robust, sustained surface activities (bulk transport of regolith, 1000 km scale traverses, etc.)
- Enable sampling of South Pole Aitken Basin
- Enable extended operations in permanently shadowed regions (more than VIPER)
- Enable ingress, exploration, and egress of subsurface voids

Navigation

- Enable navigation with minimal infrastructure (surface or orbital)
- Enable hazard detection in all lunar environments and conditions
- Enable localization better than VIPER with similar (or reduced) size/weight/power/cost (SWaP-C)
- Enable autonomous operations (local area / worksite and "cross country")

Many other areas (avionics, dust, power, thermal, etc.)

NASA Extreme Access R&D

Game Changing Development Program	• Cooperative Auton. Distributed Robotic Explorers – TRL 8 • High TRL Rover LIDAR – TRL 8 • TP-CubeRover [Astrobotic] – TRL 8	• Lightweight Surface Manipulation System – TRL 6 • Micro Video Guidance System – TRL 6	• Day/Night Lunar Rover Auto Obs. Avoid. & Localization – TRL 5 • Extreme Terrain Access for Lunar Exploration Assessment
NIAC Program	• Phase III – Robotic Technologies Enabling the Exploration of Lunar Pits [Carnegie Mellon/Astrobotic] – TRL 5		
SBIR / STTR	• Phase II Seq. – Rover Slip Est. & Traction Control for Optimal Mobility in Lunar Env. [ProtoInnovations] – TRL 7 • Phase II – CubeRover for Lunar Science and Exploration [Astrobotic] – TRL 5 • Phase I – Dynamically Reconfig. SW & Mobility Arch. for Auton. Planetary Rovers [ProtoInnovations,] – TRL 4 • Phase I – Integrating Robot Operating System (ROS) 2 with the Core Flight System [TRAClabs] – TRL 4 • Phase I – Magnetic Gearing Applications for Space [US Hybrid Corporation] – TRL 4 • Phase I – PLUMMRS: A collection of Plan Ledgers and Unified Maps for Multi-Robot Safety [TRACLabs] – TRL 4 • Phase I – Robust Vis. Perception Tech. for Intel. & Adaptive Space Robotics [Edge Case Research] – TRL 4 • Phase I – Modeling Rover Interactions with Lunar Regolith in Permanently Shadowed Regions [Blueshift] – TRL 3		
Early Career	• Assemblers – TRL 3-4 • Joint Aug. Reality Visual Info. Sys. – TRL 3-4	• Kin. Nav. & Cartography Knapsack (KNaCK) – TRL 3-4 • Multifunctional Sensor Platform Enabled by AM – TRL 3-4	
Space Tech Research Grants	• Burrowing Robot for Extraterrestrial Soil Sampling and Anchoring [UC Santa Barbara] – TRL 3 • Non-Contact Eddy Current Manipulation in Microgravity Environments [Cornell University] – TRL 3 • Traction Optimization of a Planetary Rover via Control of a Flywheel Energy Storage [UC Berkeley] – TRL 3 • *Early Career Faculty 2020 – Coordinated Multi-Robots for Planetary Exploration*		
Challenges	• NASA Breakthrough, Innovative, and Game-changing (BIG) Idea Challenge – Systems and technologies to explore and operate in lunar Permanently Shadowed Regions – TRL 2-3 • Space Robotics Centennial Challenge Phase 2 – TRL 2-3 • NASA Tournament Lab – Miniaturized Payloads for Small Rovers Ideation Challenge – TRL 2-3		
Center Invest	• Neuromorphic Learning for Adaptive Control – TRL 1-2		

Closing Thoughts

Missions

- Focus on “high-priority” missions (from various stakeholders)
- Also consider bolder, more ambitious missions to help push technology

Technology

- “Pull” – **Develop requirements** (user needs) from proposed lunar missions and/or design references missions
- “Push” – **Propose new capabilities** that will enable new types of missions, new science, new opportunities

Not just NASA

- How to close the gap between terrestrial SOA and space SOA?
- How to sustain **and** leverage commercial space (CLPS vendors interested in mobility services)?
- How to mature new technology & missions at a faster pace?