Automated Reconfigurable Mission Adaptive Digital Assembly Systems (ARMADAS): Cost-effective Large-Scale Instrumentation for Planetary Science

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The Automated Reconfigurable Mission Adaptive Digital Assembly Systems (ARMADAS) project at NASA Ames Research Center is developing autonomous spacecraft, infrastructure, and instrumentation assembly and manufacturing capabilities for next generation exploration and science missions, with a goal to change the cost scaling of these missions relative to mission size and duration. Using a building-block approach with a 'kit of parts' composed of ultra-light, high-performance mechanical metamaterials, simplified robots leverage the period environment to achieve high levels of autonomy and reliability for in-space assembly of large-scale apertures, solar-arrays, booms, and other structures. Robots and structure break down into a compact form factor for launch. By leveraging economies of scale and achieving high-packing ratios, ARMADAS technology can revolutionize possible space missions by overcoming launch shroud limitations, decreasing development times, and decreasing mission costs for transformative science capability.

To date, the ARMADAS project has demonstrated autonomous assembly of large numbers of structural modules into a meters-scale structure in an earth gravity environment. The mechanical performance is on par with conventional space structures, at a fraction of the cost. By using highly repeatable manufacturing processes (injection molding carbon fiber reinforced space-rated polymers), the structures are both cost effective and highly precise. The ARAMADAS system carefully designs parts for high-precision assembly–the simple and cost-effective robots build structures much larger and more precise than themselves. This technology is suitable for assembly of large-scale apertures, booms, towers, as well as in-space assembly of entire spacecraft for lower-cost and faster deployed missions. While maintaining structural efficiency, the ARMADAS system encompasses many functional module types, including for solar power, comm/power routing, etc., that will enable entire spacecraft systems to be engineered and autonomously assembled (on orbit, if desired) with modular parts. With well-defined interfaces, custom instrumentation modules can easily be added to fit many mission objectives.

Planetary Science Technical Challenges Addressed:

- **Instrumentation sizes beyond current launch shroud capabilities:** Assembly allows spacecraft structure and components to be stowed compactly for launch and assembly into much larger structures after launch. Since structures don't have to survive launch in their assembled state or contain complicated deployment mechanisms, these structures can be extremely mass efficient. Larger apertures can enable higher-resolution science, especially at radio frequencies, even within smaller space-craft sizes and mission budgets.
    - Missions Applications: Large-scale solar deployment for New Frontiers Titan Orbiter, radio instrumentation for New Frontiers Titan Orbiter, Jupiter System

Observatory at Sun-Jupiter Lagrangian Point One, Radar aperture for Titan Orbiter

- **Reduce mission cost by offering a 'kit of parts' approach to spacecraft design:** Generalized mechanical metamaterial structural building blocks can be outfitted with custom instrumentation and other functional modules to create modular spacecraft, reducing cost by leveraging economies of scale
    - Mission Applications: Interstellar Object Interceptor, New Frontiers Titan Orbiter, broad applicability across most missions
- **Faster development and just-in-time deployment via in-space assembly of general parts and upgradable instrumentation:** Modular spacecraft can reduce mission development time and cost. For missions like Interstellar Object Interceptor, manufacturing spacecraft on-orbit for just-in time deployment, with upgradable modular instrumentation, will enable effective observation of events with low lead times and durations. The ARMADAS 'kit of parts' approach ensures that generic parts are stocked to a robotic assembly facility with low-cost ride share, while custom instruments can be fitted to the spacecraft with well-defined interfaces.
    - Mission Applications: Interstellar Object Interceptor

The ARMADAS project is funded by the Space Technology Mission Directorate (STMD) Game Changing Development (GCD) program.