Meeting the needs of Lunar Autonomy – Trust in AI Algorithms & Testbeds of Tomorrow

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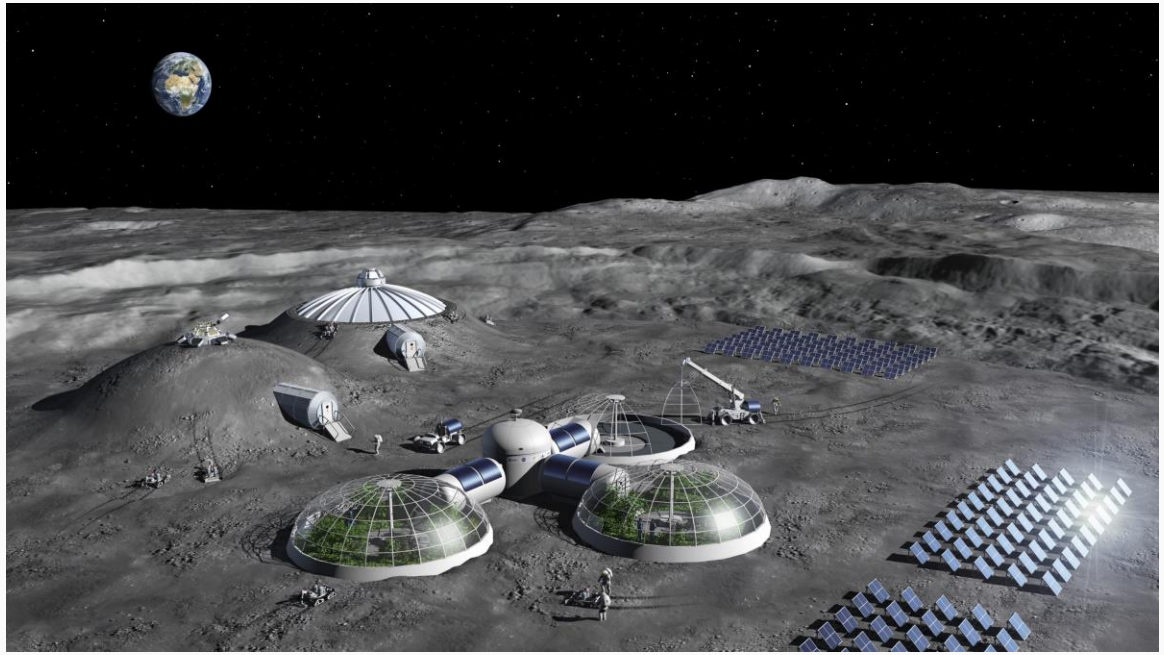
Overview

What challenges lay ahead

- Achieving a sustained presence on the lunar surface will require innovations across myriad disciplines, including material and building sciences, power systems, robotics and sensors, and autonomy.
- For lunar operations, scaling autonomy reduces operational costs and increases capacity by employing human teamed robotic systems.
- Digital Testbeds provide a cost efficient tool to optimize operational scenarios and trial out the blending of new and legacy technologies.



