NASA SBIR 2022 Phase I Solicitation

S16.06  Command, Data Handling, and Electronics

Lead Center: GSFC

Participating Center(s): JPL, LaRC, MSFC

Scope Title:
Analog-to-Digital Conversion Components

Scope Description:

NASA's space-based observatories, flyby spacecraft, orbiters, landers, and robotic and sample-return missions require robust command and control capabilities. Advances in technologies relevant to command and data handling and instrument electronics are sought to support NASA's goals and several missions and projects under development.

The 2022 subtopic goals are to develop platforms for the implementation of miniaturized highly integrated avionics and instrument electronics that:

- Are consistent with the performance requirements for NASA missions.
- Minimize required mass/volume/power as well as development cost/schedule resources.
- Can operate reliably in the expected thermal and radiation environments.

Successful proposal concepts should significantly advance the state of the art. Furthermore, proposals developing hardware should indicate an understanding of the intended operating environment, including temperature and radiation. Note that environmental requirements vary significantly from mission to mission. For example, some low-Earth-orbit missions have a total ionizing dose (TID) radiation requirement of less than 10 krad(Si), whereas planetary missions can have requirements well in excess of 1 Mrad(Si).

Specific technologies sought by this scope include:

- Radiation-hardened mixed-signal structured application-specific integrated circuit (ASIC) platforms to enable miniaturized and low-power science sensor readout and control, with sufficient capability to implement 12-bit digital-to-analog converters (DACs), monotonic and 12- to 16-bit analog-to-digital converters (ADCs) (<100 kHz 16-bit and 1 to 2 MHz 12-bit), and also charge-sensitive amplifiers for solid-state detectors and readout integrated circuit (ROIC) for silicon photomultipliers.
- Low-power, radiation-hardened ASIC devices to enable direct capture of analog waveforms.
Expected TRL or TRL Range at completion of the Project: 1 to 4

Primary Technology Taxonomy:
Level 1: TX 02 Flight Computing and Avionics
Level 2: TX 02.1 Avionics Component Technologies

Desired Deliverables of Phase I and Phase II:

- Prototype
- Hardware
- Software
- Analysis
- Research

Desired Deliverables Description:

Desired Phase I deliverables include the design, simulation, and analysis to demonstrate viability of proposed component.

Desired Phase II deliverables include a prototype mixed-signal ASIC implemented with a proof-of-concept end-user design. The proof-of-concept design should demonstrate the stated performance capabilities of the ASIC.

State of the Art and Critical Gaps:

There is a need for a broader range of mixed-signal structured ASIC architectures. This includes the need for viable options for mixed ASICs with high-resolution, low-noise analog elements, especially 12-bit DACs and 12- to 16-bit ADCs. The current selection of mixed-signal structured ASICs is limited to 10-bit designs, which do not provide the accuracy or resolution to perform the science required of many of the instruments currently being flown. Mixed-signal structured ASICs can integrate many functions and therefore can save considerable size, weight, and power over discrete solutions—significantly benefiting NASA missions. The lack of parts with high-precision analog is greatly limiting their current application.

Relevance / Science Traceability:

Mixed-signal structured ASIC architectures are relevant to increasing science return and lowering costs for missions across all Science Mission Directorate (SMD) divisions. However, the benefits are most significant for miniaturized instruments and subsystems that must operate in harsh environments. These missions include interplanetary CubeSats and SmallSats, outer-planet instruments, and heliophysics missions to harsh radiation environments. For all missions, the higher accuracy would provide better science or allow additional science through the higher density integration.

References:

The following resources may be helpful for descriptions of radiation effects in electronics:

1. NASA Technical Reports Server: https://ntrs.nasa.gov/
2. NASA Electronic Parts and Packaging Program: https://nepp.nasa.gov/
Scope Title:
Low-Cost Data Acquisition System

Scope Description:

Destinations such as Mars, Venus, and Titan pose many challenges for entry, descent, and landing (EDL) data acquisition systems, including radiation, g-loading, and volume constraints. Recent notable examples of such systems are the Mars Entry, Descent, and Landing Instrumentation (MEDLI) and MEDLI2 sensor suites, which successfully acquired EDL data in 2012 and 2021, respectively. The NASA MEDLI and MEDLI2 data acquisition systems were very well designed and robust to the extreme environments of space transit and EDL but came at a great financial burden to these missions. The high cost prohibits smaller mission classes such as Discovery and New Frontiers from using MEDLI-like systems, therefore limits the EDL science that can be conducted by NASA. In an effort to bring EDL instrumentation to all missions, NASA seeks a low-cost, robust, high-accuracy data acquisition system. Wireless data acquisition capability would eliminate external radio-frequency interference coupling effects and represents a significant cost and mass savings opportunity on future NASA missions. For example, the sensor cable mass for the Orion Exploration Flight Test 1 (EFT-1) Developmental Flight Instrumentation (DFI) suite was 700 lb. of the entire 1200-lb DFI system. A wireless option for the low-cost data acquisition system is therefore highly desirable.

