Collaborative Architecture for Surface Mobility (CASM)

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Background

To support ongoing Moon to Mars NASA objectives the Advanced Concepts Organization(ACO) has completed a rapid study[1] looking at an integrated architecture for mobility operations with a focus on preparation and construction of a lunar landing pad. Outlined in this study is a draft plan using MSFC capabilities in regolith sintering, rover guidance and control, navigation outposts, mission operations and including humans in the decision loop to complete this objective.

The CASM TIP aims to build on the ACO study by autonomously preparing the precursor attributes of a landing site.

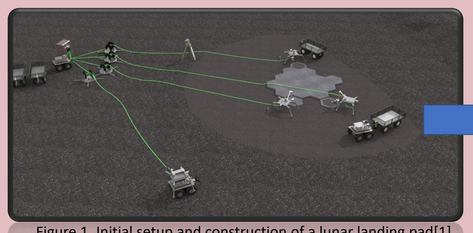


Figure 1. Initial setup and construction of a lunar landing pad[1]

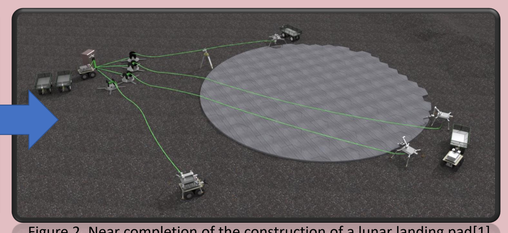


Figure 2. Near completion of the construction of a lunar landing pad[1]

Introduction

Description:

The Collaborative Architecture for Surface Mobility (CASM) is a Technical Investment Program (TIP) funded for FY24. The CASM TIP develops an integrated architecture for lunar surface autonomous construction operations on the Lunar Regolith Terrain (LRT) using 4 MSFC homegrown technologies :

1. Kinematic Navigation and Cartography Knapsack Autonomous Rover (KNaCK) – ST13/EV42
2. Smart Video Guidance Sensor (SVGS)-EV41
3. Lunar Harpoon-EV42
4. Autonomous Network of Telerobotic Systems(ANTS) –EV43

These technologies will be applied to explore, map hazards, and set up the precursor stages of a lunar basecamp.

Motivation:

- To advance TRL of multiple technologies related to lunar surface mobility.
- Provide a growth platform for further integration and expansion of upcoming lunar technologies.

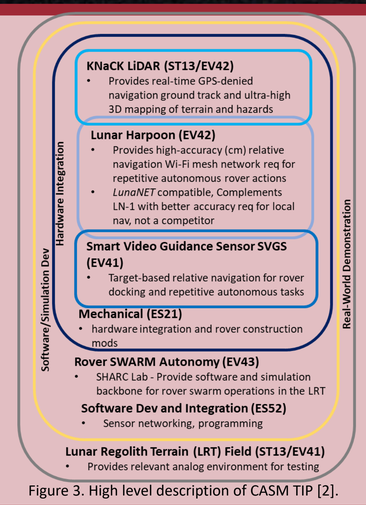


Figure 3. High level description of CASM TIP [2].



Figure 4. View of LRT from ground level.



Figure 5. Top-down view of LRT[3].

Lunar Regolith Terrain (LRT)

Description:

The Lunar Regolith Terrain is an outdoor planetary analog environment facility located on base at MSFC containing 500 tons of lunar regolith simulant confined within a 125 ft x 125 ft (38 m x 38 m) area with a depth range between ~5 in - ~4 ft (~13 cm – 1.2m) that can be modified to suit user needs.

Infusion:

The LRT is the testing site and final demonstration area of the CASM Con-Ops. The lunar terrain provides a large footprint environment for the CASM team to map and modify.

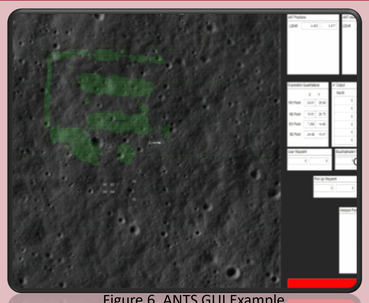


Figure 6. ANTS GUI Example.