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Building Trust in Autonomy

A Roadmap to AI Deployment

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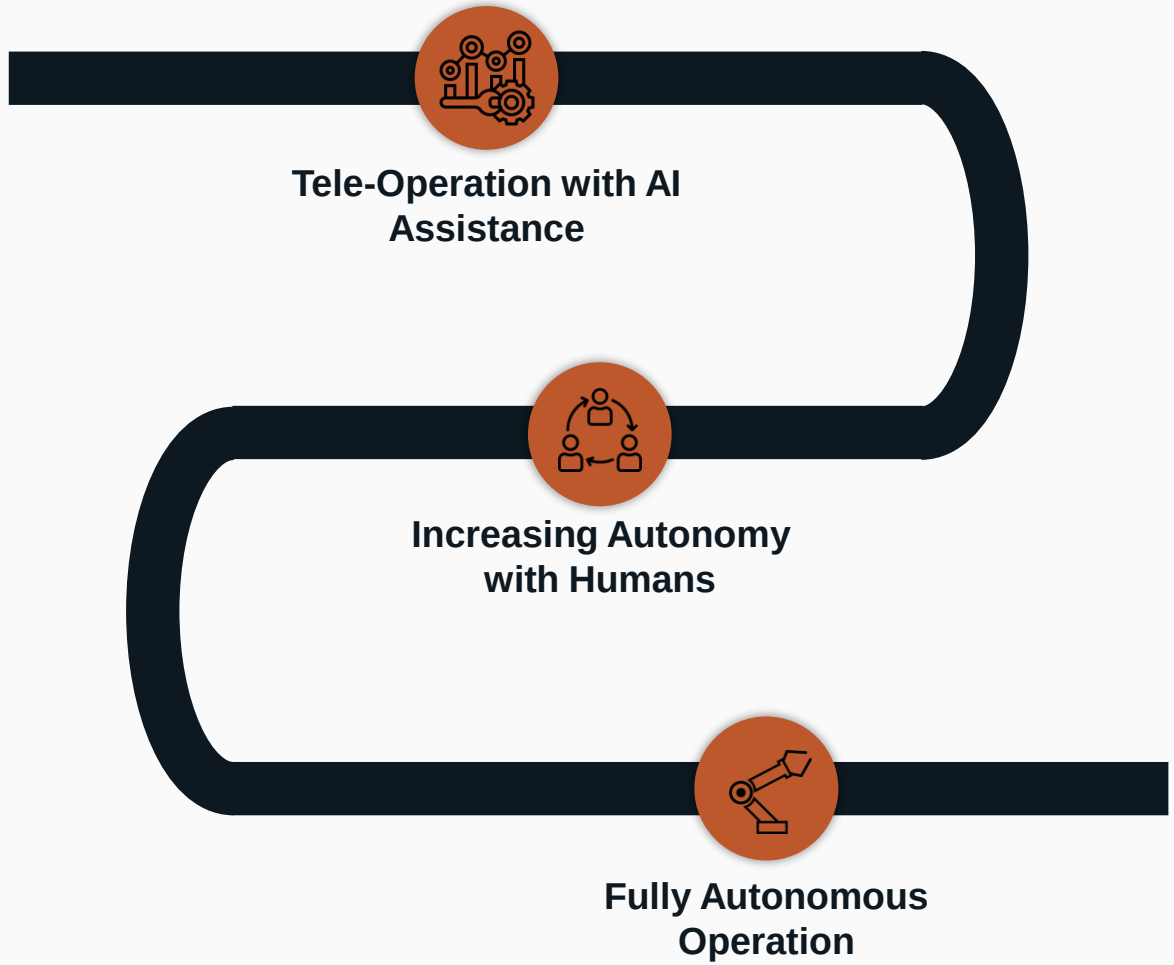
Meeting the Needs – Trust in AI Autonomy

Roadmap to Full AI Autonomy

- While there are hard technological challenges across all of the domains required for a lunar outpost, autonomy is unique in that there are also cultural challenges to overcome: namely human trust in autonomous space systems operating directly with human crews and habitable structures.

- To build this trust, the levels of autonomy must be increased gradually, with human involvement increasingly augmented until full autonomy with minimal oversight is achieved.



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Phase I - Tele-operations with AI assistance

Roadmap to Full AI Autonomy

- Control of the robotic systems will be done by human operators on Earth via tele-robotics.
- The deliberative AI algorithms intended for eventual deployment on the flight hardware will be used to provide planning capabilities on the ground, including suggestions on task planning, arm and rover motion planning, and obstacle avoidance.
- In this approach, AI models are updated periodically using newly captured data from the lunar surface and human operator feedback.

