NASA SBIR 2019 Phase I Solicitation

H9.07 Cognitive Communication

Lead Center: GRC

Participating Center(s): GSFC, JPL

Technology Area: TA5 Communication and Navigation

Cognitive Capabilities

NASA's Space Communication and Navigation (SCaN) program seeks innovative approaches to increase mission science data return, improve resource efficiencies for both SCaN customers and networks, and ensure resilience in the unpredictable space environment. The Cognitive Communication subtopic focuses on advances in artificial intelligence, machine learning, and signal and data processing including:

- Adaptive, autonomous, and cognitive link technologies to improve mission communication capabilities.
- Networking technologies to move data through and among network nodes in a more efficient and intelligent manner, including on-board processing of data packets.
- System-wide approaches to optimize scheduling of network relay satellites and ground stations to balance utilization and reach maximum data transfer potential.

A cognitive system is envisioned to sense, detect, adapt, and learn from its experiences and environment to optimize the communications capabilities for the user mission satellite or network infrastructure. Goals of this capability are to improve communications capability and efficiency, mitigate channel impairments, and reduce operations complexity and costs through intelligent and autonomous communications and data handling.

The overall goal is to perform research and/or technology development to optimize space communication links, networks, and system-wide resource scheduling. Specific focus areas include:

- Flexible communication platforms, modules, and/or antennas that include novel signal processing technology [e.g., graphics processing units - GPUs - for space applications, neuromorphic approaches, and phased array antennas with integrated processing for interference mitigation].
- Wideband sensing and communications for S-, X-, and Ka-bands, coupled with machine learning algorithms that learn from the environment [e.g., learning channel impairments, spectrum sharing in noisy environments].
- On-board processing technology and decentralized networking techniques to enable data switching, routing, storage, and scheduling on a spacecraft [e.g., routing based on quality of service and data flow-specific requirements such as latency].
- Other innovative, related areas of interest.

This subtopic seeks innovations that address the unique needs of NASA's data communication requirements for the space environment, specifically focusing on low size, weight, power, and cost applications suitable for small satellite or cubesat operations. Proposed systems should highlight advancements to provide the needed communications capability while minimizing on-board resources such as power consumption and thermal dissipation. Proposals should consider how the technology can mature into a successful demonstration using one or several cubesat platforms.

Phase I will emphasize research aspects for technical feasibility, infusion potential into space operations, clear and achievable benefits (e.g., 2x-5x increase in throughput, 25-50% reduction in power, improved quality of service or efficiency, reduction in operations costs), and show a path towards a Phase II proposal. Phase I Deliverables include feasibility and concept of operations of the research topic, simulations and measurements, validation of the proposed approach to develop a given product (TRL 3-4), and a plan for further development of the specific capabilities or products to be performed in Phase II. Early development and delivery of prototype hardware/software is encouraged.

Phase II will emphasize hardware/software development with delivery of specific hardware or software product for NASA targeting demonstration operations on a cubesat platform. Phase II deliverables include a working prototype or engineering model of the proposed product/platform or software, along with documentation of development, capabilities, and measurements (showing specific improvement metrics), documents and tools as necessary for NASA to modify and use the cognitive software capability or hardware component(s). Proposed prototypes shall demonstrate a path towards a flight-capable cubesat platform. Opportunities and plans should also be identified and summarized for potential commercialization or NASA infusion. Software applications and platform/infrastructure deliverables for SDR platforms shall be compliant with the latest NASA standard for software defined radios, the Space Telecommunications Radio System (STRS), NASA-STD-4009 and NASA-HNBK-4009.

Cognitive networks and operations are a key goal of the HEOMD SCaN Program communications plan, including the SCaN Next Generation Architecture. As communications and networks become more complex, cognition and automation will play a larger role to mitigate complexity and reduce operations costs. Machine learning will configure networks, choose radio configurations, adjust for impairments and failures, and monitor short and long-term performance for improvements. SCaN has invested in Phase III CRP SBIR contracts and stands ready for additional investments. STMD recently awarded two Early Career Faculty grants to study topics related to Cognitive Communication including distributed network routing and blockchain-based data processing.

The SCaN Cognitive Communications project intends to fly a multi-cubesat mission in the early 2020s. This mission is intended to demonstrate research results obtained both internally and resulting from prior SBIR awards. Results from this subtopic would be candidates for this initial mission or future demonstrations.

Related Subtopic Areas

The focus of this subtopic is the application of advanced processing power to communication systems, especially for cubesats and small satellites. Development of the requisite processors and low-cost radiation hardening techniques is best suited to the Z8 topic area, particularly Z8.03 (Low Cost Radiation Hardened Integrated Circuit Technology). Development of neuromorphic processors and related enhanced processing capability to enable cognitive algorithms in general spacecraft applications is best suited to the H6 topic area, particularly H6.22 (Neuromorphic Processors for In-Space Autonomy and Cognition).

References:

Several reference papers that have been published through the Cognitive Communications Project include:

- "Implementation of a Space Communications Cognitive Engine" https://ntrs.nasa.gov/search.jsp?R=20180002166
- "Multi-Objective Reinforcement Learning-based Deep Neural Networks for Cognitive Space Communications" https://ntrs.nasa.gov/search.jsp?R=20170009153
- "Assessment of Cognitive Communications Interest Areas for NASA Needs and Benefits" https://ntrs.nasa.gov/search.jsp?R=20170009386
- "Architecture for Cognitive Networking within NASAs Future Space Communications Infrastructure" https://ntrs.nasa.gov/search.jsp?R=20170001295
- "Modulation Classification of Satellite Communication Signals Using Cumulants and Neural Networks"

https://ntrs.nasa.gov/search.jsp?R=20170006541

- Results of the Cognitive Communications for Aerospace Applications workshop are available at: http://ieee-ccaa.com/ccaaw-summary/