NASA/TM—2015-218904

An Overview of 2014 SBIR Phase I and Phase II Communications Technology and Development

Hung D. Nguyen, Gynelle C. Steele, and Jessica R. Morris
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December 2015

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Abstract

NASA's Small Business Innovation Research (SBIR) program focuses on technological innovation by investing in development of innovative concepts and technologies to help NASA mission directorates address critical research needs for Agency programs.

This report highlights eight of the innovative SBIR 2014 Phase I and Phase II projects that emphasize one of NASA Glenn Research Center's six core competencies—Communication Technology and Development. The technologies cover a wide spectrum of applications such as X-ray navigation, microsensor instrument for unmanned aerial vehicle airborne atmospheric measurements, 16-element graphene-based phased array antenna system, interferometric star tracker, ultralow power fast-response sensor, and integrated spacecraft navigation and communication. Each featured technology describes an innovation, technical objective, and highlights NASA commercial and industrial applications.

This report provides an opportunity for NASA engineers, researchers, and program managers to learn how NASA SBIR technologies could help their programs and projects, and lead to collaborations and partnerships between the small SBIR companies and NASA that would benefit both SBIR.

[1] Lewis' Educational and Research Collaborative Internship Project (LERCIP).

The Compact Hyperspectral Aberration-Corrected Platform (CHAP)

An Instrument for Microspacecraft

.Minimizing the mass and power of an instrument reduce the size, complexity and therefore the mission cost. To enable more capable missions without high cost we propose to develop a hyperspectral/multispectral imager designed for a microsatellite platform that will function in a reduced light environment while minimizing the mass and power consumption. This type of instrument is crucial to the study of small bodies such as near earth asteroids and for missions further afield by maximizing capability while minimizing the instrumental cost and complexity. The Compact Hyperspectral Aberration-corrected Platform (CHAP) is proposed as a new, innovative instrument using an aberration-correcting holographic grating to make maximal use of two optical components. The optical design of CHAP produces a white light zeroth order image from undiffracted light to be formed at the telescope focus, enabling the co-registration of spatial and spectral information, providing unprecedented context never before seen in an instrument for planetary and lunar science low-light observation.

Applications

NASA

- ► Earth observations that require hyperspectral imaging, such as:
    - o Water health
    - o Deforestation
    - o Carbon emission monitoring

Commercial

- ► Monitoring of tropical rainforests for climate change effects
- ► Agriculture varietal and health mapping
- ► Detection of hydrocarbon seepages and pipeline leakages
- ► Environmental clean-up and contamination mapping
- ► Mining, oil and gas resource exploration
- ► Mining pollution monitoring

Phase II Objectives

- ► Build of a flight ready CHAP hyperspectral imager
- ► Instrument calibration and data analysis system development
- ► Flight qualification of the optical bench and mounting systems

Benefits

- ► High spectral resolution in a compact package
- ► Simple two optic solution that is highly scalable and reconfigurable in spatial scales or wavelengths observed
- ► Low cost unit cost after NRE
- ► Suitable for space flight

Firm Contact

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Integrated Spacecraft Navigation and Communication Using Radio, Optical, and X- rays

Novel enabling technology for Earth orbit and interplanetary navigation

This program proposes to design and evaluate novel technology of X-ray navigation for augmentation and increased capability of high data-rate spacecraft communications. NASA's current concept for an integrated radio and optical communications (iROC) system is being developed to provide communication technology that does not constrain the science yield of their deep space missions. iROC requirements include accurate navigation and pointing solutions so that narrow optical beams are precisely transmitted directly to their Earth-based reception stations. X-ray source techniques and methods have been successfully demonstrated to determine independent position and attitude solutions for deep space vehicles. Therefore, ASTER Labs proposes to integrate the X-ray sensors directly into the iROC concept, such that the combined radio, optical, and X-ray system, referred to as iROX, can operate over a wide variety of applications and missions, increasing NASA's capability to explore the solar system.

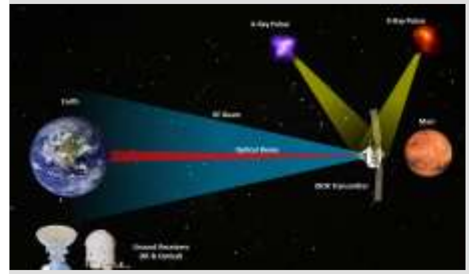
Applications

NASA

- ► Accurate deep space navigation and attitude
- ► High-rate data deep-space communication
- ► High definition video transmissions
- ► Advanced X-ray transmitters and detectors
- ► Accurate relative navigation for formation flying

Commercial

- ► High-data rate communication for DoD and commercial telecommunication satellites
- ► Improved detectors for manufacturing, production, and inspection
- ► Enhanced X-ray pulse generators and detectors for medical and diagnostic imaging
- ► Communication technology for re-entry and hypersonic communications during RF-blackout



Phase II Objectives

- ► Evaluate the integrated system
- ► Design a prototype detector system that augments the existing iROC concept
- ► Evaluate the performance of the integrated iROX system
- ► Identify the feasibility and capability of such a system based upon the design architecture

Benefits

- ► Increased capability of high data-rate spacecraft communications, including:
  - High-resolution observations
  - Inter-satellite communications
  - Interplanetary video
  - Health and status monitoring data
- ► Relative navigation between vehicles to maintain accurate formations
- ► Independent navigation capability reduces DSN workload

Firm Contact

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Proposal number: H9.05-9729

Chemical Microsensor Instrument for UAV Airborne Atmospheric Measurements

Real-time measurements of trace gases

Chemical species mapping using unmanned aerial vehicles (UAVs) enables model validation and attaining data that augments traditional aerial and satellite data. However, there are limited options adapting commercial chemical sensors for species and ranges of interest. Wet electrochemical cells are slow (30-60 s), sensitive to pressure changes, and a potential hazard from leakage. Most commercial CO2 monitors are based on NDIR, with response time in the order of minutes. Hydrocarbons are monitored by generic combustible gas sensors. Makel Engineering is developing an Airborne Chemical Microsensor System suitable for real-time, UAV-based measurements of trace CO2, SOX, and CH4. The instrument adapts low cost, low power microsensor technology demonstrated for fire detection and emissions monitoring to airborne measurements. The lightweight, fast response, robust instrument is suitable for a wide range of platforms including aerostats (balloons, kites) and UAVs (Dragon Eye, SIERRA).