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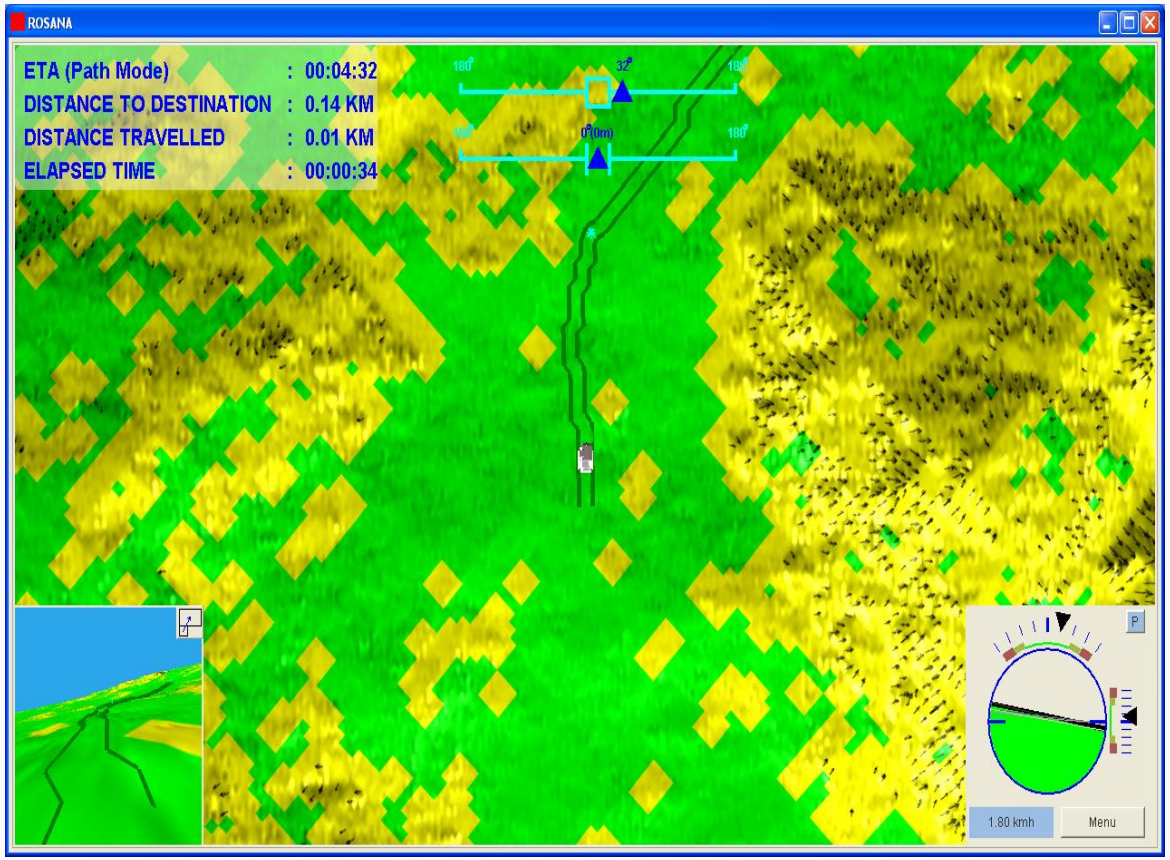
Phase II - Increasing Autonomy with Humans

Roadmap to Full AI Autonomy

- Once the initial objectives have been completed the tasks will be repeated numerous times, transferring more control to the autonomous systems, while keeping humans in-the-loop for adequate oversight, checkpointing and go/no-go decisions.

- As these proposed plans become more reliable, the need for human oversight during operations can be considered for reduction on a case by case basis. Oversight can never be eliminated.

- This will provide a blueprint for “teaching” autonomous systems in situ to perform specific tasks within a full-scale mission.