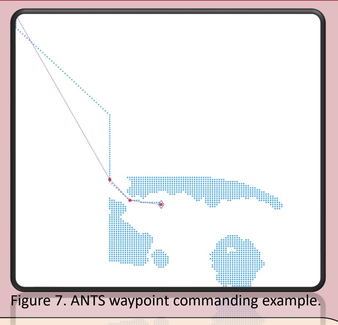


Figure 7. ANTS waypoint commanding example.

Autonomous Network of Telerobotic Systems (ANTS)

Description:

A simulation and rover command software based in Matlab/Simulink that implements algorithms for rover path planning, multiple rover management, mission task commanding, and a human GUI for high level tasks.

Infusion:

ANTs is the 'brain' of CASM allowing a user to input high level commands, such as "disseminate the mesh network", and ANTS autonomously providing low-level path planning and commanding to the rover associated with commanded tasks.



Figure 8. KNaCK Backpack.



Figure 9. KNaCK rover.

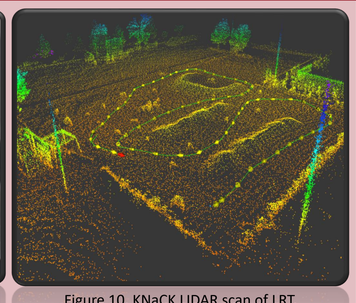


Figure 10. KNaCK LIDAR scan of LRT.

Kinematic Navigation and Cartography Knapsack (KNaCK)

Description:

The KNaCK backpack is a light detection and ranging(LIDAR) based 3D terrain mapping, navigation, and algorithm development tool.

Infusion:

The KNaCK Autonomous Rover (KNaCAR) provides the CASM project with a way to learn about the surrounding terrain and hazards through real-time simultaneous localization and mapping(SLAM) as well as means to determine the progress of ANTS commanding through LIDAR change detection.

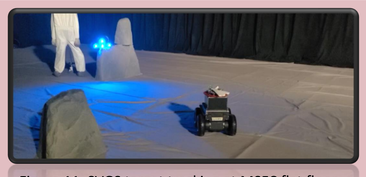


Figure 11. SVGS target tracking at MSFC flat floor.

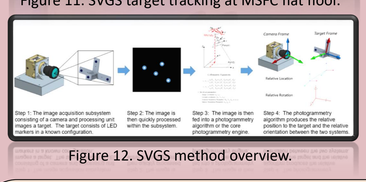


Figure 12. SVGS method overview.



Figure 13. SVGS relative motion at LRT.

Smart Video Guidance Sensor (SVGS)

Description :

SVGS is a camera-target based relative navigation sensor that images an LED target of known dimension and determines 6-Degree of Freedom Pose between the camera and the target.

Infusion :

SVGS acts as a Rendezvous, Proximity Operation, and Docking sensor for the CASM project and works with ANTs to complete the docking and dissemination of the Lunar Harpoons UWB mesh.



Figure 14. Lunar Harpoon node.



Figure 15. Lunar Harpoon mesh network test.

Lunar Harpoon

Description:

Lunar Harpoon is a localized ultra-wide band(UWB) mesh network that provides centimeter scale precision position information to systems equipped with a harpoon node within the mesh.

Infusion :

Lunar harpoon will provide a local and highly precise navigation network to the ANTs workers allowing them to navigate the KNaCK mapped terrain to complete tasks.



Figure 16. Rover outfitted with plough.

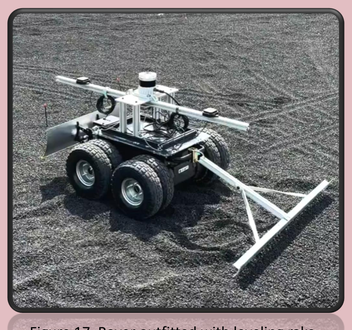


Figure 17. Rover outfitted with leveling rake.

ANT Worker

Description:

A rover outfitted with hardware to allow for manipulation of regolith.

