Research Technologies for Robotic Construction of Lunar Surface Assets

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Introduction

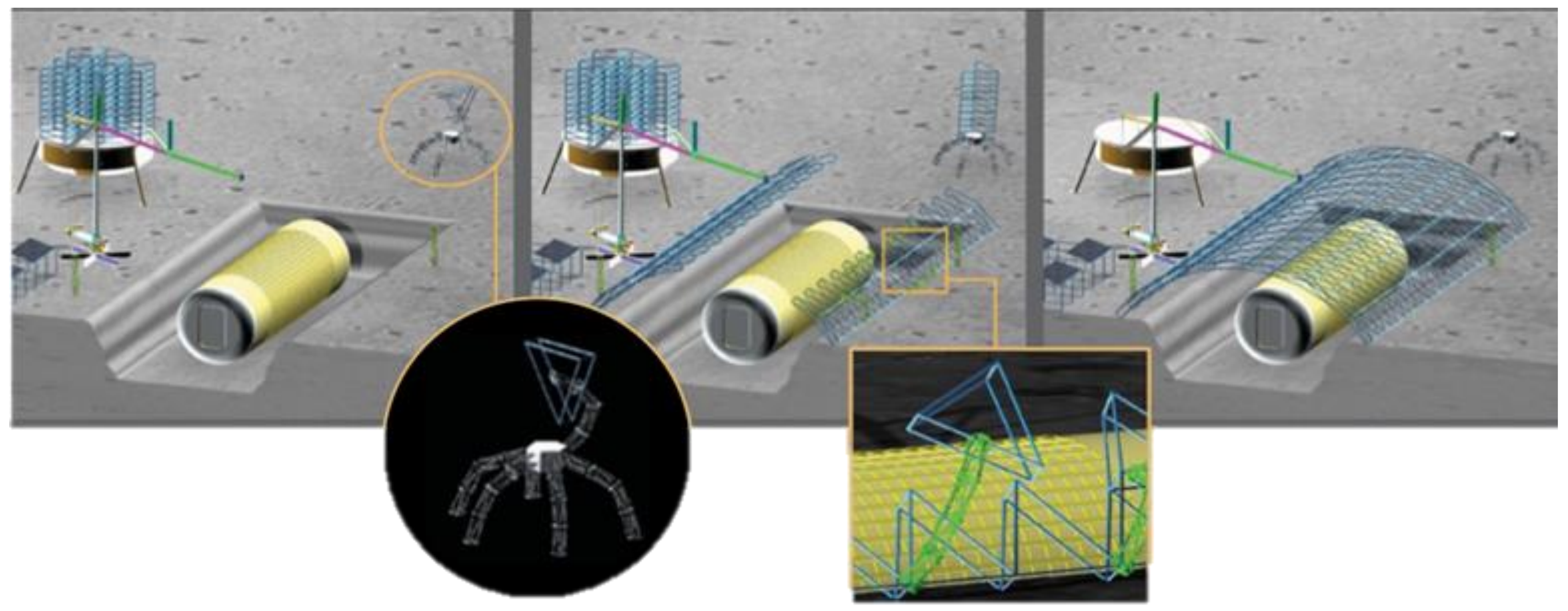

Figure 1: Lunar surface construction concept by a heterogeneous team of robots

In-space assembly technologies utilized for planetary construction are a critical technology to ensure efficiency and safety for long term extraterrestrial missions. However, even as interest in long-term surface missions increases, there is need for robotic architectures to construct and maintain facilities for said missions. Collaborative assembly with heterogeneous robots allows for both gross and dexterous manipulation operations, increasing the capabilities of a small fleet of robots.

By making such a robotic architecture autonomous, large scale construction endeavors become possible as they can occur before crew members arrive on the surface. Once crew arrive, autonomous infrastructure then increase the available crew time by handling maintenance and payload management tasks.