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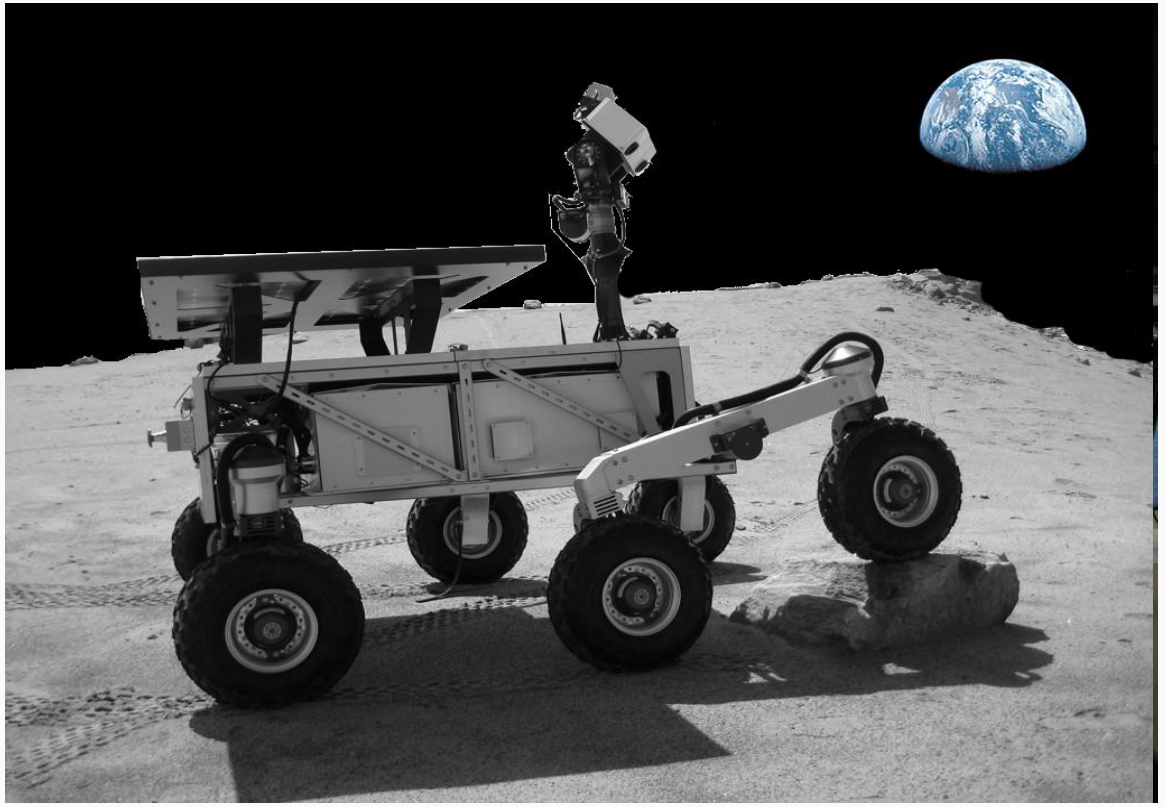
Phase III - Fully Autonomous Operation

Roadmap to Full AI Autonomy

- Through the staged approach defined above, both deliberative and proprioceptive algorithms are eventually certified to run autonomously.
- This may also be done in a staged manner wherein humans monitor the execution of the autonomously generated plan, serving as a redundant safety measure, leading eventually to fully autonomous lunar operations, and certification as an autonomous element.
- Demonstration operations could trial elements of a mission agnostic roadmap for the commissioning of full autonomy.



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Connecting the Community

A Lunar Testbed

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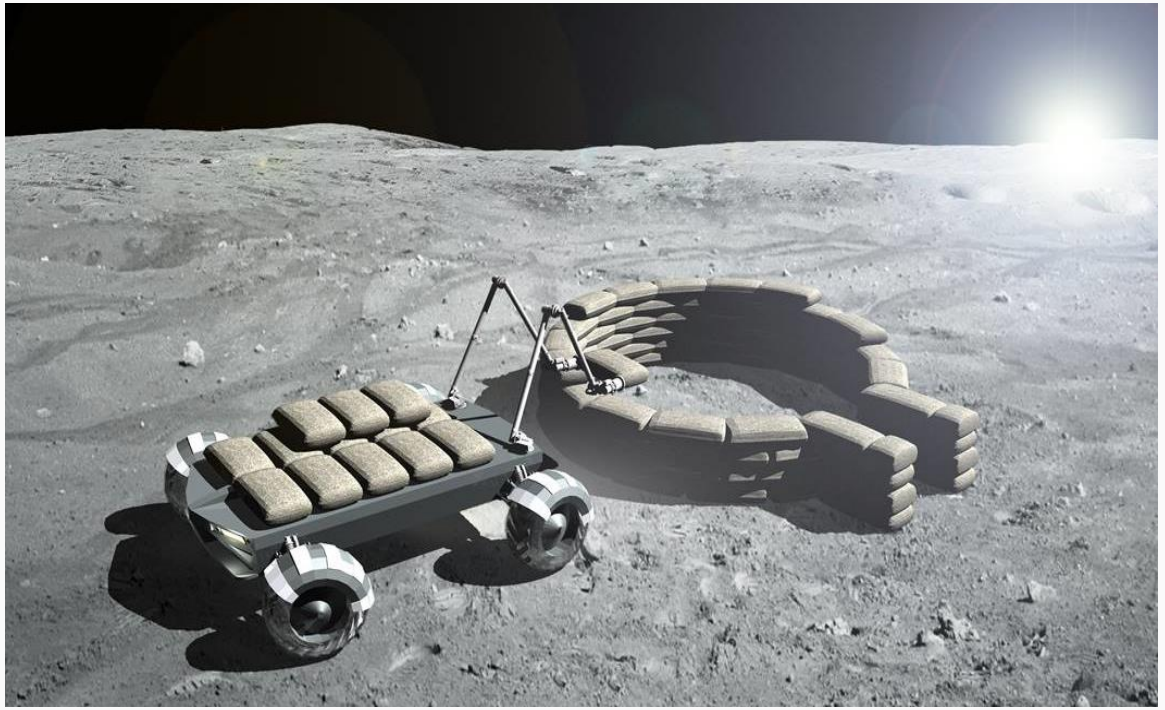
Meeting the Needs - Connecting the Community

