NASA SBIR 2016 Phase I Solicitation

H9.02 Advanced Space Communication Systems

Lead Center: GRC

Participating Center(s): GSFC, JPL

NASA's future systems require increased levels of adaptive, cognitive, and autonomous system technologies to improve mission communication capabilities for science and exploration. Goals of this capability are to improve communications efficiency, mitigate impairments (e.g., scintillation, interference), and reduce operations complexity and costs through intelligent and autonomous communications and data handling. These goals are further described in the TA05 Communications, Navigation, and Orbital Debris Tracking and Characterization Systems Roadmap, Sections 5.1, 5.2, 5.3 and 5.5.

Over the past 10 years software defined radio platforms and their applications have emerged and demonstrated the applicability of reconfigurable platforms and applications to space missions. This solicitation seeks advancements in cognitive and automation communication systems, networks, waveforms and components. While there are a number of acceptable definitions of cognitive systems/radio, for simplicity, a cognitive system should sense, detect, adapt, and learn from its environment to improve the communications capabilities and situation for the mission. Cognitive systems naturally lead to advanced multi-function RF platforms; platforms that serve more than one user or function and are reconfigurable, on-demand, either autonomously or by the user for arbitrary applications. NASA can leverage these systems, techniques, hardware, algorithms and waveforms for use in space applications to maximize science data return, enable substantial efficiencies, reduce operations costs, or adapt to unplanned scenarios. While much interest in cognitive radio in other domains focuses on dynamic spectrum access, this subtopic is primarily interested in much broader ways to apply cognition and automation. Areas of interest to develop and/or demonstrate are as follows:

- *System wide intelligence* – While much of the current research often describes negotiations and improvements between two radio nodes, the subtopic seeks solutions to understand system wide aspects and impacts of this new technology. Areas of interest include (but not limited to) -cognitive architectures considering mission spacecraft, relay satellites, other user spacecraft, and ground stations, system wide effects to decisions made by one or more communication/navigation elements, handling unexpected or undesired decisions, self-configuring networks, coordination among multiple spacecraft nodes in a multiple access scheme, cooperation and planning among networked space elements to efficiently and securely move data through the system, and automated link planning and scheduling to optimize data throughput and reduce operations costs. Capabilities may include interference mitigation, maximizing data throughput and efficiency, and intelligent network routing (best route) and disruptive tolerant networking over cognitive links. The focus here is on a cognitive understanding of, and adaptation to, temporally or spatially non-contiguous communications paths.
- *Advanced waveform development in the digital domain. Specifically* - The foundation has been laid through prior NASA investments in the area of generating the infrastructure for software-based algorithms. These investments led to the development and demonstration of the Space Telecommunication Radio System (STRS) architectural standard for software-defined radios. STRS based advanced backend platforms

generate (for transmission) or process (from reception) the appropriate waveform at a common Intermediate Frequency (IF) for transmission to, or reception from, an appropriate RF front-end. In addition, the backend processor is reconfigurable, by the user, for a specific application at a given time (radar vs. short range communications link, etc.).

- *Flexible and adaptive hardware systems -* Signal processing platforms, wideband and multi-band adaptive front ends for RF (particularly at S-, X-, and Ka-bands) or optical communications, and other intelligent electronics that advance or enable flexible, cognitive, and intelligent operations. The development and demonstration of advanced RF Front-Ends that cover NASA RF bands of interest; specifically S-Band, X-Band and/or Ka-Band. These RF front-ends may support time-multiplexed waveforms such as radar or (digitized) half-duplex voice transmissions as well as frequency duplexed waveforms such as full-duplex two-way navigation and data communications. Specifically, these front-ends are expected to leverage state-of-the-art RF materials (e.g., GaN, SiC, CMOS, etc.), packaging (e.g., MIC, SMT, etc.), device (e.g., MMIC, MEMS, etc.) and component techniques to minimize mass, volume and energy resource usage while supporting multi-functionality
- *Autonomous Ka-band and/or optical communications antenna pointing -* Future mission spacecraft in low Earth orbit may need to access both shared relay satellites in geosynchronous orbit (GEO) and direct to ground stations via Ka-band (25.5-27.0 GHz) and/or optical (1550 nm) communications for high capacity data return. To maximize the use of this capacity, user spacecraft will need to point autonomously and communicate on a coordinated, non-interfering basis along with other spacecraft using these same space- and ground-based assets. Included here are electronically steered antennas, especially at Ka-Band. Applications include large, high-performance electronically-steered antennas required for a dedicated communications relay spacecraft with multiple simultaneous connections, advanced multifunction antennas to support science missions that utilize a multifunction antenna to both communicate and conduct science, and small, lightweight antennas for communications only that provide moderate gain without the use of mechanical steering. Antennas that are reconfigurable in frequency, polarization, and radiation pattern that reduce the number of antennas needed to meet the communication requirements of NASA missions are desired.

For all technologies, Phase I will emphasize research aspects for technical feasibility, clear and achievable benefits (e.g., 2x-5x increase in throughput, 25-50% reduction in bandwidth, improved quality of service or efficiency, reduction in operations staff or costs) and show a path towards Phase II hardware/software development with delivery of hardware or software product for NASA. Proposals should demonstrate and explain how and where cognitive and automation technologies could be applied to NASA space systems and be discussed in the proposal.

Phase I Deliverables - Feasibility study and concept of operations of the research topic, including simulations and measurements, proving the proposed approach to develop a given product (TRL 3-4). Early development and delivery of the simulation and prototype software and platform(s) to NASA. Plan for further development and verification of specific capabilities or products to be performed at the end of Phase II.

Phase II Deliverables - Working engineering model of proposed product/platform or software delivery, along with documentation of development, capabilities, and measurements (showing specific improvement metrics). User's guide and other documents and tools as necessary for NASA to recreate, modify, and use the cognitive software capability or hardware component(s). 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 NASA standard for software defined radios, the Space Telecommunications Radio System (STRS), NASA-STD-4009 and NASA-HNBK-4009, found at: (https://standards.nasa.gov/documents/detail/3315910).