



Astrobee Payload Demonstration of REACCH Capture Mechanism

Kall Morris Inc (KMI)

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Technical Objectives & Outcomes

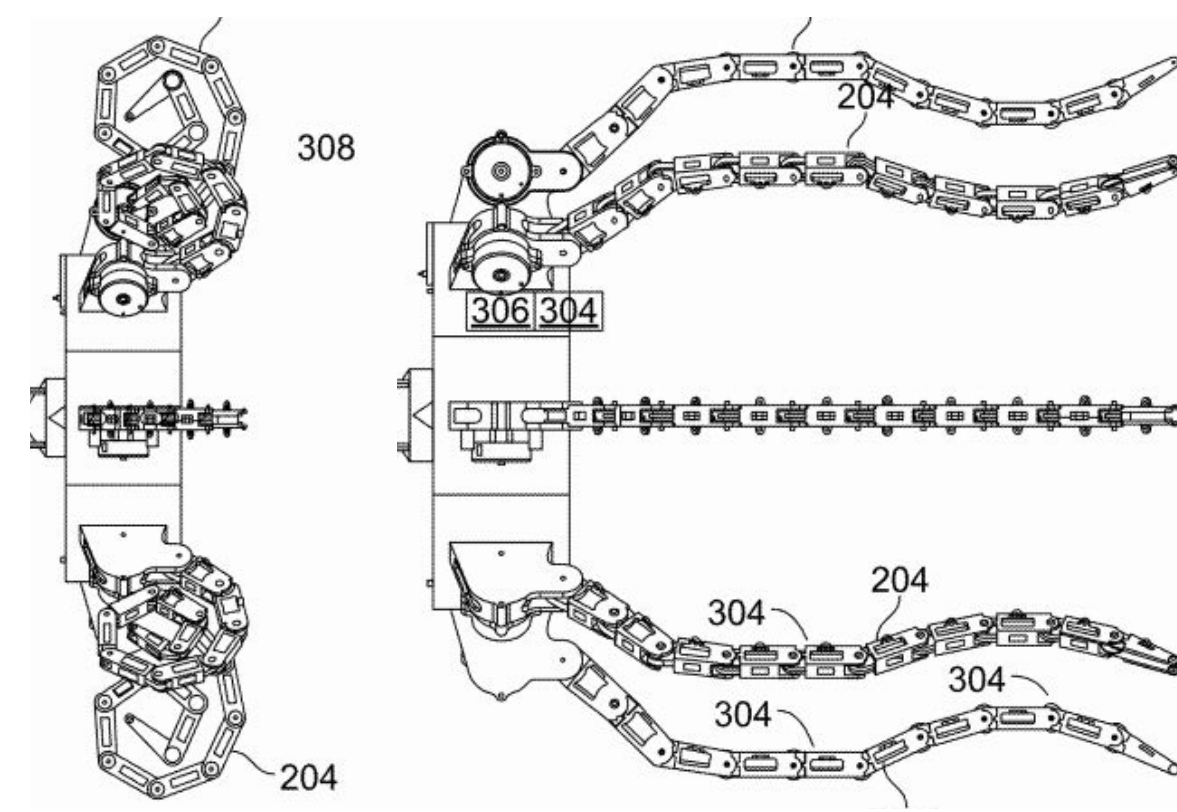
The technology development goals and project aims are to validate the capability of a **Reactive Electro-Adhesive Capture Cloth (REACCH)** to reliably interact with and capture free-floating objects of various surface conditions and materials in a microgravity environment, in order to illustrate the capacity of the patented technology to safely retrieve debris objects for ADR.

Achieving this goal entails the capture of a target (defined as a grapple reducing relative velocity to 0m/s), securely (force exerted by REACCH is translated rigidly into the target), and non-destructively (no loss of function for REACCH or dismantling of the targets).

