SUBTOPIC DESCRIPTION

This subtopic solicits proposals to develop enabling concepts, components, and subsystems based on innovative avionics architectures for small spacecraft. Of interest are wireless systems that demonstrate reliable data transfer across avionics components, subsystems, and interfaces to simplify system integration, reconfiguration, and testing. Solutions that enable new avionic architectures and provide capabilities that expand mission performance while decreasing the Size, Weight, and Power (SWaP) consumption and cost of the resulting spacecraft are highly desirable. The goal of this effort is to mature wireless avionics technology that facilitates the reuse of components, subsystems and software across multiple spacecraft and missions while reducing production and operating costs.

Modularity is defined as utilizing a set of standardized parts or independent units to form a full avionics system and flexibility allows adapting modular components across different configurations, missions, and design stages. For example, wireless subnets improve modularity by eliminating the physical data connections from each component, simplifying physical integration. The scope is intended to range from simple wireless sensors to complete avionics systems including software incorporating functions compatible with common spacecraft components. This means being able to integrate a given component or entire subsystem into flight hardware and software using object-oriented frameworks allowing components or functions to be added to a new or existing spacecraft design without requiring significant changes to the other non-related components or subsystems.

This subtopic also solicits proposals to develop techniques, components, and systems that reduce or eliminate the dependency on wires, connectors, and penetrations for sensing and for the transmission of data and power across avionics subsystems, interfaces, and structures. Of interest are techniques that enable new applications through the use of innovative methods such as the use of flexible materials and additive manufacturing. The use of additive manufacturing and 3D printing to embed avionics components such as antennas, sensors, transmission lines and interface functions into a spacecraft structure during the design and manufacturing process can increase efficiency while maintaining structural integrity. Similarly, the use of thin and flexible materials to construct passive wireless sensors enables sensing systems for structures such as parachutes and inflatable spacecraft without breaching the pressure interface. Systems that are applicable to small spacecraft (typically 6U/12U/24U CubeSats including ESPA-class), but scalable to large vehicles can result in a significant reduction of risk for more complex and longer duration missions. Near-term missions include: cislunar, lunar orbiting, lunar landed, exploration precursor; Low Earth Orbit (LEO) “swarms” for Earth science and heliophysics; disaggregated cooperative ensembles and sustained infrastructure for human exploration. New applications might include manned spacecraft inspection, repair, communications support and related areas. Proposals that provide reliable performance in extreme environments and that show a path to a flight demonstration are preferable.
The subtopic solicits developments in wireless avionics and wireless sensing for small spacecraft and may include technologies that:

1. Improve the reliability and applicability of wireless avionics for small spacecraft with significant improvements in subsystem size, mass, volume, particularly if the technology can simplify the spacecraft fabrication, test and integration process.
2. Allow innovative architectures for wireless avionics featuring plug-and-play software supporting modular subsystems that can be easily incorporated into specific small satellite missions.
3. Improve fault detection aboard spacecraft using wireless sensor systems to augment current wired sensors and which include the capability of adding sensors to address Developmental and Flight Instrumentation use.
4. Use additive manufacturing techniques for embedding sensors and other avionics components into a spacecraft to reduce or eliminate large and heavy cables and connectors or that enable data transfer inside and across rotating mechanisms and pressure interfaces or into remote locations where it is difficult or unfeasible to run cables or where cables are at risk of failure.
5. Use additive manufacturing of wireless components such as antennas, sensors and processing elements into materials and structures that enable in-situ structural health management, contributing to the development of smart structures and materials.
6. Include sensors and actuators that can be distributed among cooperative spacecraft to enable automated inspection of space assets or resource detection at the surface of the moon, Mars or other celestial bodies.

References
WAIC Systems: https://ntrs.nasa.gov/archive/nasa/casi.ntrs.nasa.gov/20170000686.pdf
Backscatter Systems for WAIC: https://ntrs.nasa.gov/search.jsp?R=20180004760
NASA Trade Study: https://pdfs.semanticscholar.org/b7d6/e6d92ec78b6beee4cfd5a7f613b90b4508b8.pdf?_ga=2.244696965.1804159109.1563897519-1127952606.1563032260
PWST Workshops – https://attend.ieee.org/wisee-2019/program/workshops/

Expected TRL or TRL range at completion of the project

TRL 1 to 2 concepts for science instruments and sensory systems for vehicles and observatories

TRL 3 to 6 for embedded sensor systems and modular avionics technology development and prototype demonstration

Desired Deliverables of Phase II

Prototype Hardware and Software, Demonstrations

Desired Deliverables Description

Possible deliverables include bench-top hardware systems that demonstrate reliable wireless inter-connectivity of two or more modules with a host flight CPU, or payload/DFI processor, inside a Cubesat or Small Satellite form-factor bus. This system need not be flight-ready, but it should be in a path to a flight demonstration that would serve as technology maturation and risk reduction activity for larger NASA missions such as Lunar Gateway, and other Artemis projects.
Specific Deliverables Include:

- Methods of improving reliability of wireless avionics technology
- Redundancy methods to broaden mission applicability
- Improvements in tolerance to extreme environments including radiation
- Novel avionics architecture definition and demonstration
- Software support for redundant modular avionics
- Plug and Play methods for handling dynamic changes to avionics configuration
- Fault detection and recovery for wireless avionics
- Improvements in spacecraft production
- Improvements in spacecraft Integration and Test
- Technologies that use additive manufacturing technology for embedded avionics systems that reduce cables, connectors, and penetrations and show a path to a full solution.
- Sensors and sensor systems based on current technology needs to develop point solutions that are applicable to NASA missions in near to mid-range time frames

State of the Art and Critical Gaps

Development of small satellites missions benefits from a growing number of users worldwide, resulting in a large pool of COTS components available for specific missions, depending on the type and class of mission. A variety of C&DH (Command and Data Handling) developments for CubeSats have resulted from in-house development, from new companies that specialize in CubeSat avionics, and from established companies who provide spacecraft avionics for the space industry in general. Presently there are a number of commercial vendors who offer highly integrated systems that contain the on-board computer, memory, electrical power system and the ability to support a variety of input & output for the CubeSat class of small spacecraft. Wireless networks have been incorporated as crew support networks aboard ISS, freeing the astronauts from cables. Wireless sensor networks have been flown as demonstrations aboard CubeSats. Dynamic self-configuring wireless networks have been evaluated in the lab. The AIAA has defined the Space Plug-and-Play (SPA) standard and flight demonstrations are planned.

The maturation of additive manufacturing and 3D printing technology are making embedded wireless sensors and avionics a possibility. Embedding transmission lines, antennas, connectors, and sensors onto a spacecraft structure turns that structure into a multi-functional system that reduces or eliminates bulky cables and connectors. Embedded passive wireless sensors can greatly increase sensing and telemetry capabilities, including providing low-cost techniques for vehicle health management for future missions. Moreover, flexible embedded passive sensors created with conductive and functional fabrics are enabling new opportunities for sensing in surfaces and systems where sensing has been traditionally absent such as parachutes and inflatable structures

Relevance / Science Traceability

NASA and other space agencies are exploring the application of SmallSats for deep space missions. The availability of modular wireless data connectivity alleviates complexity in testing and integration of systems. Modular components allow easier reconfiguration and late additions to any design. This is a benefit conferred to any spacecraft of any size, with the larger systems benefiting from savings in mass due to a larger reduction in cable harnesses and connectors.