A Lunar Testbed

- Real-world testing at lunar analog sites is infrequent because it is costly and challenging to coordinate among many diverse teams. Further, virtual testbeds will be essential for producing quantitative metrics to enable apples-to-apples comparisons while reducing the need for costly real-world testing.

- To address the above need, we propose the development of a Lunar Autonomy Testbed for Technology Exploration – a modular, open-source virtual sandbox that will enable cross-team and cross-discipline collaboration on technologies for a sustained human presence on the moon. Details are as follows…



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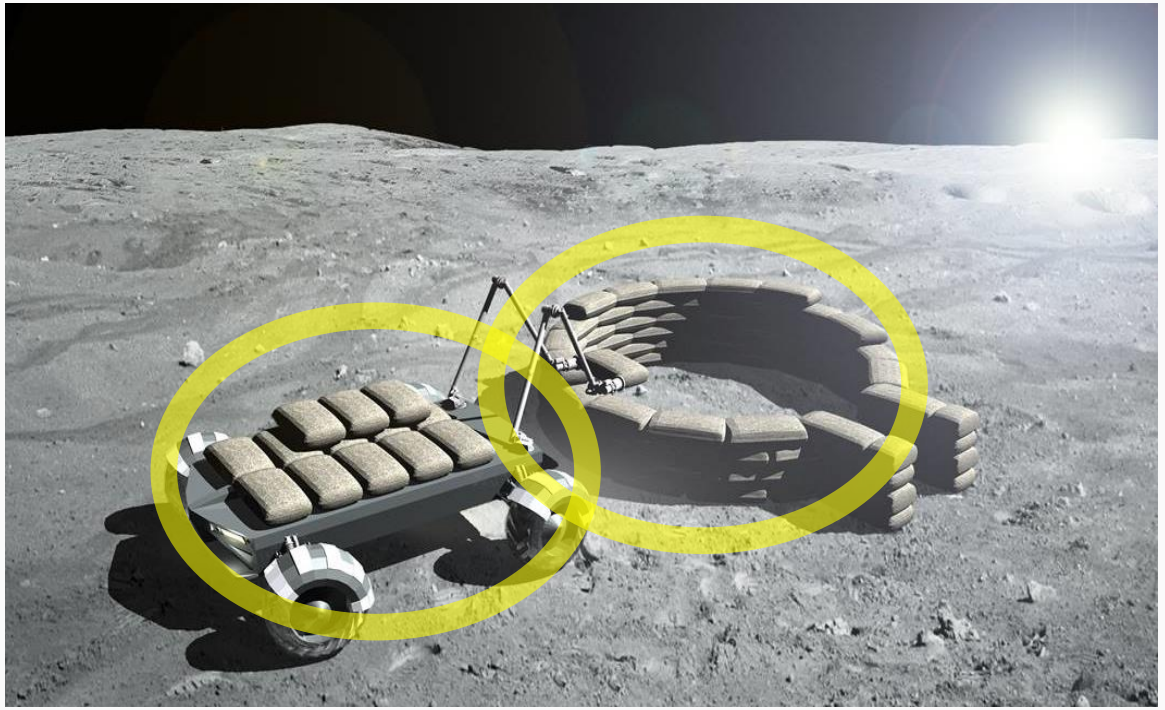
Assets

A Lunar Testbed

- Any proposed physical object that is not currently present on the lunar surface is considered an Asset.
- This includes robotic hardware and tools, sensors, materials, and structures (either from Earth or manufactured in situ on the moon), and human agents.



