NASA/TM—2015-218828

An Overview of SBIR Phase 2 Communications Technology and Development

Hung D. Nguyen and Gynelle C. Steele
Glenn Research Center, Cleveland, Ohio

July 2015

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An Overview of SBIR Phase 2 Communications Technology and Development

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Abstract

Technological innovation is the overall focus of NASA's Small Business Innovation Research (SBIR) program. The program invests in the development of innovative concepts and technologies to help NASA's mission directorates address critical research and development needs for agency projects.

This report highlights innovative SBIR Phase II projects from 2007-2012 specifically addressing areas in Communications Technology and Development which is one of six core competencies at NASA Glenn Research Center**.** There are eighteen technologies featured with emphasis on a wide spectrum of applications such as with a security-enhanced autonomous network management, secure communications using on-demand single photons, cognitive software-defined radio, spacesuit audio systems, multiband photonic phased-array antenna, and much more. Each article in this booklet describes an innovation, technical objective, and highlights NASA commercial and industrial applications.

This report serves as an opportunity for NASA personnel including engineers, researchers, and program managers to learn of NASA SBIR's capabilities that might be crosscutting into this technology area. As the result, it would cause collaborations and partnerships between the small companies and NASA Programs and Projects resulting in benefit to both SBIR companies and NASA.

Security-Enhanced Autonomous Network Management

For networking in space and dynamic military environments

Ensuring reliable communication in next-generation space networks requires a novel network management system to support greater levels of autonomy and greater awareness of the environment and assets. Intelligent Automation, Inc., has developed a security-enhanced autonomous network management (SEANM) approach for space networks through cross-layer negotiation and network monitoring, analysis, and adaptation. The underlying technology is bundle-based delay/disruption-tolerant networking (DTN).

The SEANM scheme allows a system to adaptively reconfigure its network elements based on awareness of network conditions, policies, and mission requirements. Although SEANM is generically applicable to any radio network, for validation purposes it has been prototyped and evaluated on two specific networks: a commercial off-the-shelf hardware testbed using Institute of Electrical Engineers (IEEE) 802.11 Wi-Fi devices and a military hardware testbed using AN/PRC-154 Rifleman Radio platforms. Testing has demonstrated that SEANM provides autonomous network management resulting in reliable communications in delay/disruptive-prone environments.

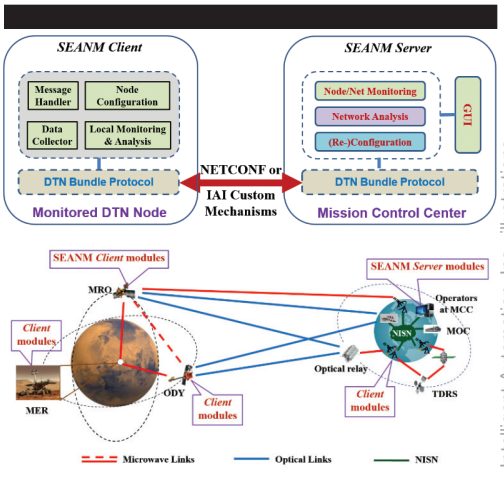
Applications

NASA

- Space Communications and Navigation (SCaN) network integration
- Robotic missions

Commercial

- Dynamic and tactical military environments
- Undersea networks
- Satellite communications
- Wireless sensor and ad hoc networks



Intelligent Automation, Inc., illustrations

Phase II Objectives

- Develop an autonomous networking and network management system for space networks:
  - Advanced bundle protocol-based DTN network support
  - Proactive network monitoring and prediction
  - Cross-layer information sharing and negotiation
  - Network analysis and reconfiguration
- Implement the proposed SEANM scheme using hardware implementations
- Perform extensive performance evaluations
- Develop and incorporate the developed concepts and techniques into prototypes

Benefits

- Reduces costs
- Enhances reliability

Firm Contact

Intelligent Automation, Inc.
Hui Zeng
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Rockville, MD 20855–2737
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Proposal Number: 10-2 O1.06-8084

Radiation-Hardened Electronics for Advanced Communications Systems

Novel approach enables high-speed special-purpose processors

Advanced reconfigurable and reprogrammable communication systems will require sub-130-nm electronics. Legacy single event upset (SEU) radiation-tolerant circuits are ineffective at speeds greater than 125 MHz. In Phase I of this project, ICs, LLC, demonstrated new base-level logic circuits that provide SEU immunity for sub-130-nm high-speed circuits. In Phase II, the company developed an innovative self-restoring logic (SRL) circuit and a system approach that provides high-speed, SEU-tolerant solutions that are effective for sub-130-nm electronics scalable to at least 22-nm processes. The SRL system can be used in the design of NASA's next-generation special-purpose processors, especially reconfigurable communication processors.

The SRL semicustom library is designed to replace triple modular redundancy (TMR) as the on-chip means for fault tolerance. With these building blocks in place, advanced reconfigurable and programmable high-speed devices can be implemented. ICs designed and fabricated a robust test circuit. Radiation testing to fully characterize SRL verified the SRL synthesis library for developing advanced communication systems with clock speeds even higher than 700 MHz. The innovation enables the development of special-purpose, high-speed application-specific integrated circuits (ASICs).

