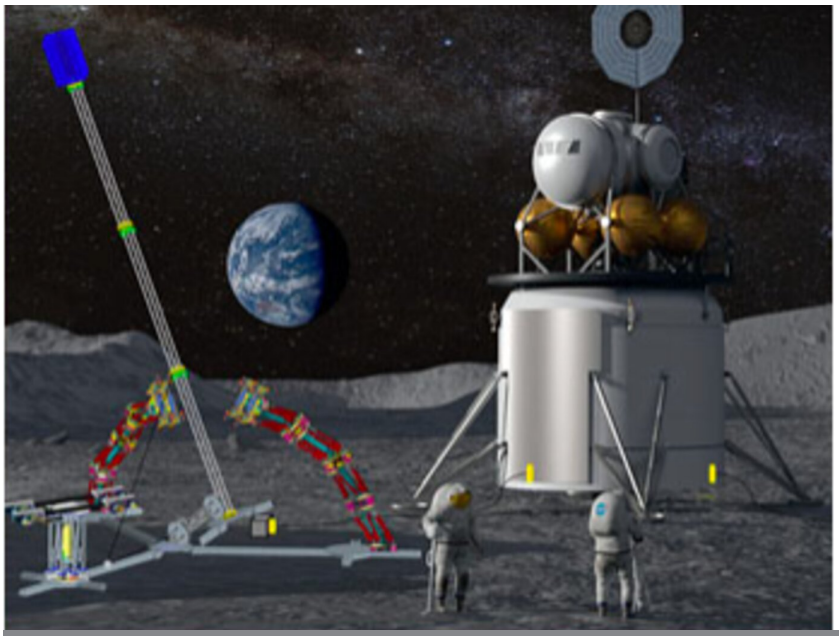


National Aeronautics and Space Administration

NASA

TECHNOLOGY SOLUTION

Robotics, Automation and Control

Assemblers

Teams of modular robots build structures in space, autonomously or with humans-in-the-loop

In-space and planetary surface assembly for human exploration is a challenging domain that encompasses various technological thrusts to support human missions. NASA is developing autonomous assembly agents to build structures like habitats and antennae on the Moon. These modular and reconfigurable Assembler robots will provide robotic assembly of structures, even in locations that prohibit constant human oversight and teleoperation. This system is capable of scheduling, reconfiguring, and executing structural assembly tasks; assessing construction; and correcting errors in assembly as needed. On command, the Assemblers stack themselves into robot team members for the task. For example, a few Assemblers might build a solar array as shown in the above image. The Assembler technology builds upon recent advancements in lightweight materials, state estimation, modern control theory, and machine learning. The Assembler technology builds upon recent advancements in multi-agent planning, state estimation, modern control theory, and machine learning. Compared with existing short-reach/high-accuracy and long-reach/low accuracy-assembly robots, Assemblers provides both long- and short-reach capability with accuracy and precision. NASA has developed a prototype of the technology and seeks companies that are interested in licensing the technology and commercializing it for space or other applications.

BENEFITS

- Serviceability: Estimates indicate the Assemblers can enable 5- to 15-year mission life.
- Expandability: The modular architecture enables robots that are as short or as long as needed.
- Packing efficiency: Assemblers are made of advanced lightweight material.
- Modularity: Modules can be reconfigured to produce a wide range of capabilities, eliminating the need for mission-specific technologies.