Data acquisition requirements:

- Compatibility: Minimum 15 thermocouples (minimum of 2 Type R and minimum of 8 Type K) and 8 pressure transducers (120- or 350-ohm bridge).
- Power: 16 W or less.
- Size: Modularity encouraged, max. module size of 10 cm$^3$, four modules max.
- Measurement resolution: 12 bit or higher.
- Acquisition rate: 8 Hz or higher.
- Weight: 5 kg or less.
- Accuracy: +/-0.5% of FSR (full scale range).
- Radiation tolerant by design: Minimum of 10 krad (30 krad or better desired).
- Axial loading capability: minimum 15g (Venus missions could require 100g to 400g).
- Temperature capability: -40 to +85 °C.
- Cost: Fully qualified target of ~$1M (recurring).

Optional wireless capability:

- Centralized or distributed architecture.
- Scalable architecture.
- 0.0% packet loss.
- Capable of operating independently for a minimum of 2 years.
- Completely wireless: data acquisition and communication powered by a battery or harvested energy (e.g., solar, thermal).

Expected TRL or TRL Range at completion of the Project: 1 to 4

Primary Technology Taxonomy:
Level 1: TX 02 Flight Computing and Avionics
Level 2: TX 02.2 Avionics Systems and Subsystems
Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware
- Software

Desired Deliverables Description:

Phase I deliverables would include electrical system design, trade studies, component selections, requirements definitions, and systems analysis to result in a modeled and analyzed data acquisition system architecture. Early breadboard circuits or prototypes may be included.

Phase II deliverables would include production of a prototype low-cost data acquisition system and results from electrical performance testing. Testing may include some environmental and stress testing.

State of the Art and Critical Gaps:

The NASA MEDLI and MEDLI2 data acquisition systems were very well designed and robust to the extreme environments of space transit and EDL, but this comes at a great financial burden to these missions. The high cost prohibits smaller mission classes such as Discovery and New Frontiers from using MEDLI-like systems, therefore limiting the EDL science that can be conducted by NASA. To bring EDL instrumentation to all missions, NASA seeks a low-cost, robust, high-accuracy data acquisition system.

Relevance / Science Traceability:

This technology would be especially relevant to upcoming Science Mission Directorate (SMD) planetary missions, such as DAVINCI and VERITAS, but low-cost data acquisition systems with these capabilities would also be relevant to the other science lines of business, especially for future cost and volume-constrained and distributed-systems missions.

References:

2. MEDLI: https://mars.nasa.gov/msl/spacecraft/instruments/medli/
4. NASA to Explore Divergent Fate of Earth’s Mysterious Twin with Goddard’s DAVINCI+:
5. VERITAS: https://www.jpl.nasa.gov/missions/veritas

Scope Title:

Printed High Density Interconnects

Scope Description:

As the size of circuit boards continues to shrink and electronic component sizing continues to approach bare die form factors, NASA's need for high-reliability, high-density interconnection solutions is increasing. The ability to
connect components or even larger assemblies together without the need for conventional connectors and harnessing stands to offer significant advantages to the size and weight requirements of command, data handling, and electronics systems. High-reliability interconnect methodologies that can operate in space environments (vacuum, vibration) and deliver hundreds of signal/power connections while using as little physical board area as possible are desired.

Chip-scale interconnection methodologies such as wirebonding are size and volume efficient, but present manufacturing, reliability, and handling challenges when applied in an exposed manner on otherwise conventional circuit board assemblies. NASA seeks manufacturing technologies that could be applied at the circuit board assembly level to create high-reliability, high-density electrical connections across three-dimensional (3D) topologies, such as connecting to the top surface of microcircuit die adhered to a substrate. Emerging additively manufactured and printed hybrid electronics technologies offer potential solutions that also address the reliability and handling challenges present with larger assembly implementations, but further development is needed to demonstrate performance and reliability for NASA applications.

Specifically, NASA is seeking:

- Capability to reliably print or produce 400 or more conductive traces, on the order of 50 to 100 µm width, with 100 to 200 µm pitch.
- Capability to reliably print or produce traces that can traverse a vertical shift to an elevated topology shifts of up to 1.5 mm in height. Printing or producing fillets or ramps to accommodate smooth transitions for the vertical topology shifts is acceptable.
- Electrical resistivity of the traces shall be no more than 300 ohm/mm, and isolation to adjacent traces shall be on the order of gigaohms.
- Printed or produced traces shall demonstrate alignment to target features on the substrates and the elevated topology surfaces.
- Demonstrated reliability and workmanship testing performance, such as vibration and thermal cycling.