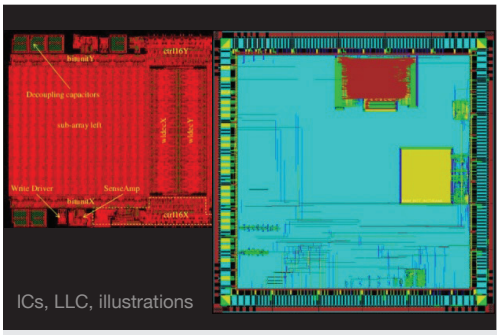
Applications

NASA

- Sub-130-nm electronic foundation for SEU-tolerant electronics
- Electronic base for reconfigurable communication systems
- Single-chip communication systems

Commercial

- Aircraft systems
- Security organizations
- Financial systems
- Automobile systems
- Real-time control electronics



ICs, LLC, illustrations

Phase II Objectives

- Design SRL synthesis library for use with commercial computer-aided design tools:
  - Traditional latches, logic, and arithmetic elements
  - Low-voltage digital switching (LVDS) modules
  - On-chip random access memory (RAM) cells
  - Serial-to-parallel and parallel-to-serial converters
- Design and fabricate SRL test chip for performance and radiation testing:
  - SRL latches to conclusively prove high-speed operation
  - Control legacy radiation hardening by design (RHBD) cells
  - Nonredundant storage elements
  - LVDS circuits
  - Memory cells

Benefits

- Utilizes high-quality commercial complementary metal oxide semiconductor (CMOS) processes for SEU-tolerant ASICs
- Offers high-speed, radiation-hardened, fault-tolerant capabilities

Firm Contact

ICs, LLC
Sterling Whitaker
whitaker@ics-rhbd.com
4615 Cumberland Road NW
Albuquerque, NM 87120–3863
Phone: 505–980–3083

Proposal Number: 10-2 O1.02-9491

Scintillation-Hardened GPS Receiver

Improves system reliability and flexibility

CommLargo, Inc., has developed a scintillation-hardened Global Positioning System (GPS) receiver that improves reliability for low-orbit missions and complies with NASA's Space Telecommunications Radio System (STRS) architecture standards. A software-defined radio (SDR) implementation allows a single hardware element to function as either a conventional radio or as a GPS receiver, providing backup and redundancy for platforms such as the International Space Station (ISS) and high-value remote sensing platforms.

The innovation's flexible SDR implementation reduces cost, weight, and power requirements. Scintillation hardening improves mission reliability and variability. In Phase I, CommLargo refactored an open-source GPS software package with Kalman filter–based tracking loops to improve performance during scintillation and also demonstrated improved navigation during a geomagnetic storm. In Phase II, the company generated a new field-programmable gate array (FPGA)-based GPS waveform to demonstrate on NASA's Space Communication and Navigation (SCaN) testbed.

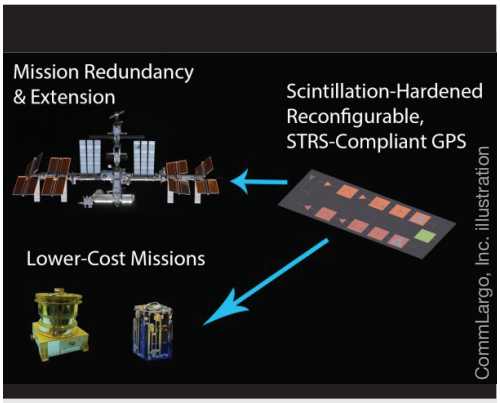
Applications

NASA

- ISS
- Television Infrared Observation Satellite (TIROS) Program
- Mini-satellites
- Cube-shaped satellites (CubeSats)
- Nanosatellites

Commercial

- Satellites
- CubeSats
- Software services



Phase II Objectives

- Develop an open-source GPS software package with scintillation-hardening
- Refactor the software package into an STRS-compliant waveform compatible with the SCaN SDR testbed on the ISS
- Perform software development, testing, and verification
- Complete an STRS toolkit to provide a radio-based implementation that is compliant yet affordable

Benefits

- Delivers a government unlimited rights waveform for the STRS waveform repository
- Allows a single hardware element to function as a conventional radio or as a GPS receiver
- Provides backup and redundancy for high-value remote-sensing platforms

Firm Contact

CommLargo, Inc.
Donald R. Stephens
don@commlargo.com
8316 36th Avenue North
St. Petersburg, FL 33710–1018
Phone: 727–345–9668

Proposal Number: 11-2 O1.06-9056

Precision Time Protocol-Based Trilateration for Planetary Navigation

Non–GPS innovation offers bidirectional position information over communications channels

Progeny Systems Corporation has developed a high-fidelity, field-scalable, non-Global Positioning System (GPS) navigation system that offers precision localization over communications channels. The system is bidirectional, providing position information to both base and mobile units. It is the first-ever wireless use of the Institute of Electrical and Electronics Engineers (IEEE) Precision Time Protocol (PTP) in a bidirectional trilateration navigation system. The innovation provides a precise and reliable navigation capability to support traverse-path planning systems and other mapping applications, and it establishes a core infrastructure for long-term lunar and planetary occupation. Mature technologies are integrated to provide navigation capability and to support data and voice communications on the same network.

On Earth, the innovation is particularly well suited for use in unmanned aerial vehicles (UAVs), as it offers a non-GPS precision navigation and location service for use in GPS-denied environments. Its bidirectional capability provides real-time location data to the UAV operator and to the UAV. This approach optimizes assisted GPS techniques and can be used to determine the presence of GPS degradation, spoofing, or jamming.