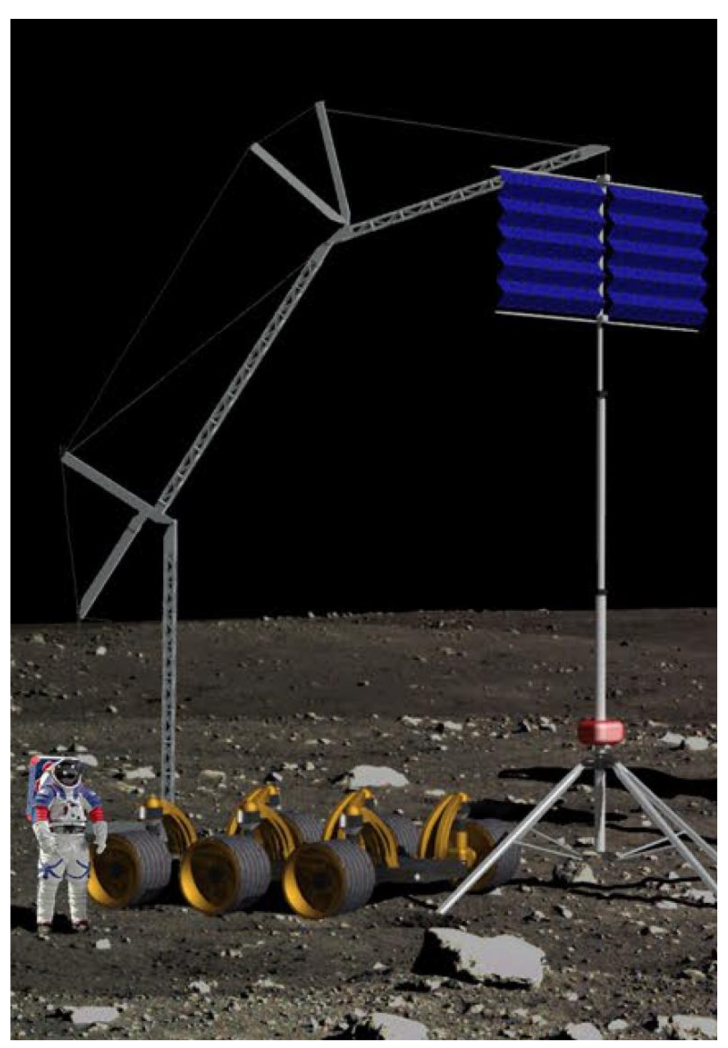

Figure 2: LSMS for surface operation [1]

To enable a reliable autonomous robotic system on the lunar surface, research is required in making robotic collaboration and construction robust. **FASER Lab seeks to fill this gap by innovating autonomous methods for better robot and component interaction, with efforts for both long reach manipulation and a planning model for precise outfitting tasks.**