**Expected TRL or TRL Range at completion of the Project:** 1 to 4

**Primary Technology Taxonomy:**
Level 1: TX 02 Flight Computing and Avionics
Level 2: TX 02.2 Avionics Systems and Subsystems

**Desired Deliverables of Phase I and Phase II:**

- Research
- Analysis
- Prototype
- Hardware
- Software

**Desired Deliverables Description:**

Phase I deliverables would include development of prototype design, materials selection and trade studies, production of necessary equipment fixtures and tooling, and ultimately demonstration of the proposed interconnect manufacturing.

Phase II deliverables would include refinement of prototype designs, demonstration of consistent print production
across multiple samples, electrical performance, and results of workmanship and reliability tests of produced designs.

**State of the Art and Critical Gaps:**

The current assembly process for arrays of die and sensors is wire bonding. However, as die become smaller and die pads become smaller and denser, this pushes the limits of wire bonding capabilities. The next generation of NASA science missions have needs for higher density interconnect solutions. Printed hybrid electronics technologies are emerging; however, they have not yet demonstrated suitable repeatability and reliability for use in NASA applications.

**Relevance / Science Traceability:**

These technologies would be broadly beneficial to command and data handling (C&DH) architectures on many NASA missions. There is also a crossover need for this technology on high-density detector systems that will be needed for NASA's next-generation science missions.

- Missions/Programs/Projects that could use the technology:
  - Large UV/Optical/IR Surveyor (LUVOIR).
  - Habitable Exoplanet Observatory (HabEx).
  - Cosmic Evolution Through UV Spectroscopy (CETUS).

**References:**

The following resources may be helpful for descriptions of radiation effects in electronics:

1. NASA Technical Reports Server: [https://ntrs.nasa.gov/](https://ntrs.nasa.gov/)
2. NASA Electronic Parts and Packaging Program: [https://nepp.nasa.gov/](https://nepp.nasa.gov/)
4. LUVOIR: [https://asd.gsfc.nasa.gov/luvoir/](https://asd.gsfc.nasa.gov/luvoir/)
5. Habitable Exoplanet Observatory (HabEx): [https://www.jpl.nasa.gov/habex/](https://www.jpl.nasa.gov/habex/)

**Scope Title:**

Intelligent Hardware Supervisors

**Scope Description:**

The space radiation environment and single-event effects (SEE) are known to cause errors and interruptions in electronics circuitry. NASA has an increasing need to achieve higher performance processing and microcircuits, and this often requires infusion of commercial electronic parts, which may not be explicitly designed for radiation tolerance. One critical aspect to successfully using these commercial technologies in a space system is being able to recognize when a component has been hit by a SEE and commanding that component to reset itself, without causing major disruption to the entire system.

To this goal, NASA seeks responsive or intelligent hardware supervisor components for SEEs. Ideally, a microcircuit that can monitor the operational profile of other components and intelligently determine what is and is not a latchup or other event versus a computationally intense processing state, especially for consumer/COTS (commercial-off-the-shelf) electronics.
Expected TRL or TRL Range at completion of the Project: 1 to 4

Primary Technology Taxonomy:
Level 1: TX 02 Flight Computing and Avionics
Level 2: TX 02.1 Avionics Component Technologies

Desired Deliverables of Phase I and Phase II:

- Research
- Analysis
- Prototype
- Hardware
- Software

Desired Deliverables Description:

Phase I deliverables would include system design, trade studies, component selections, requirements definitions, and systems analysis to result in a modeled and analyzed system architecture. Early breadboard circuits or prototypes may be included.

Phase II deliverables would include production of a prototype(s) and electrical performance testing. Testing may include some environmental and stress testing.

State of the Art and Critical Gaps:

Existing hardware supervisors do exist, but they do not fully address the needs of NASA missions seeking to infuse modern COTS components. Supervisor methodologies are either too conservative, and overly reset devices causing undue downtime and data loss or are more intelligent to distinguish upsets but require computationally intense processing and power resources to implement. NASA needs supervisor components that can intelligently determine latchups or other events without a computationally intense processing state.

Relevance / Science Traceability:

These technologies would be relevant to increasing science return and lowering costs for missions across all Science Mission Directorate (SMD) divisions. However, the benefits are most significant for miniaturized instruments and subsystems that must operate in harsh environments. These missions include interplanetary CubeSats and SmallSats, outer planets instruments, and heliophysics missions to harsh radiation environments.

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