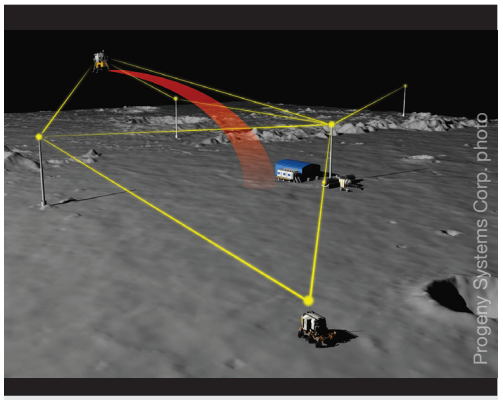
Applications

NASA

- Lunar and planetary habitation, exploration, and mining
- Manned and unmanned mobile systems
- Landing systems for lunar and planetary reentry

Commercial

- Identification of GPS jamming and spoofing affecting combatant aircraft and ground assets
- Navigation in urban environments where GPS is spotty or nonexistent
- Vehicle tracking in urban environments
- Emergency responder localization in multilevel buildings
- Near-port marine tracking in severe weather conditions
- Air traffic control and precision runway monitoring



Phase II Objectives

- Establish key performance requirements
- Prototype multimode wireless network, employing PTP for demonstration
- Complete electronics design and identification of components
- Complete design of radio frequency (RF) transmitter, receiver, and antenna components
- Develop link models for the lunar environment
- Complete tower design with finite element analysis and fabricate a scale model
- Demonstrate trilateration processing in prototype wireless network
- Deliver prototype hardware and firmware

Benefits

- Offers a lightweight and compact package
- Uses low power
- Operates reliably and precisely
- Uses existing and planned communications infrastructure

Firm Contact

Progeny Systems Corporation
Ron Murdock
rmurdock@progeny.net
60 Hammarlund Way
Middletown, RI 02842
Phone: 401–846–0111 ext. 102

Proposal Number: 08-2 O4.03-9024

Advanced Bayesian Method for Planetary Surface Navigation

For rovers, robots, and autonomous vehicles

Autonomous Exploration, Inc., has developed an advanced Bayesian statistical inference method that leverages current computing technology to produce a highly accurate surface navigation system. The method combines dense stereo vision and high-speed optical flow to implement visual odometry (VO) to track faster rover movements. The Bayesian VO technique improves performance by using all image information rather than corner features only. The method determines what can be learned from each image pixel and weighs the information accordingly. This capability improves performance in shadowed areas that yield only low-contrast images. The error characteristics of the visual processing are complementary to those of a low-cost inertial measurement unit (IMU), so the combination of the two capabilities provides highly accurate navigation.

The method increases NASA mission productivity by enabling faster rover speed and accuracy. On Earth, the technology will permit operation of robots and autonomous vehicles in areas where the Global Positioning System (GPS) is degraded or unavailable.

Applications

NASA

- Planetary rovers
- Robots

Commercial

- Autonomous vehicles
- Robots

Phase II Objectives

- Develop advanced ground-truth data
- Improve and enhance the Bayesian VO algorithm
- Transfer the algorithm to a real-time computer
- Develop the prototype design
- Construct the prototype module
- Demonstrate and test the prototype

Benefits

- Low cost
- Lightweight
- Fast and accurate
- More productive

Firm Contact

Autonomous Exploration, Inc.
Julian Center
jcenter@ieee.org
385 High Plain Road
Andover, MA 01810–3234
Phone: 978–269–4120

Proposal Number: 09-2 04.03-9337

Scalable Lunar Surface Networks and Adaptive Orbit Access

For wireless networks with intermittent links

Teranovi Technologies, Inc., has developed innovative network architecture, protocols, and algorithms for both lunar surface and orbit access networks. A key component of the overall architecture is a medium access control (MAC) protocol that includes a novel mechanism of overlaying time division multiple access (TDMA) and carrier sense multiple access with collision avoidance (CSMA/CA), ensuring scalable throughput and quality of service. The new MAC protocol is compatible with legacy Institute of Electrical and Electronics Engineers (IEEE) 802.11 networks. Advanced features include efficiency power management, adaptive channel width adjustment, and error control capability.

A hybrid routing protocol combines the advantages of ad hoc on-demand distance vector (AODV) routing and disruption/delay-tolerant network (DTN) routing. Performance is significantly better than AODV or DTN and will be particularly effective for wireless networks with intermittent links, such as lunar and planetary surface networks and orbit access networks.

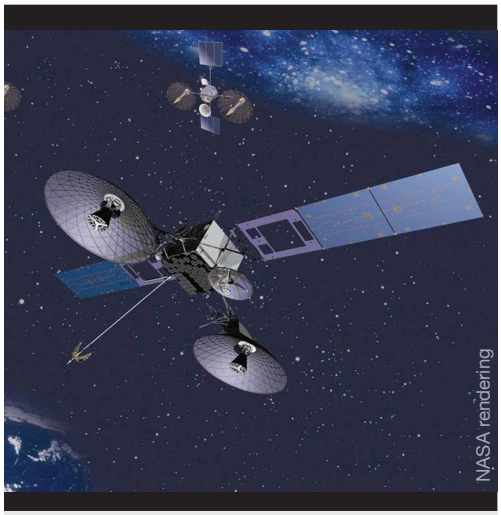
Applications

NASA

- Lunar and planetary exploration
- Orbit access communications
- Satellite communications
- Deep-space communication networks

Commercial

- Long-distance networking
- Military battlefield communication networks
- Mesh networks (IEEE 802.11 and 802.16) and their integrated systems