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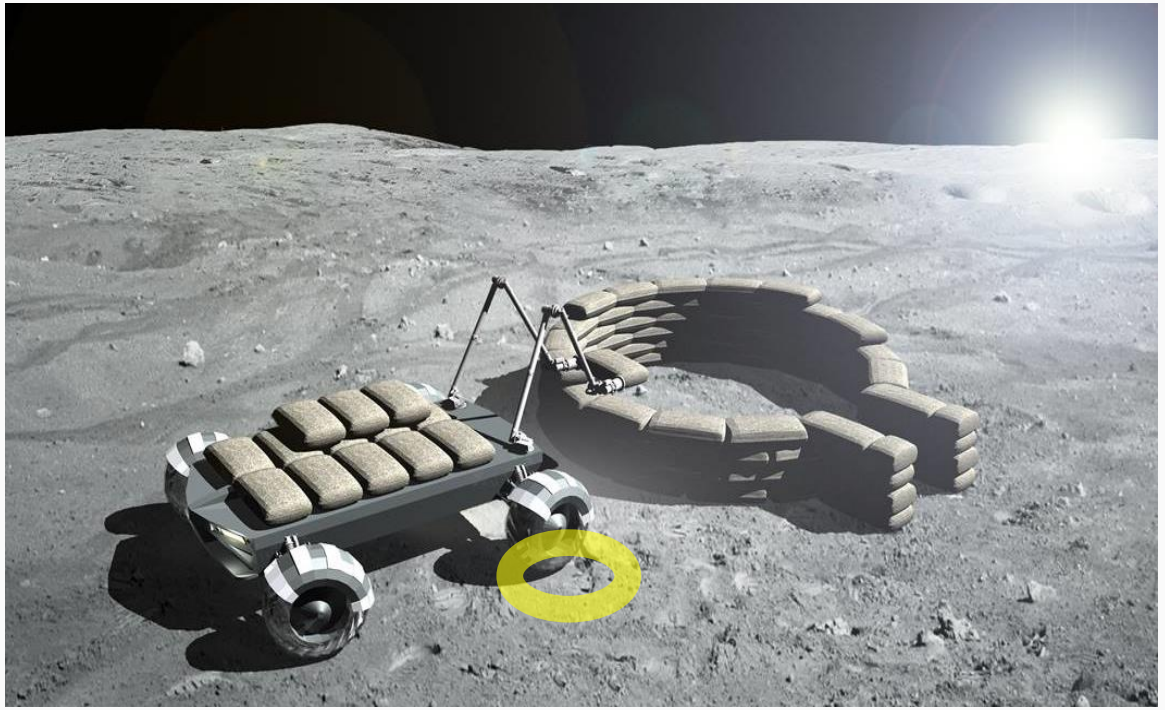
Simulators

A Lunar Testbed

- Fast, high-fidelity simulators are an essential component of any virtual testbed. Given the diverse nature of the technologies needed for Base Camp, there will need to be several different simulators, including visual and point-cloud simulators, physics simulators for regolith and other materials' behaviors, and robot and structure dynamics.