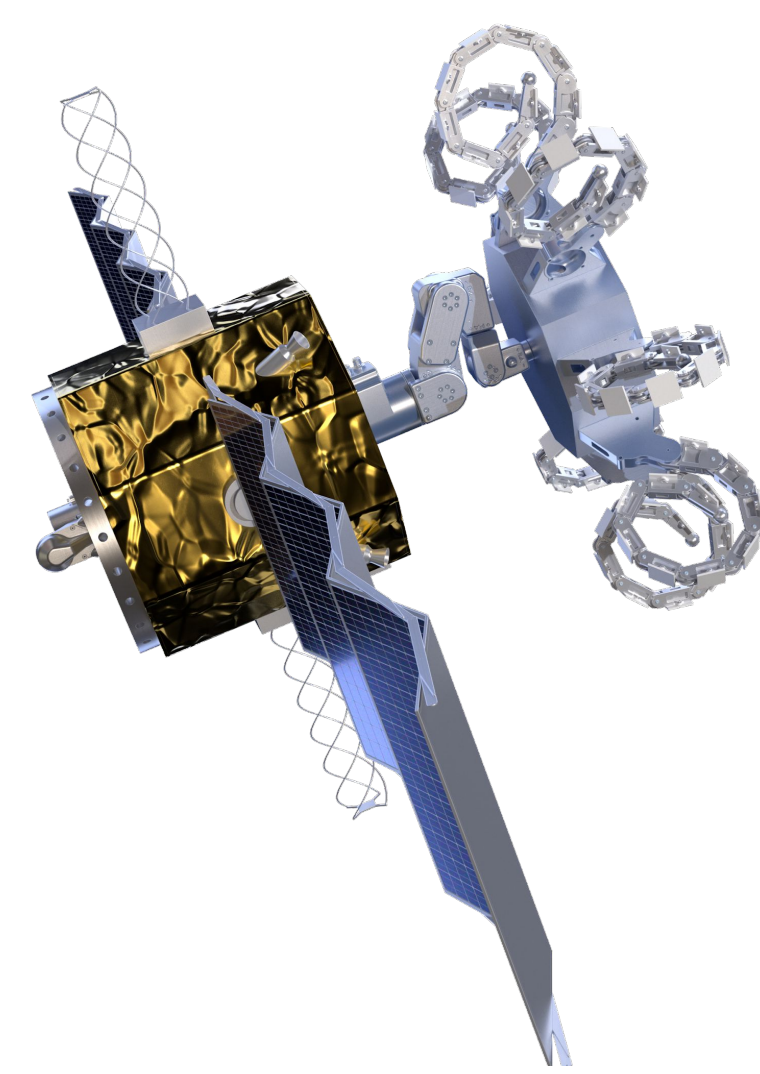
The specific objectives of this project include:

- Demonstrate capture of a free-floating target object with REACCH by securing the object with REACCH's tentacles and negating relative motion between the two objects
- Demonstrate capture of target objects having smooth surface conditions, such as flat panels of Kapton, Pyralux, acrylic, and carbon fiber
- Demonstrate capture of target objects having rough surfaces, such as MLI blanket, solar cell arrays, and 3D printed surfaces with large and small bumps covered in Kapton
- Demonstrate release of a captured target with no remaining residue, damage, or indication of previous adhesion