NASA rendering

Phase II Objectives

- Enhance IEEE 802.11 MAC on a reconfigurable radio
- Design and implement TDMA overlaying CSMA/CA
- Design and implement advanced MAC features, including power efficient scheduling, adaptive channel width adjustment, error control capability, and standard compatibility support
- Enhance and implement hybrid routing for AODV/DTN
- Integrate MAC and routing on an embedded PC and test the prototype system in field trials

Benefits

- Reconfigurable
- Adaptive
- Efficient
- Reliable

Firm Contact

Teranovi Technologies, Inc.
Xudong Wang
wxudong@teranovi.com
10033 NE 140th Street
Bothell, WA 98011–5214
Phone: 425–425–9853

Proposal Number: 08-2 O1.08-9622

Desensitized Optimal Filtering and Sensor Fusion Toolkit

Processing navigational data from multiple sensor sources

Analytical Mechanics Associates, Inc., has developed a software toolkit that filters and processes navigational data from multiple sensor sources. A key component of the toolkit is a trajectory optimization technique that reduces the sensitivity of Kalman filters with respect to model parameter uncertainties. The sensor fusion toolkit also integrates recent advances in adaptive Kalman and sigma-point filters for non-Gaussian problems with error statistics.

This Phase II effort provides new filtering and sensor fusion techniques in a convenient package that can be used as a stand-alone application for ground support and/or onboard use. Its modular architecture enables ready integration with existing tools. A suite of sensor models and noise distribution as well as Monte Carlo analysis capability are included to enable statistical performance evaluations.

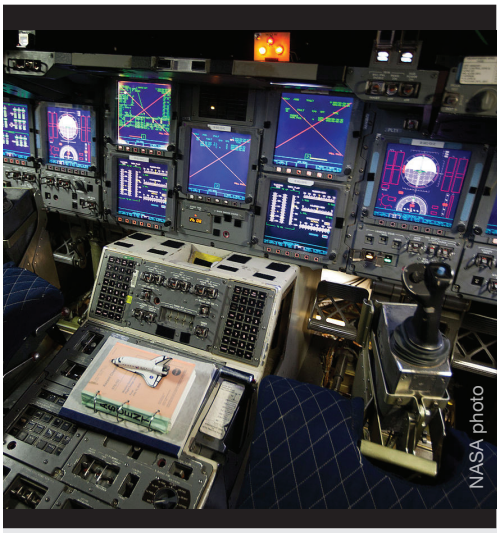
Applications

NASA

- Use in spacecraft and aircraft ground and/or onboard facilities to process navigational data from multiple sensor sources
- Analysis and testing of flight software and onboard data processing algorithms

Commercial

- Marine vessel navigation
- Commercial airline navigation
- Seismic data acquisition and analysis
- Atmospheric observation data collection and processing



Phase II Objectives

- Investigate approaches to reducing the sensitivity of the Kalman filter with respect to model parameter uncertainties
- Develop the detailed software design for the desensitized filtering and sensor fusion toolkit
- Integrate the toolkit modules with existing applications, such as NASA's GPS-Enhanced Onboard Navigation System (GEONS)

Benefits

- Convenient
- Autonomous
- Modular

Firm Contact

Analytical Mechanics Associates, Inc.
Christopher D. Karlgaard
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303 Butler Farm Road, Suite 104A
Hampton, VA 23666–1568
Phone: 757–865–0000

Proposal Number: 09-2 O4.04-9465

Optoelectronic Infrastructure for Radio Frequency and Optical Phased Arrays

For sensing and data transfer applications

Optoelectronic integrated circuits offer radiation-hardened solutions for satellite systems in addition to improved size, weight, power, and bandwidth characteristics. ODIS, Inc., has developed optoelectronic integrated circuit technology for sensing and data transfer in phased arrays. The technology applies integrated components (lasers, amplifiers, modulators, detectors, and optical waveguide switches) to a radio frequency (RF) array with true time delay for beamsteering. Optical beamsteering is achieved by controlling the current in a two-dimensional (2D) array. In this project, ODIS integrated key components to produce common RF-optical aperture operation.

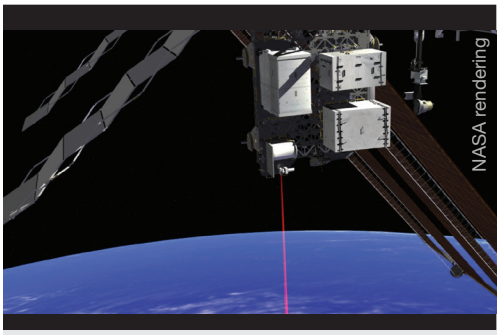
Applications

NASA

- Satellite sensors in the Ka-band and Ku-band for surface and object characterization
- Integrated platform circuits for laser and RF communications, internal satellite networking, RF photonics and analog-to-digital (AD) conversion, and high-speed systems
- Integrated platform imaging devices for spectral sensing

Commercial

- Computer buses
- AD converters
- Optical data links
- Optical switching matrices
- Optical routers
- Active optical cables
- High-speed servers
- Digital signal processors



Phase II Objectives

- Demonstrate the feasibility of combining RF and optical emission from a single aperture
- Demonstrate generation of low-phase noise RF using an optoelectronic oscillator
- Determine and demonstrate true time delay RF array-steering using microresonators to produce differential group delay
- Demonstrate feasibility of optical distribution of RF power and optoelectronic control of beam direction
- Display 2D optical beamsteering from coherent array via current control
- Prove viability of optoelectronic architecture for RF-optical cell