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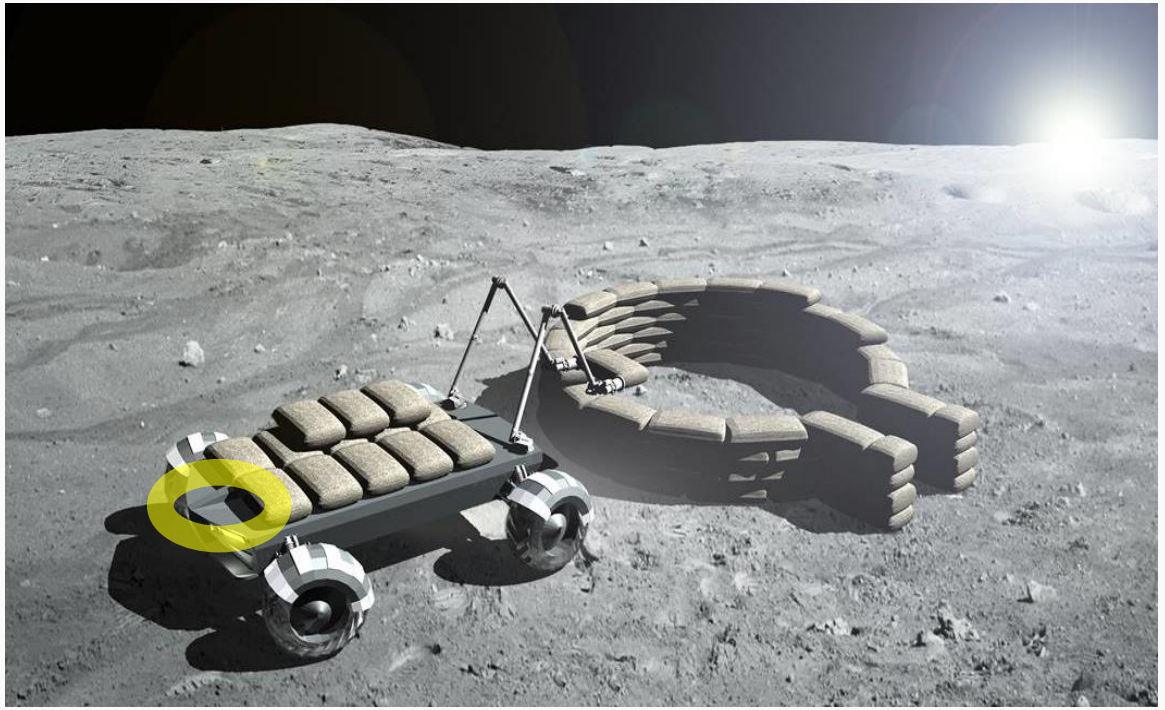
Algorithms

A Lunar Testbed

- Given the complex nature of the tasks at hand, a variety of categories of algorithms will need to be explored and refined, including autonomous, tele-operated, and hybrid control, system health monitoring, perception, and planning.

- High autonomy AI modules could be deployed for in situ decision making.



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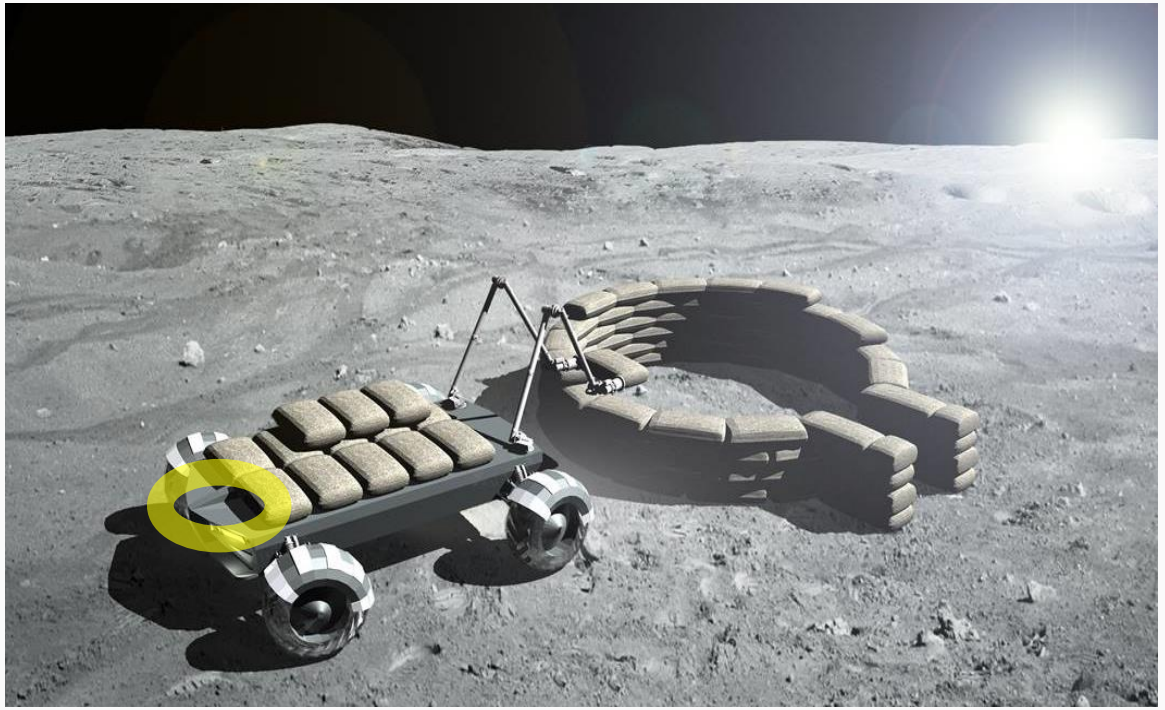
ConOps Library