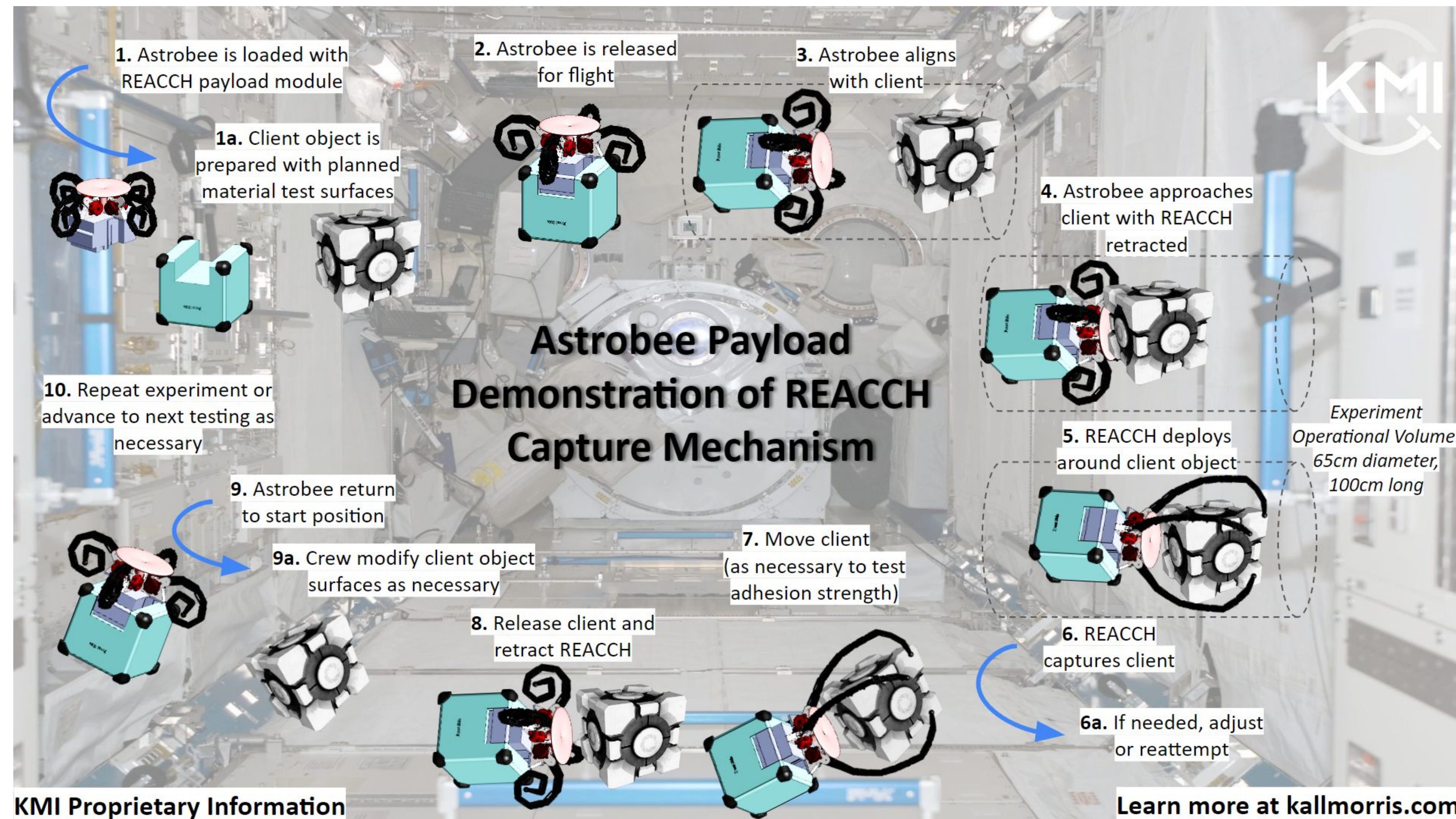
Conducting this testing and successfully demonstrating these secure capture capabilities in a microgravity environment that provides 6DOF will elevate this end effector technology to TRL 6 by completing a system prototype demonstration in a relevant space environment. Additional demonstration, test conditions, data collection, and research will be conducted as possible.



Patent No.: US 11,661,217



ADR Spacecraft: Laelaps



Innovation

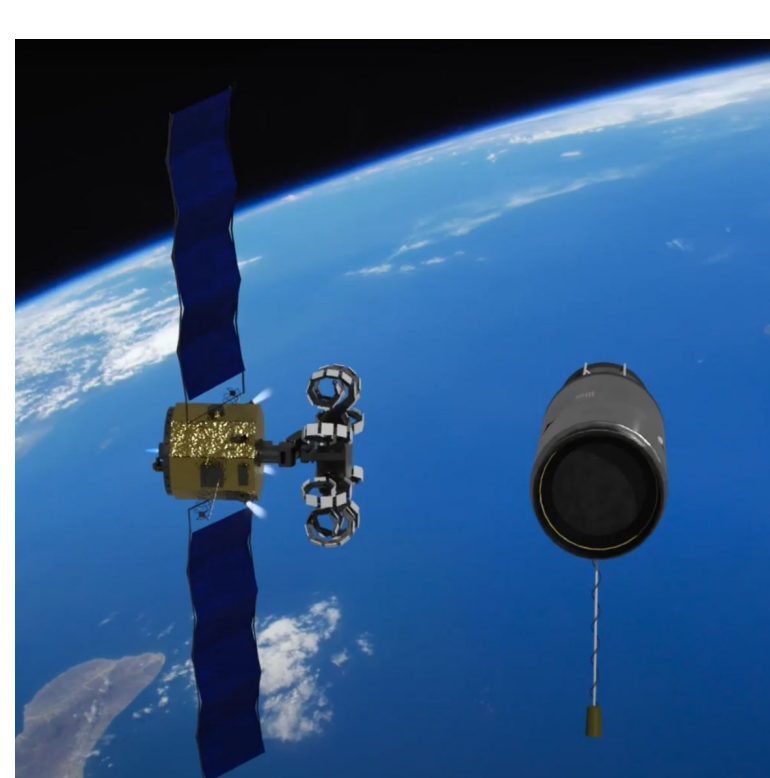
REACCH represents the culmination of developments in directional mechanical adhesives, such as gecko adhesion, and the advancement of miniaturized electrostatic adhesion pads to create a mutually beneficial combination that increases the strength of both adhesion methods to a degree greater than either could achieve independently.