Benefits

- Enables collocation of RF and optically emitting devices in array formats
- Permits antiguiding to produce coherent optical beams
- Provides beamsteering of supermodes
- Offers optical distribution of RF by photodetector conversion
- Provides optical return signal remoting
- Permits true time delay for RF beamsteering

Firm Contact

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Mansfield, CT 06268–2768
Phone: 860–486–3466

Proposal Number: 10-2 O1.01-9727

Multiband Photonic Phased-Array Antenna

For high data rate communication

A multiband phased-array antenna (PAA) can reduce the number of antennas on shipboard platforms while offering significantly improved performance. Crystal Research, Inc., has developed a multiband photonic antenna that is based on a high-speed, optical, true-time-delay beamformer. It is capable of simultaneously steering multiple independent radio frequency (RF) beams in less than 1,000 nanoseconds. This high steering speed is 3 orders of magnitude faster than any existing optical beamformer. Unlike other approaches, this technology uses a single controlling device per operation band, eliminating the need for massive optical switches, laser diodes, and fiber Bragg gratings. More importantly, only one beamformer is needed for all antenna elements.


NASA rendering

Applications

NASA

- High data rate communications:
  - Lunar and planetary exploration
  - Landers
  - Probes
  - Lunar relay satellites
  - Lunar rovers and habitats
  - Suborbital vehicles
  - Sounding rockets
  - Balloons
  - Unmanned aerial vehicles
  - Expendable launch vehicles
- Remote sensing:
  - Radiometers
  - Passive radar interferometer platforms
  - Synthetic aperture radar platforms for planetary science

Commercial

- Mobile satellite communications
- Military electronics
- Broadband wireless communications

Phase II Objectives

- Refine detailed architecture of the multiband photonic PAAs
- Develop modulation techniques for multichannel RF links
- Develop fiber-optic packaging for wavelength tunable lasers
- Fabricate electro-optic wavelength tunable lasers
- Fabricate electro-optic beamformers
- Develop system control and electronics module
- Integrate electrical, microwave, photonic, and mechanical functions
- Prepare and submit reports and deliver prototype

Benefits

- Wideband multibeam operation
- High-speed steering
- Microwave delay compatibility
- Small size
- Light weight
- Low power consumption
- Immunity to electromagnetic interference

Firm Contact

Crystal Research, Inc.
Suning Tang
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48501 Warm Springs Blvd., Suite 103
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Phone: 510–445–0833

Proposal Number: 09-2 O1.02-9839

Tactile Data Entry System

For task-saturated, dynamic environments

Future spacesuits may be equipped with onboard computing, networking, and helmet-mounted graphical displays to provide astronauts with access to some of the same applications that terrestrial smart phone users now take for granted. These may include textual and voice communications, map-based navigation, video/image acquisition, document viewing/editing, and news/weather alerts. Unfortunately, bulky space suit gloves make it impractical to employ conventional user interfaces, such as a touch screen, keyboard, or mouse.

The patent-pending Glove-Enabled Computer Operations (GECO) design leverages extravehicular activity (EVA) glove design features as platforms for instrumentation and tactile feedback, enabling the gloves to function as human-computer interface devices. Flexible sensors in each finger enable control inputs that can be mapped to any number of functions (e.g., a mouse click, a keyboard strike, or a button press). Tracking of hand motion is interpreted alternatively as movement of a mouse (change in cursor position on a graphical user interface) or a change in hand position on a virtual keyboard. Programmable vibrotactile actuators aligned with each finger enrich the interface by creating the haptic sensations associated with control inputs, such as recoil of a button press.

Prototype GECO gloves were developed in collaboration with Flagsuit LLC and the University of Washington Biorobotics Laboratory and successfully evaluated in two separate test campaigns in the Advanced Suit Laboratory at NASA's Johnson Space Center.

Applications

NASA

- Surface navigation
- Document editing
- Communications
- Telerobotic control

Commercial

- Underwater construction and repair
- Firefighting
- Explosive ordnance disposal
- Hazardous material handling
- Military aviation

Background: NASA; inset photo: Barron Associates, Inc.

Phase II Objectives

- Develop a glove-integrated data entry system for EVA human-computer interaction
- Demonstrate system effectiveness for EVA data entry operations
- Deliver a demonstration unit compatible with testing by suited crewmembers

Benefits

- Provides a human-computer interface for task-saturated, dynamic environments
- Replicates the familiar capabilities of standard desktop interfaces
- Enables an expansive set of information system applications

Firm Contact

Barron Associates, Inc.
Richard J. Adams
adams@bainet.com
1410 Sachem Place, Suite 202
Charlottesville, VA 22901–2559
Phone: 434–973–1215

Proposal Number: 09-2 O3.01-8967

Automatic Speech Acquisition and Recognition for Spacesuit Audio Systems

Enables voice recognition technology in noisy and reverberant environments

NASA has a widely recognized but unmet need for novel human-machine interface technologies that can facilitate communication during astronaut extravehicular activities (EVAs), when loud noises and strong reverberations inside spacesuits make communication challenging. WeVoice, Inc., has developed a multichannel signal-processing method for speech acquisition in noisy and reverberant environments that enables automatic speech recognition (ASR) technology inside spacesuits. The technology reduces noise by exploiting differences between the statistical nature of signals (i.e., speech) and noise that exists in the spatial and temporal domains. As a result, ASR accuracy can be improved to the level at which crewmembers will find the speech interface useful.

