# NASA SBIR 2017 Phase I Solicitation

## H6.03 Spacecraft Autonomous Agent Cognitive Architectures for Human Exploration

**Lead Center: ARC**

**Participating Center(s): JSC, MSFC**

**Technology Area: TA4 Robotics, Telerobotics and Autonomous Systems**

Future human spaceflight missions will place crews at long distances from Earth causing significant communication lag due to the light distance as well as occasional complete loss of communication with Earth. Novel artificial intelligence capabilities augmenting crews will be required for them to autonomously manage spacecraft operations and interact with Earth mission control under these conditions, including spacecraft and systems health, crew health, maintenance, consumable management, payload management, training, as well as activities such as food production and recycling.

Autonomous agents with cognitive architectures would be able to interface directly with the crew as well as with the onboard systems and mission control, thus reducing the cognitive loads on the crew as well as performing many tasks that would otherwise require scheduling crew time. In addition, this cognitive computing capability is necessary in many circumstances to respond to off-nominal events that overload the crew; particularly when the event limits crew activity, such as high-radiation or loss of atmospheric pressure events.

In deep space, crews will be required to manage, plan, and execute the mission more autonomously than is currently done on the International Space Station (ISS); which from Low Earth Orbit has instantaneous ground support. NASA expects to migrate significant portions of current operations functionality from Earth flight control to deep-space spacecraft to be performed autonomously. These functionalities will be performed jointly by the crew and cognitive agents supervised by the crew; so the crew is not overburdened. Cognitive agents that can effectively communicate with the crew could perform tasks that would otherwise require crew time by providing assistance, directly operating spacecraft systems, providing training, performing inspections, and providing crew consulting among other tasks.

Due to the complexity of such cognitive agents and the need for them to be continually updated, their software architecture is required to be modular. A requirement for the cognitive software architecture is that modules can dynamically be added, removed, and enhanced. Types of modules would likely include a smart executive, state estimator, planner/scheduler, diagnostics and prognostics, goal manager, etc. Other modules that may be supported include a dialog manager, risk manager, image recognition, instructional drawing, crew task manager, etc. This type of modular cognitive architecture is consistent with that proposed by Prof. Marvin Minsky in "The Society of Mind", 1988, and subsequent proposals and realizations of cognitive agents. Recent venues for cognitive architectures include: ICCM (http://acs.ist.psu.edu/iccm2016/) and CogArch 2016 @ ASPLOS (http://researcher.watson.ibm.com/researcher/view_group.php?id=5848).

Due to NASA's need for fail-safe capabilities, such as continued functionality during high-radiation events, the cognitive architecture will be required to be capable of supporting multiple processes executing on multiple processors, in order to meet the expected computational loads as well as be robust to processor failure. Cognitive architectures capable of being certified for crew support on spacecraft are also required to be open to NASA with interfaces open to NASA partners who develop modules that integrate with other modules on the cognitive agent in contrast to proprietary black-box agents. Note that a cognitive agent suitable to provide crew support on spacecraft may also be suitable for a variety of Earth applications, but the converse is not true; thus requiring this NASA investment.

The emphasis of proposed efforts are expected to be on analyzing and demonstrating the feasibility of various configurations, capabilities, and limitations of a cognitive architecture suitable for crew support on deep space missions. The software engineering of a cognitive architecture is to be documented and demonstrated by implementing a prototype goal-directed cognitive agent that interacts with simulated spacecraft systems and humans.

For Phase I, a preliminary cognitive architecture, preliminary feasibility study, a cognitive agent prototype that supports a human operating a simulate complex system that illustrates a candidate cognitive agent architecture, and a detailed plan to develop a comprehensive cognitive architecture feasibility study are expected. For Phase II, it is expected that the proposed detailed feasibility study plan is executed. In Phase II it is expected that a comprehensive cognitive architecture will be generated, along with a demonstration of an agent prototype that instantiates the architecture. The agent prototype should interact with a spacecraft simulator and humans executing a plausible HEOMD design reference mission beyond cis-lunar (e.g., Human Exploration of Mars Design Reference Mission: https://www.nasa.gov/pdf/373665main_NASA-SP-2009-566.pdf). Phase II deliverables are also expected to include a comprehensive feasibility study report, and a detailed plan to develop a fully instantiated robust cognitive architecture suitable for proposing to NASA and other organizations interested in funding a flight capability. A Phase II prototype suitable for a compelling flight experiment or simulation interfacing with the ISS or a spacecraft-relevant robotic system is encouraged.