The combination of these two, known as electrostatic/gecko adhesion (EGA) is further supported by installing it on articulated robotic tentacles that provide high geometric conformance. The level of dynamic, flexible grip enabled by this combined REACCH system drastically expands the type of objects that can be captured in terms of their material composition, surface contiguity, and overall geometry, as well as in their orientation and attitude motion on orbit. The on-demand soft capture methodology through multiple contact points on each tentacle support a variety of distinct functions promoting safe space operation, including contact/grapple of cooperative satellite clients for handoff, object anchoring for temporary stability, and retrieval of selected objects for ADR.

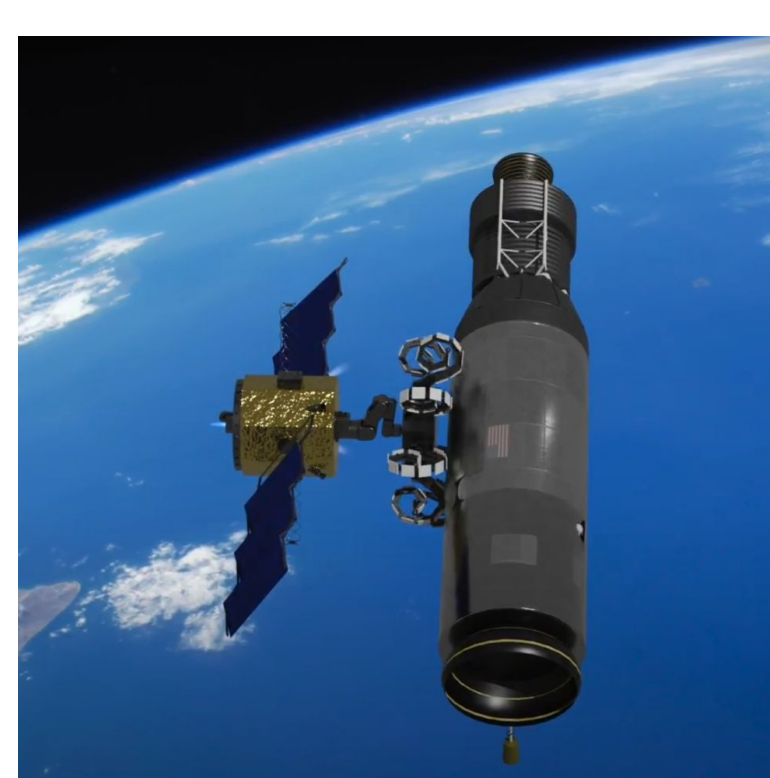
Currently available technology primarily relies on docking adapters, targeting fiducials, and sometimes provided telemetry. These technologies use pre-existing models or prior inspection missions to understand what their target looks like before embarking on a retrieval mission. Unlike the currently available technology, REACCH utilizes novel applicators and EGA to assist in the capture of unprepared objects which has been widely unexploited in ADR missions thus far.

The REACCH system will be supplemented in the full ADR mission by the KMI proprietary TumbleEye technology, recently selected for an Air Force research contract, to enable rendezvous, retrieval, and relocation without requiring previous knowledge of the target's geometry, orientation, or tumble rate. By proving these distinct hardware and software technologies and integrating them with one another, KMI can accomplish repeatable, efficient ADR.

Rendezvous



Retrieve



Relocate



Company Information

KMI is a space solutions company based in Marquette, Michigan developing technology to rendezvous, retrieve, and relocate objects in orbit to safeguard space and the services from it. Growing from academia and industry, KMI is moving from the lab to LEO in 2024.

With a future fleet of AI/ML enabled spacecraft to non-destructively secure a variety of in-space opportunities, KMI will be moving kilograms kilometers for decades to come.

Previous & Related Efforts

Previous endeavors aboard the ISS have included different applications of gecko adhesion for conceptually testing the technology in microgravity.