System components and features include beam forming/multichannel noise reduction, single-channel noise reduction, speech feature extraction, feature transformation and normalization, feature compression, and ASR decoding. Arithmetic complexity models were developed and will help designers of real-time ASR systems select proper tasks when confronted with constraints in computational resources. In Phase I of the project, WeVoice validated the technology. The company further refined the technology in Phase II and developed a prototype for testing and use by suited astronauts.

Applications

NASA

- Voice command rover navigation systems
- Voice-controlled robots
- Voice entry for information search and retrieval
- Dictation systems
- Data entry systems
- In-helmet voice communications

Commercial

- Mobile phones
- Automotive devices
- Home electronics and appliances
- Video games and toys
- Information and computer systems used by disabled persons
- Speech-driven intelligent systems used in military environments

Phase II Objectives

- Collect multichannel speech data from inside spacesuits under various working conditions
- Analyze and minimize scientific and engineering uncertainties regarding in-suit speech recognition
- Gain knowledge about next-generation spacesuit processing systems to define a more intuitive and easy-to-memorize set of dialog commands
- Study the architecture of the proposed speech-command interface for spacesuit processing systems and design a prototype
- Explore and suggest appropriate computer processing devices that can implement the developed in-suit speech-command interface
- Implement the interface with a real-time system and demonstrate its performance

Benefits

- Efficient
- Compact
- Lightweight
- High performance

Firm Contact

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Phone: 908–575–8955

Proposal Number: 08-2 O3.02-9018

Turbo-Brayton Power Converter

For space flight and extreme environments

Future NASA space missions will require advanced thermal-to-electric power converters that are reliable, efficient, and lightweight. Creare, LLC, is developing a turbo-Brayton power converter that offers high efficiency and specific power. The converter employs gas bearings to provide maintenance-free, long-life operation. Discrete components can be packaged to fit optimally with other subsystems, and the converter's continuous gas flow can communicate directly with remote heat sources and heat rejection surfaces without the need for ancillary heat-transfer components and intermediate flow loops.

Creare has completed detailed analyses, trade studies, fabrication trials, and preliminary designs for the components and converter assembly. The company is fabricating and testing a breadboard converter.

Applications

NASA

- Space exploration probes
- Unmanned surface rovers
- Nuclear electric propulsion
- Space station power systems

Commercial

- Unmanned aerial vehicles
- Unmanned undersea vehicles
- Mobile electric generators
- Environments with significant particulate contamination (e.g., sand, dirt, dust)
- Environments exposed to corrosive substances (e.g., seawater)


Creare, LLC, photo

Phase II Objectives

- Develop detailed component designs
- Design breadboard converter assembly
- Fabricate turbomachine
- Fabricate heat exchangers
- Assemble converter
- Measure converter performance characteristics
- Demonstrate benefits for space flight applications
- Enhance readiness level for future programs

Benefits

- Reliable
- Efficient
- Lightweight
- Maintenance-free
- Long-life operation
- Scalable

Firm Contact

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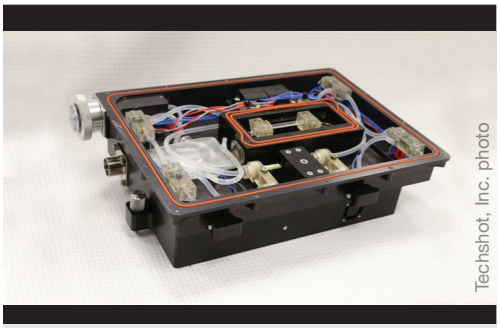
Proposal Number: 12-2 H8.03-9492

Observation Platform for Dynamic Biomedical and Biotechnology Experiments Using the International Space Station (ISS) Light Microscopy Module (LMM)


Techshot, Inc. photo

Innovation will greatly accelerate ISS biomedical experiments

Techshot, Inc., has developed an observation platform for the LMM on the ISS that will enable biomedical and biotechnology experiments. The LMM Dynamic Stage consists of an electronics module and the first two of a planned suite of experiment modules. Specimens and reagent solutions can be injected into a small, hollow microscope slide—the heart of the innovation—via a combination of small reservoirs, pumps, and valves.

A life science experiment module allows investigators to load up to two different fluids for on-orbit, real-time image cytometry. Fluids can be changed to initiate a process, fix biological samples, or retrieve suspended cells. A colloid science experiment module conducts microparticle and nanoparticle tests for investigation of colloid self-assembly phenomena. This module includes a hollow glass slide and heating elements for the creation of a thermal gradient from one end of the slide to the other. The electronics module supports both experiment modules and contains a unique illuminator/condenser for bright and dark field and phase contrast illumination, power supplies for two piezoelectric pumps, and controller boards for pumps and valves. This observation platform safely contains internal fluids and will greatly accelerate the research and development (R&D) cycle of numerous experiments, products, and services aboard the ISS.