APPLICATIONS

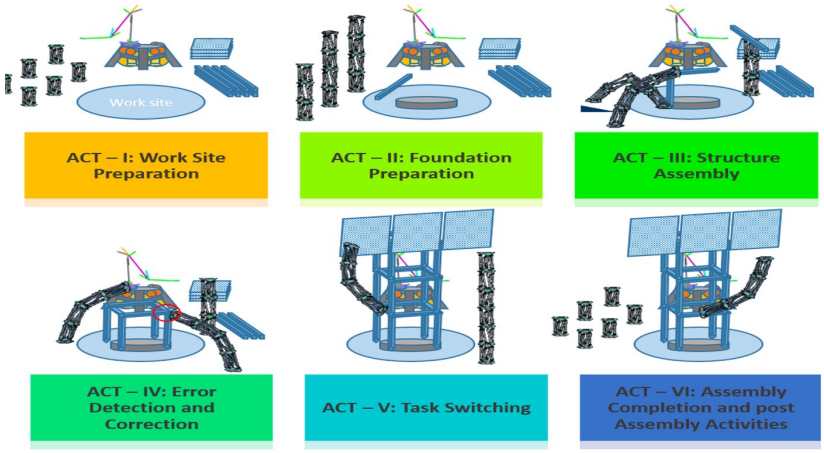
The technology has several potential applications:

- Fabrication of structures on- orbit or on the lunar surface including habitats, power trusses, science equipment, telescope supports, refueling stations, aeroshells, antennae, gravity-generator facilities, or solar arrays
- Advanced industrial manufacturing and assembly

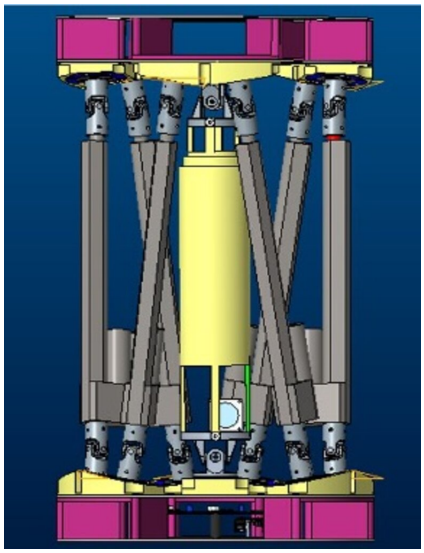
THE TECHNOLOGY

Assemblers are a team of modular robots that work together to build things. Each Assembler is a stack of one or more Stewart platforms, or hexapods, made up of two plates connected by six linear actuators for movement, enabling a full six-degree-of-freedom (DOF) pose of the top plate relative to the bottom plate (see figure to the right). An end effector on each Assembler enables gripping, lifting, and welding/joining. The Assemblers system architecture features novel control algorithms and software, sensors, and communicator technology that coordinate operations of Assembler teams. The control system includes an important module for task management that estimates how many robots are needed, the optimal number of hexapods in each Assembler, and the estimated voltage needed. There are also modules for trajectory generation, joint control, sensor fusion, and fault detection. The novel control system directs the Assembler operations for high accuracy and precision, yet there is built-in dynamic resilience to failure. For example, if a single hexapod on an Assembler fails, the system deems it “rigid” in its last pose and redistributes the work to the other Assemblers.

The image below shows a storyboard of operations for how Assemblers might build a solar array. NASA has developed a hardware demo with communications between subsystems, backed up by detailed simulations of the kinematics and actuator dynamics.



A current Assemblers project focuses on lunar surface solar array construction. The concept of the Assemblers' operation is described as a storyboard in six acts, starting with work-site preparation (Act 1).



Assemblers comprise stacked hexapods. As shown, six linear actuators connect a top and bottom plate, enabling a full six-DOF pose of the top plate relative to the bottom.

PUBLICATIONS

Patent Pending

D. Balaban, J. Cooper and E. Komendera, "Inverse Kinematics and Sensitivity Minimization of an n-Stack Stewart Platform," 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2019, pp. 6794-6799, doi: 10.1109/IROS40897.2019.8968190. John R. Cooper, James H. Neilan, Matthew Mahlin and Laura M. White, "Assemblers: A Modular, Reconfigurable Manipulator for Autonomous in-Space Assembly," 2020 AIAA Ascend Conference.Published Online:2 Nov 2020. https://doi.org/10.2514/6.2020-4132

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