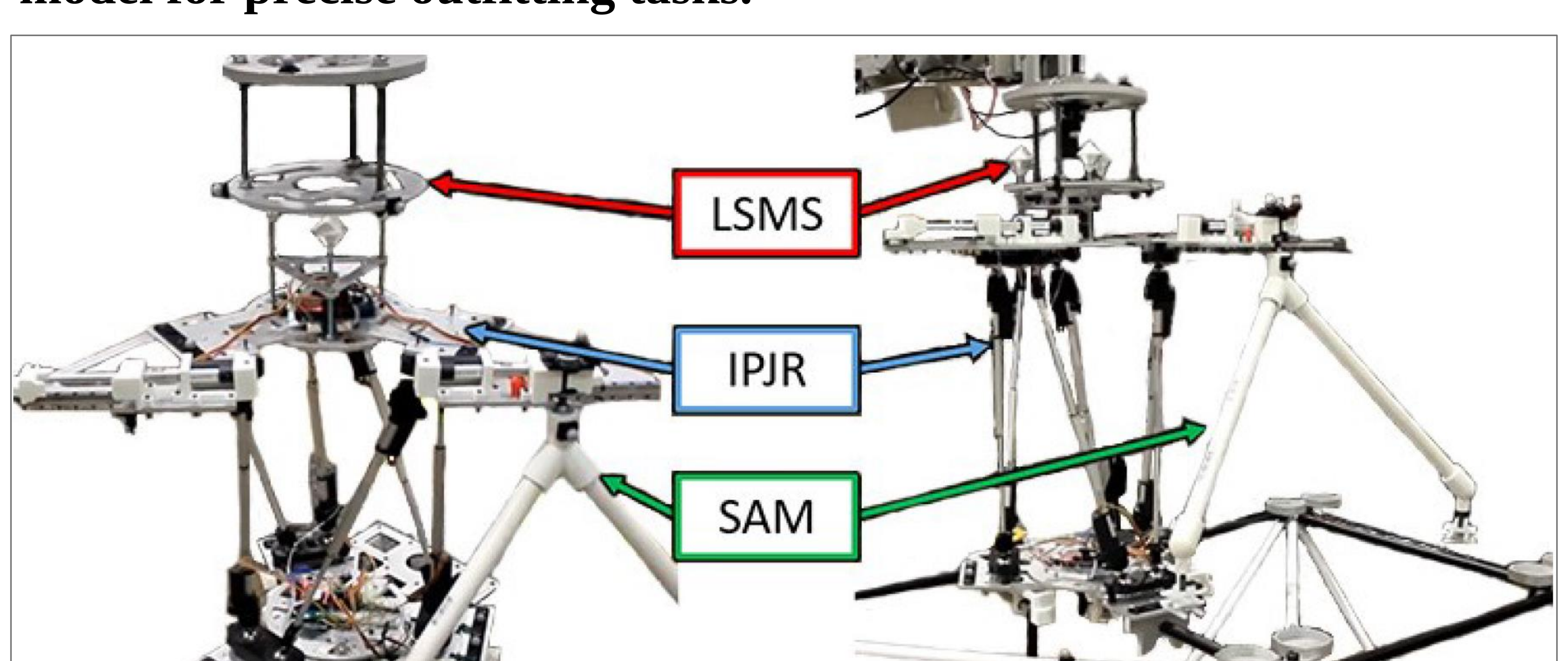

Figure 2: Prior Experiment with LSMS and Dexterous Manipulator for assembly [2]

Long Reach Manipulator: LSMS

The Lightweight Surface Manipulation System (LSMS) is a scalable robotic crane, originally designed and built at NASA Langley Research Center (LaRC) [3]. The robot architecture is strength/mass efficient, with a reach of 7.5m and a load capacity of 1000kg on the moon, allowing it to be a viable option to provide extraplanetary robotic manipulation for large components.

FASER Lab has built a new LSMS with a focus on updating components and implementing COTS parts for use in a laboratory setting. The modifications keep original load capacities and range of motion, while allowing future robot collaborations.

The Hoist System was redesigned to use a COTS based system and was verified to ensure proper load capacities. In addition, the LSMS architecture was changed to implement a network-based system: all motors, sensors and other potential add-ons are controlled over ethernet. The kinematic model remains the same as previous LSMS specialized software work performed at NASA LaRC.