Applications

NASA

- On-orbit analysis of cultured cells from biotechnology experiments
- Cultivation and analysis of microbial samples
- On-orbit blood analysis
- Real-time observations of cell growth and differentiation
- Colloid physical self-assembly and crystallization experiments

Commercial

- Magnetic cell separation and analysis technologies

Phase II Objectives

- Develop detailed technical requirements document
- Design and build components to space flight specifications:
  - Electronics module to fit cold plate of LMM
  - Life science experiment module
  - Colloid science experiment module
- Develop the LMM Dynamic Stage observation platform verification plan
- Test the observation platform subsystems using the verification plan
- Complete laboratory testing via specific biology and physics microscopy observations and ground experiments

Benefits

- Enables more versatile biomedical experiments aboard the ISS
- Accelerates R&D cycles for numerous experiments, products, and services
- Creates novel uses and users of the LMM on the ISS

Firm Contact

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Proposal Number: 09-2 O3.03-9290

Remotely Controlled Mixers for Light Microscopy Module (LMM) Colloid Samples

Automation enables samples to be processed quickly and efficiently

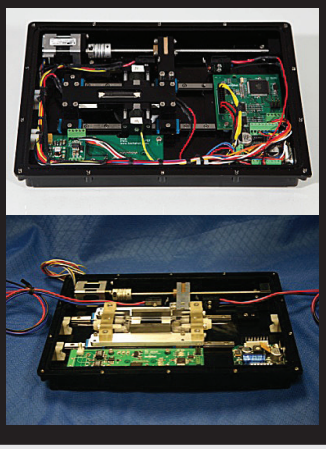
Developed by NASA Glenn Research Center, the LMM aboard the International Space Station (ISS) is enabling multiple biomedical science experiments. Techshot, Inc., has developed a series of colloid specialty cell systems (C-SPECS) for use in the colloid science experiment module on the LMM. These low-volume mixing devices will enable uniform particle density and remotely controlled repetition of LMM colloid experiments. By automating the experiment process, C-SPECS allow colloid samples to be processed more quickly. In addition, C-SPECS will minimize the time the crew will need to spend on colloid experiments as well as eliminate the need for multiple and costly colloid samples, which are expended after a single examination.

This high-throughput capability will lead to more efficient and productive use of the LMM. As commercial launch vehicles begin routine visits to the ISS, C-SPECS could become a significant means to process larger quantities of high-value materials for commercial customers.

Applications

NASA and Commercial

- On-orbit analysis of colloid samples
- On-orbit analysis of macromolecular samples



Techshot, Inc., photos

Phase II Objectives

- Finalize design requirements
- Design and fabricate flight-like hardware for C-SPECS
- Conduct C-SPECS performance tests

Benefits

- Automates colloid biomedical experiments aboard the ISS
- Allows colloid samples to be processed more quickly
- Offers potential for better understanding of pharmacological processes

Firm Contact

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Proposal Number: 11-2 O3.02-9621

Reconfigurable, Cognitive Software-Defined Radio

Enabling multimode operation and scalable architecture

Software-defined radio (SDR) technology allows radios to be reconfigured to perform different communication functions without using multiple radios to accomplish each task. Intelligent Automation, Inc., has developed SDR platforms that switch adaptively between different operation modes. The innovation works by modifying both transmit waveforms and receiver signal-processing tasks.

In Phase I of the project, the company developed SDR cognitive capabilities, including adaptive modulation and coding (AMC), automatic modulation recognition (AMR), and spectrum sensing. In Phase II, these capabilities were integrated into SDR platforms. The reconfigurable transceiver design employs high-speed field-programmable gate arrays, enabling multimode operation and scalable architecture. Designs are based on commercial off-the-shelf (COTS) components and are modular in nature, making it easier to upgrade individual components rather than redesigning the entire SDR platform as technology advances.

Applications

NASA

- Space Telecommunications Radio Systems (STRS) Project
- Communications, Navigation, and Networking Reconfigurable Testbed (CoNNeCT) Project
- Reconfigurable communication radios for extravehicular activities and space missions

Commercial

- Cognitive radios
- High-bandwidth, plug-and-play waveform synthesizers
- Real-time digital processors
- Unmanned aerial vehicle (UAV)-based communications and radar functions


NASA photo

Phase II Objectives

- Implement STRS with COTS or custom-designed SDR platforms
- Identify, study, and test AMC requirements for selected waveforms
- Design and demonstrate a prototype transmitter system with desired AMC capabilities
- Modify, test, and implement AMR algorithms on the prototype SDR platform
- Demonstrate joint operation of AMC and AMR operations in a controlled environment and on SDRs configured as dedicated transmitters and receivers
- Implement advanced SDR features for the NASA CoNNeCT Project
- Identify a path to space qualification

Benefits

- Reconfigurable
- Scalable
- Multimode-operation capable
- Adaptable

Firm Contact

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Proposal Number: 08-2 01.03-9360

Fault-Tolerant Software-Defined Radio on Manycore

Flexible radio provides multimode operation and high processing performance

Software-defined radio (SDR) platforms generally rely on field-programmable gate arrays (FPGAs) and digital signal processors (DSPs), but such architectures require significant software development. In addition, application demands for radiation mitigation and fault tolerance exacerbate programming challenges. MaXentric Technologies, LLC, has developed a manycore-based SDR technology that provides 100 times the throughput of conventional radiation-hardened general purpose processors. Manycore systems (30–100 cores and beyond) have the potential to provide high processing performance at error rates that are equivalent to current space-deployed uniprocessor systems. MaXentric's innovation is a highly flexible radio, providing over-the-air reconfiguration; adaptability; and uninterrupted, real-time, multimode operation. The technology is also compliant with NASA's Space Telecommunications Radio System (STRS) architecture.

In addition to its many uses within NASA communications, the SDR can also serve as a highly programmable research-stage prototyping device for new waveforms and other communications technologies. It can also support noncommunication codes on its multicore processor, collocated with the communications workload—reducing the size, weight, and power of the overall system by aggregating processing jobs to a single board computer.

