NASA STTR 2021 Phase I Solicitation

T10.03 Coordination and Control of Swarms of Space Vehicles

Lead Center: JPL

Participating Center(s): LaRC

Scope Title:

Enabling Technologies for Swarm of Space Vehicles

Scope Description:

This subtopic is focused on developing and demonstrating technologies that enable cooperative operation of swarms of space vehicles in a dynamic environment. Primary interest is in technologies appropriate for low-cardinality (4- to 15-vehicle) swarms of small spacecraft, as well as planetary rovers and flyers (e.g., Mars helicopter). Large swarms and other platforms are of interest if well motivated in connection to NASA's Strategic Plan and needs identified in decadal surveys.

The proposed technology must be motivated by a well-defined "design reference mission" presented in the proposal with clear connection to the needs identified in decadal surveys. The proposed design reference mission is used to derive the high-level requirements for the technology development effort.

Areas of high interest are:

- Distributed estimation for exploration and inspection of a target object or phenomena by various assets with heterogenous sensors and from various vantage points.
- High-precision relative localization and time synchronization in orbit and on planet surface.
- Operations concepts and tools that provide situational awareness and commanding capability for a team of spacecraft or swarm of robots on another planet.
- Coordinated task recognition and planning, operation, and execution with realistic communication limitations.
- Communicationless coordination by observing and estimating the actions of other agents in the multiagent system.

NASA has plans to purchase services for delivery of payloads to the Moon through the Commercial Lunar Payload Services (CLPS) contract. Under this subtopic, proposals may include efforts to develop payloads for flight demonstration of relevant technologies in the lunar environment. The CLPS payload accommodations will vary depending on the particular service provider and mission characteristics. Additional information on the CLPS program and providers can be found at this link: https://www.nasa.gov/content/commercial-lunar-payload-services. CLPS missions will typically carry multiple payloads for multiple customers. Smaller, simpler, and more self-sufficient payloads are more easily accommodated and would be more likely to be considered for a NASA-sponsored flight opportunity. Commercial payload delivery services may begin as early as 2020 and flight

opportunities are expected to continue well into the future. In future years, it is expected that larger and more complex payloads will be accommodated. Selection for award under this solicitation will not guarantee selection for a lunar flight opportunity.

Expected TRL or TRL Range at completion of the Project: 3 to 6
Primary Technology Taxonomy:
Level 1: TX 10 Autonomous Systems
Level 2: TX 10.3 Collaboration and Interaction
Desired Deliverables of Phase I and Phase II:

- Research
- Prototype
- Software
- Hardware

Desired Deliverables Description:

Phase I awards will be expected to develop theoretical frameworks, algorithms, and software simulation and demonstrate feasibility (TRL 3). Phase II awards will be expected to demonstrate capability on a hardware testbed (TRL 4 to 6).

- Phase I and Phase II: Algorithms and research results clearly depicting metrics and performance of the developed technology in comparison to state of the art (SOA). Software implementation of the developed solution along with simulation platform must be included as a deliverable.
- Phase II only: Prototype of the sensor or similar if proposal is to develop such subsystem.

State of the Art and Critical Gaps:

Technologies developed under this subtopic enable and are critical for multi-robot missions for collaborative planetary exploration. Distributed task recognition, allocation, and execution, collaborative motion planning for larger science return, and distributed estimation and shared common operational picture are examples of technology needs in this area.

These technologies also enable successful formation flying spacecraft missions, robust distributed GNC, precision relative navigation, distributed tasking and execution, and distributed estimation of the swarm state as well as the science target are examples of the technology gaps in this area.

Relevance / Science Traceability:

Subtopic technology directly supports NASA Space Technology Roadmap TA4 (4.5.4 Multi-Agent Coordination, 4.2.7 Collaborative Mobility, and 4.3.5 Collaborative Manipulation) and Strategic Space Technology Investment Plan (Robotic and Autonomous Systems: Relative GNC and Supervisory control of an S/C team), and is relevant to the following concepts:

- Multi-robot follow-on to the Mars 2020 and Mars helicopter programs are likely to necessitate close collaboration among flying robots as advanced scouts and rovers.
- PUFFERs are being developed at the Jet Propulsion Laboratory (JPL) and promise a low-cost swarm of networked robots that can collaboratively explore lava tubes and other hard-to-reach areas on planet surfaces.
- A convoy of spacecraft is being considered, in which the lead spacecraft triggers detailed measurement of a very dynamic event by the following spacecraft.

Multiple concepts for distributed space telescopes and distributed synthetic apertures are proposed that rely heavily on coordination and control technologies developed under this subtopic.

References:

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[3] Evan Ackerman, "PUFFER: JPL's Pop-Up Exploring Robot; This little robot can go where other robots fear to roll,“ https://spectrum.ieee.org/automaton/robotics/space-robots/puffer-jpl-popup-exploring-robot(link is external).

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[10] Space Studies Board, "Achieving Science with CubeSats: Thinking Inside the Box," National Academies of Sciences, Engineering, and Medicine, 2016, http://sites.nationalacademies.org/SSB/CompletedProjects/SSB_160539.

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