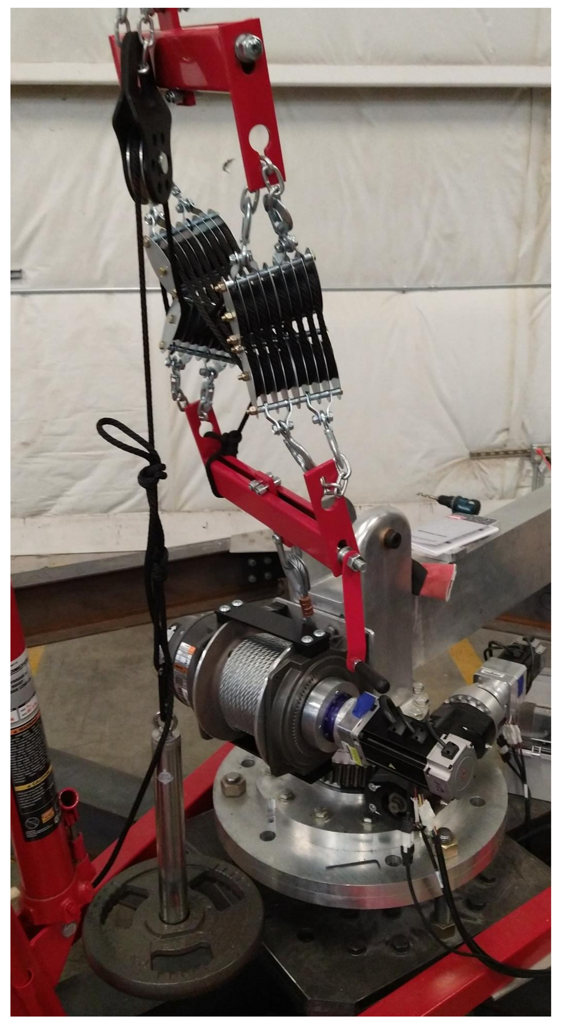

Figure 3: Hoist system test rig

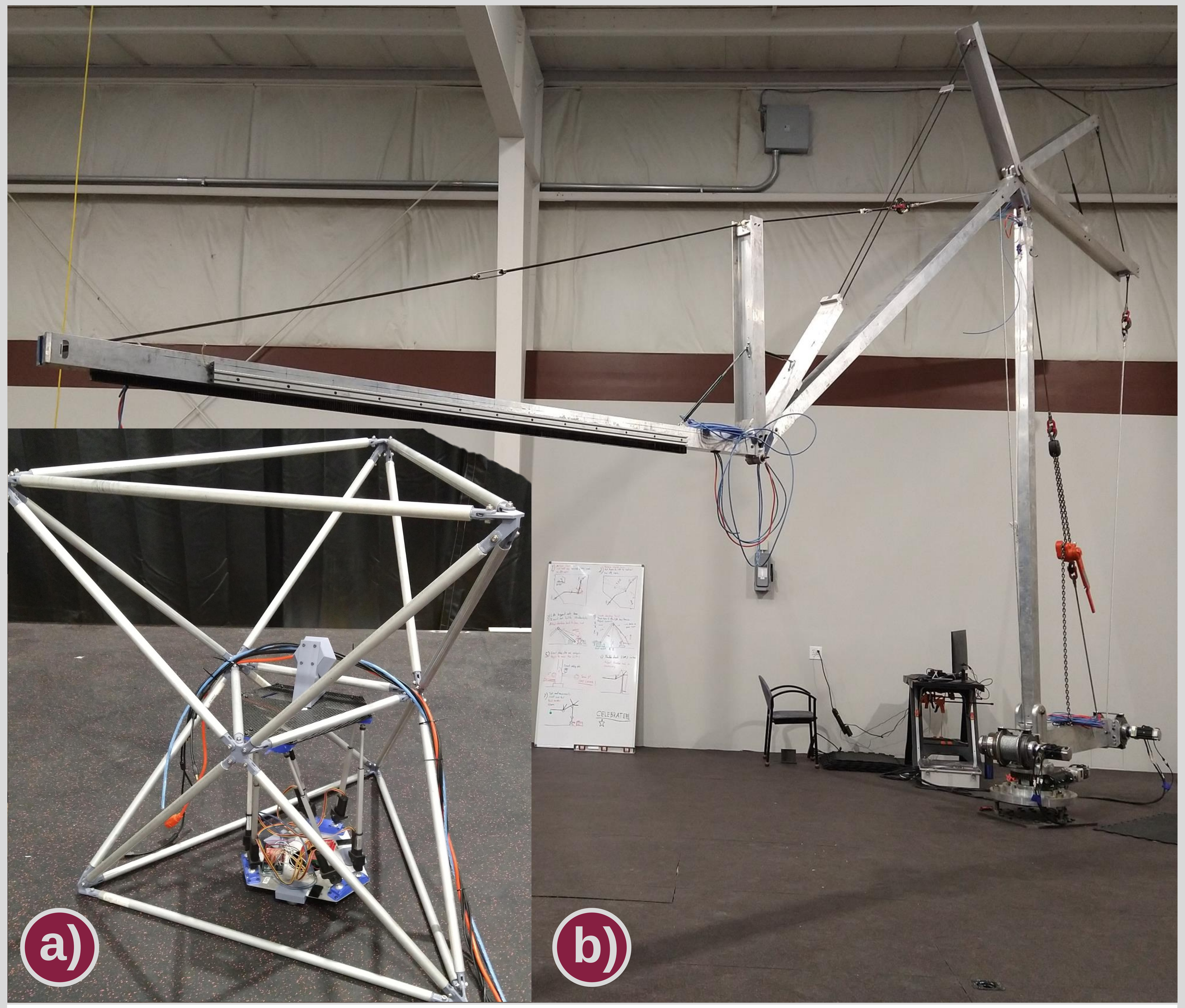

Figure 5: a) DM for outfitting concept, b) FASER Lab LSMS

SA-SLAM For Dexterous Manipulator

In addition to the LSMS, there must be a robotic paradigm for precision manipulations. One area of robotic precision tasks that must be addressed is the ability to complete outfitting construction tasks, such as cable routing, payload installation, and structural maintenance/repair. Structure-Aware Simultaneous Localization and Mapping (SA-SLAM) is a proposed model to bridge the gap between slow, high-fidelity models (finite element analysis) and a rigid body assumption to manipulate both rigid and flexible objects. Maintaining a near real-time understanding of a structure and components prevents collisions and structural disturbances.

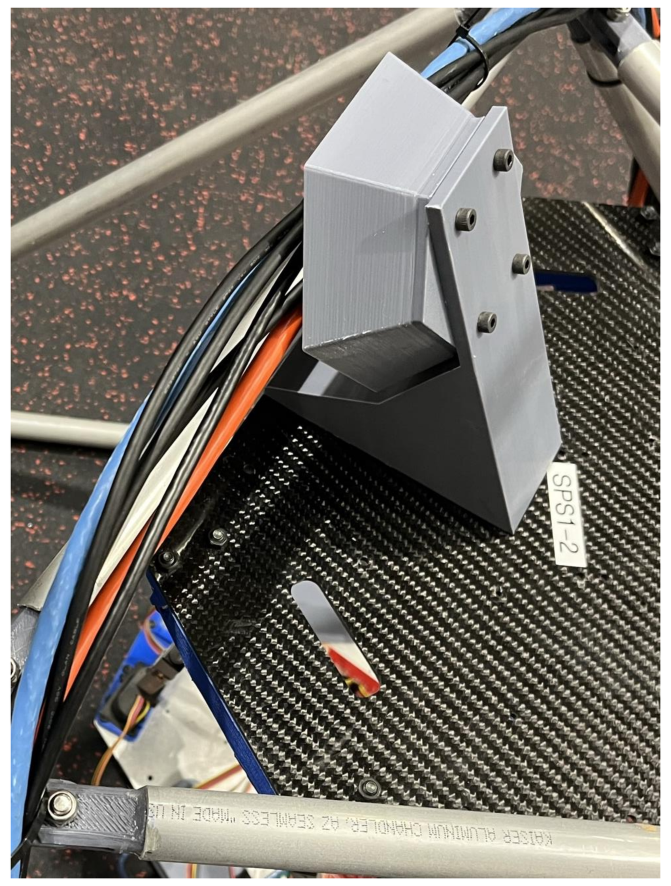

Figure 4: DM for outfitting

The SA-SLAM architecture applied to a dexterous manipulator (DM) achieves tight space and mixed rigid-flexible outfitting operations by combining existing state estimation methods with a variety of robotic autonomy concepts and a minimal state representation, including:

- Optimal Measurement Set
- Motion Planning
- Kinematic and Dynamic Model

SA-SLAM is currently under development, with an integrated model expected 2023.

Future Work

With robotic hardware prototypes completed separately, software models for both the LSMS and dexterous manipulators architectures are being developed to operate autonomously with manipulation and motion planning schemes analogous to possible surface operations. Once basic autonomy is implemented the SA-SLAM model can be incorporated to demonstrate viability for expected lunar outfitting tasks.

Additionally, efforts are underway to integrate the hardware components to demonstrate heterogenous robotic collaboration, building off the current implementation of complimentary tasks (gross manipulation and precise internal operations. One such interaction effort is to have the LSMS move the SA-SLAM DM between different locations, vastly increasing the workspace in which high precision operations can occur. Furthermore, a collaboration with NASA LaRC (LANDO) will allow FASER Lab to further develop the autonomous capabilities of the LSMS robotic architecture in the context of lunar surface operations.

Acknowledgements & References

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[1] Jones T. (2021), *AIAA ASCEND* [2] Everson H. et al. (2020), *IEEE/RSJ IROS*, 7293 - 7300, [3] Doggett W. et al. (2008), *AIAA SPACE*