- From April 6th to April 15th of 2021, Stanford University led an experiment with their gecko gripper, which also utilized the Astrobee system and Gecko adhesion with a micro-wedge design, similar adhesion to this experiment (Cutkosky and Pavone 2021).
- TU Braunschweig also performed their experiment in the beginning of 2021, known as Reduced Gravity Docking Experiment Using Gecko Adhesives (REGGAE), which successfully docked two Astrobee units together, supported by gecko adhesives (INM – Leibniz-Institute for New Materials 2021).
- This project is a further development by focusing on a more specific use-case, especially as a continuation of previously proposed research by University of Southern California (USC). KMI is proposing a new REACCH prototype to continue developing and demonstrating this gripper technology.

Unique Capabilities

With the free-floating nature of Astrobee and non-crew controlled operation, the testing of REACCH onboard an Astrobee is an ideal stand-in for the later spacecraft mission intention of the technology. The relative size between REACCH and the Astrobee is analogous to the fullscale REACCH system and supporting spacecraft, allowing confirmation of the overall motion and functionality of the assembled system in 6DOF. This will uniquely demonstrate the system prototype in a relevant space environment, progressing REACCH to TRL 6.

Due to the eventual application of REACCH in outer space, the 6DOF and microgravity interaction, and specifically for REACCH's EGA portions, it is unlikely to expect an advanced simulation to accurately determine the non-perfect scenarios that might be presented in live testing of REACCH on the ISS.

Additionally, significant ground-based R&D has been and will continue to be utilized, but is limited to 3DOF testing and air tables that simulate microgravity situations while lacking the additional angles of force that might impact the performance of the technology. Ground testing can increase DOF or negate gravity, but over the duration of an experimental test, it is prohibitively difficult to create an environment that provides the necessary 6DOF and negated gravity.

Development

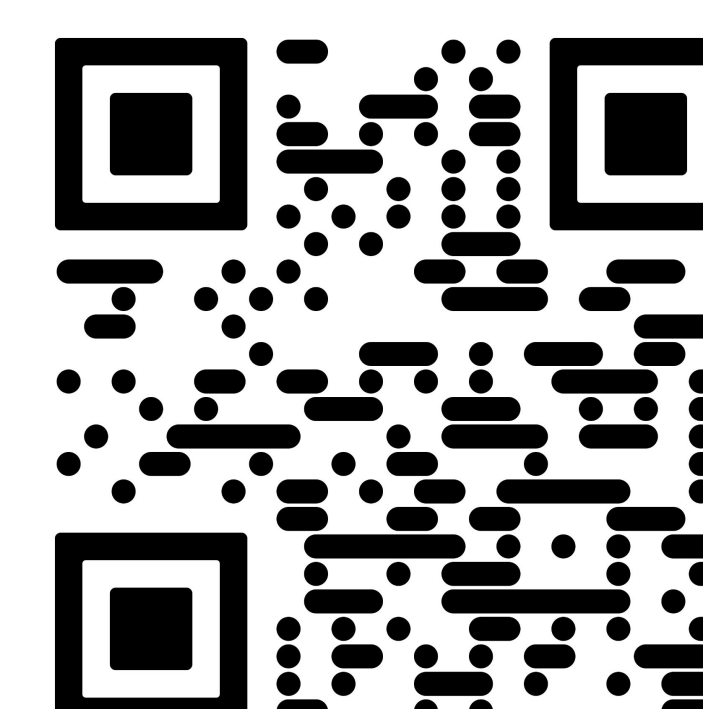
The current REACCH ground prototype has been tested with two distinct pairs of tentacles: one continuous, flexible pair and one segmented, jointed pair. Each single pair of tentacles has completed 3DOF feasibility testing at USC. Under this project, sponsored by CASIS, the ISS flight prototype will move forward with a two-pair, four tentacle system incorporating the segmented tentacle design, and will expand the demonstration to capture in all axes, testing several cycles of free-floating target capture, with swapped target surface coverings between captures to provide the necessary variety of materials and surface conditions.

REACCH is currently at TRL 5, having completed testing and demonstration in a relevant ground laboratory environment with the University of Southern California (USC), in conjunction with Air Force Research Laboratory (AFRL) through a SpaceWERX Orbital Prime effort, following co-development with NASA Jet Propulsion Laboratory (JPL) through a DARPA effort.

Acknowledgement of Critical Partnerships



USC Video Demos



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