A Lunar Testbed

- To evaluate and compare the various assets and algorithms, a collection of relevant ConOps will need to be devised. A given operation will specify which types of assets, algorithms, and simulators are required, the tasks that need to be completed, and how performance on these tasks will be quantified (metrics). For any given ConOps, a leaderboard can be maintained to track the top performing assets and algorithm implementations for that task.



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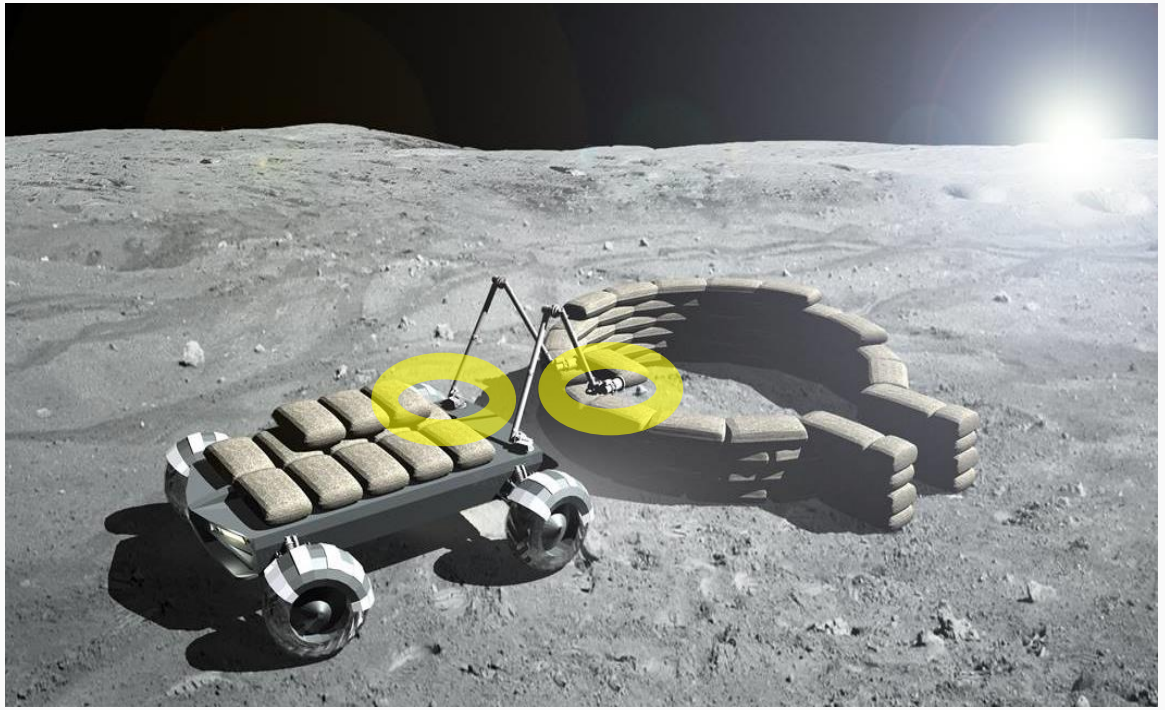
Interfaces

A Lunar Testbed

- Given the proposed open source nature of this, anyone could submit new assets, simulators, algorithms, and ConOps. The key to enabling contributions from the community is a strictly defined and managed set of interfaces between the various components.

- This will allow for changes to a single element, such as adding in a new type of sensor, a novel autonomous control algorithm, or an improved regolith physics simulator, without breaking the other assets, simulators, and algorithms already operational within the system



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Thank You

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