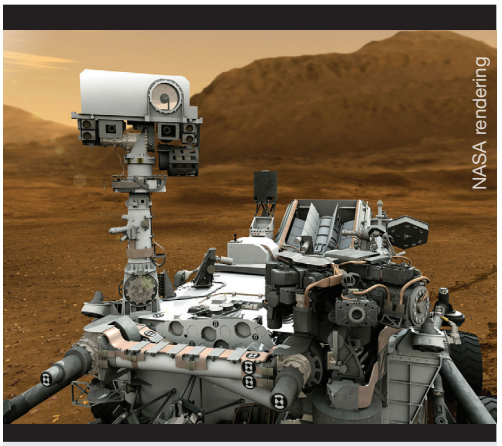
Applications

NASA

- Multimode rover communications and data processing
- Satellite communications
- Flexible research platform for communication labs and research projects

Commercial

- Military communication networks
- Satellite-based surveillance
- Automotive wireless devices



Phase II Objectives

- Complete ultraflexible baseband processing on radiation-hardened multicore
- Achieve programmable radiation-hardened multicore network stack
- Ensure compliance with STRS for multicore-based architecture
- Demonstrate support for noncommunications applications
- Finalize radiation tolerance and ruggedization for space applications

Benefits

- Radiation-hardened
- Ultraflexible
- Multimode-operation capable
- STRS compliant
- Over-the-air reconfigurable
- Easy to program

Firm Contact

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Proposal Number: 09-2 01.03-8119

Reconfigurable Very Long Instruction Word (VLIW) Processor

For software-defined radio applications

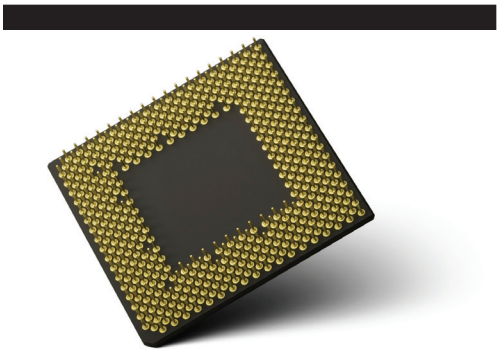
Future NASA missions will depend on radiation-hardened, power-efficient processing systems-on-a-chip (SOCs) that consist of a range of processor cores custom tailored for space applications. Aries Design Automation, LLC, has developed a processing SOC that is optimized for software-defined radio (SDR) uses. The innovation implements the Institute of Electrical and Electronics Engineers (IEEE) RazorII voltage management technique, a microarchitectural mechanism that allows processor cores to self-monitor, self-analyze, and self-heal after timing errors, regardless of their cause (e.g., radiation; chip aging; variations in the voltage, frequency, temperature, or manufacturing process). This highly automated SOC can also execute legacy PowerPC 750 binary code instruction set architecture (ISA), which is used in the flight-control computers of many previous NASA space missions.

In developing this innovation, Aries Design Automation has made significant contributions to the fields of formal verification of complex pipelined microprocessors and Boolean satisfiability (SAT) and has developed highly efficient electronic design automation tools that hold promise for future developments.

Applications

NASA and Commercial

- Implementing and verifying processor SOCs with any legacy ISA
- Adding new instructions that use reconfigurable functional units to accelerate specific applications
- Verifying properties of the resulting binary code



Phase II Objectives

- Design and verify a range of pipelined, dual-issue superscalar and VLIW processor cores
- Guarantee correct execution of legacy binary code from current space missions
- Implement new instructions that use reconfigurable functional units to accelerate SDR algorithms
- Design and verify a range of SOCs consisting of such processor cores
- Perform SAT-based technology mapping, placement, and routing of complex SDR operations to the reconfigurable functional units
- Compile SDR applications to the ISAs supported by the cores
- Run hardware-software cosimulations to measure the performance and power consumption of the SOCs and select an optimal design

Benefits

- Automated
- Fast
- Flexible
- Scalable
- Low power

Firm Contact

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Proposal Number: 09-2 O1.03-8382

High-Fidelity Down-Conversion Source for Secure Communications Using On-Demand Single Photons

Novel device provides down-conversion pairs with enhanced spectral properties

AdvR, Inc., has built an efficient, fully integrated, waveguide-based source of spectrally uncorrelated photon pairs that will accelerate research and development (R&D) in the emerging field of quantum information science. Key to the innovation is the use of submicron periodically poled waveguides to produce counter propagating photon pairs, which is enabled by AdvR's patented segmented microelectrode poling technique. This novel device will provide a high brightness source of down-conversion pairs with enhanced spectral properties and low attenuation, and it will operate in the visible to the midinfrared spectral region. A waveguide-based source of spectrally and spatially pure heralded photons will contribute to a wide range of NASA's advanced technology development efforts, including on-demand single photon sources for high-rate spaced-based secure communications.

Applications

NASA

- High-rate space-based secure communications
- Quantum metrology for precision space-based navigation
- Space-based entanglement tests of quantum and gravitational theories
- Characterization, optimization, and calibration of photon-starved detectors

Commercial

- R&D in quantum communications and computations
- Characterization and optimization of detectors used for low light level discovery
- Optical Schrödinger-cat states
- Teleportation-based quantum repeaters for quantum key distribution over unlimited distance

Phase II Objectives

- Design and fabricate potassium titanyl phosphate waveguides, optimized for quantum-phase matching, counter-propagating down-conversion pairs
- Demonstrate that macroscopic spectral properties of the individual waveguides can be matched between waveguides
- Establish the purity and separability of the down-converted photons

Benefits

- Provides a high brightness source of down-conversion photon pairs
- Accelerates R&D in the field of quantum information science

Firm Contact

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