Infusion:

The ANTs worker will be commanded by the ANTS software to complete actions needed to prepare the lunar landing site on the LRT. The workers navigate using Lunar Harpoon nodes and the hazard map created by KNaCK-SLAM.

Concept of Operations

The CASM system will initialize in an unknown environment and be commanded through the ANTS software to map and determine hazards to avoid using KNACK, apply SVGS and KNaCK to disseminate the Lunar harpoon UWB -mesh network, and prepare a precursor landing pad area using ANT workers and Lunar Harpoon navigation.

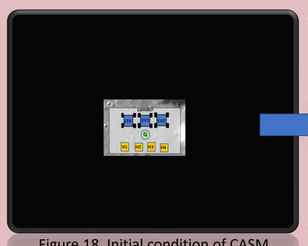


Figure 18. Initial condition of CASM

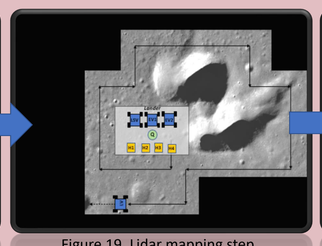


Figure 19. Lidar mapping step.

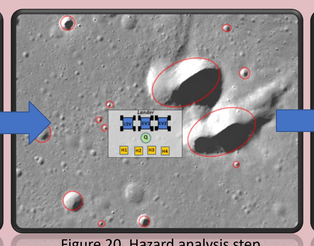


Figure 20. Hazard analysis step.

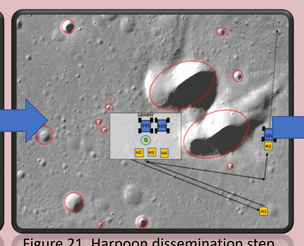


Figure 21. Harpoon dissemination step.

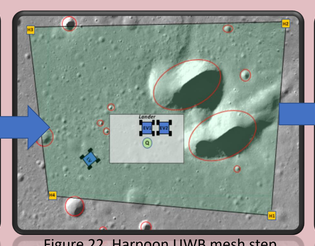


Figure 22. Harpoon UWB mesh step.

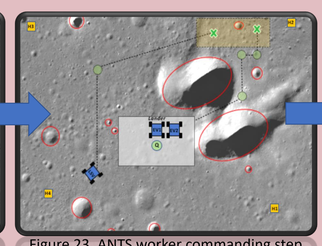


Figure 23. ANTS worker commanding step.

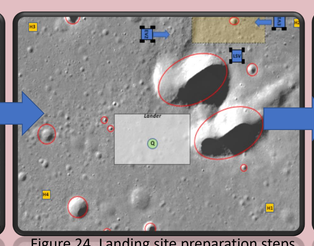


Figure 24. Landing site preparation steps.

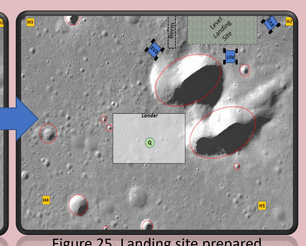


Figure 25. Landing site prepared.

Concluding Remarks

Today:

The CASM project has made great strides in the integration of the individual technologies with the majority of the KNaCK, ANTs, and the ANTS workers capability being put in place. The remaining integration needs are focused on infusion and demonstration of the SVGS and Lunar Harpoon systems toward the final con-ops.

Looking Forward:

The CASM team intends to investigate more complex con-ops relevant for Space Technology Mission Directorate (STMD) gaps, such as a ground demo of Moon-to-Mars Planetary Autonomous Construction Technology (MMPACT)-like device, integration with other rovers (e.g. robotic arm variants, high TRL rovers, etc), and further TIP/CIF work. CASM has been designed to be platform agnostic and adaptable for incorporating other architectures and systems!

Contact Information:

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Citations:

[1] – Triana, "Lunar_Mobility_Outbrief.pptx". Advanced Concept Organization, Marshall Space Flight Center. July 2023.
[2] – Zanetti. "MSFC FY24 TIP: Collaborative Autonomy for Surface Mobility (CASM).pptx". Marshall Space Flight Center. May 2023.
[3] - Image Credit to Google Earth.