Applications

NASA

- Study of volcanoes to validate atmospheric models to gain new insight into mechanisms
- Assist NASA's work studying volcanic activity such as tracking volcano emissions

Commercial

- Air quality monitoring by air quality management districts
- Remote monitoring of gas leaks in pipelines
- Remote monitoring of chemical process plants, enabling fast response to accidental chemical releases
- Monitoring equipment on aerostats or UAV to enable improved air quality forecasts and emissions compliance

Phase II Objectives

- Develop a design of a flyable multi-sensor system
- Fabricate the prototype systems
- Demonstrate prototypes in a wide range of flight conditions

Benefits

- Real-time UAV-based measurements of multiple gases
- Low cost
- Low power
- Lightweight
- Fast response
- Suitable for a wide range of platforms

Firm Contact

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Proposal number: S1.07-8813

Fully Printed Flexible 4-bit 2D (4x4) 16-Element Graphene-Based Phased Array Antenna System

Antennas with superior electronic, optical, mechanical, and thermal properties

Low-cost, high gain, light-weight, and flexible active antenna systems are highly desired for the Asteroid Redirect Mission and human expedition to Mars and beyond. In this program, we propose to develop a fully flexible ink-jet printed monolithic graphene-based high frequency PAA communication system. The superior electronic, optical, mechanical, and thermal properties offered by graphene is expected to significantly enhance the system features compared to the state-of-the-art flexible antenna systems, with operating frequency in excess of 100GHz expected. Flexible electronically steerable antenna will be useful for small spacecraft to TDRS and other GEO relay satellites links, next generation space launch systems, and human exploration vehicles.

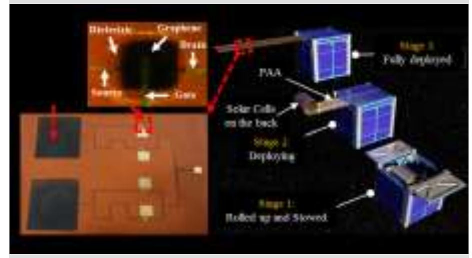
Applications

NASA

- ► Autonomous communication systems
- ► Deployable and conformal/wearable active antennas
- ► Reconfigurable antennas
- ► Large inflatable PAA

Commercial

- ► RF identification tags
- ► Smart cards
- ► Electronic pagers
- ► Large area flat panel displays and lighting
- ► Large area solar cells and batteries
- ► Sensors
- ► Thin-film transistor circuits
- ► Communication systems



Phase II Objectives

- ► Develop the fully printable integrated circuit technology and multi-layer printing and interconnection technology on flexible substrates
- ► Develop the T/R module including phase shifters and amplifiers
- ► Develop a prototype of the fully printed PAA and perform reliability tests
- ► Investigate the scalability of system manufacturing using a R2R process

Benefits

- ► Superior electronic, optical, mechanical, and thermal properties
- ► Enhanced system features from current flexible antenna systems
- ► High operating frequencies

Firm Contact

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Proposal number: T5.01-9895

Interferometric Star Tracker

A deep space lasercom beam pointing application

Laser communications (Lasercom) technology offers the promise of much higher rate data exchanges while reducing the size and weight of the telecommunications package for deep space missions. This improved system performance is due primarily to the narrow transmit signal beamwidth at the optical wavelength. The problem of pointing a laser signal can in general be decomposed into the problems of (i) stabilizing the optical line of sight and (ii) providing the appropriate pointing reference to the receiver location. Optical Physics Company (OPC) has adapted the precision interferometric star tracker it is currently developing under several DoD contracts for deep space lasercom beam pointing applications. The OPC interferometric star tracker can also be used to provide precise attitude measurements to the spacecraft for navigation and orbit determination purposes. The current concept for the beam pointing is for a star tracker to be mounted opposite to the downlink beam boresight.

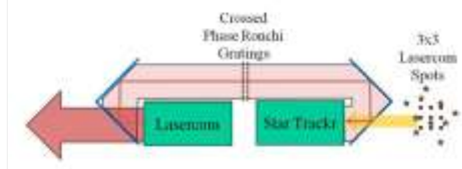
Applications

NASA

- ► Star trackers for spacecraft
- ► GPS denied navigation for armed forces
- ► Enhanced value of deep space probe missions through greater data collection and faster data return

Commercial

- ► Secure lasercom to non-transmitting locations



Phase II Objectives

- ► Develop and demonstrate an interferometric star tracker for the deep space beam pointing application
- ► Reduce the size and weight of the telecommunications package for deep space missions
- ► Code the software modules that will become the real-time processing
- ► Assemble and install the software when the processors are ready
- ► Calibrate and integrate the star tracker into the structure
- ► Lab test the star tracker to verify accurate lasercom boresighting

Benefits

- ► Efficient delivery of the transmit signal to the receiver
- ► Precise attitude measurements to the spacecraft for navigation and orbit determination purposes
- ► For outer planet missions, the sun will almost always be away from the tracker, thus allowing the tracker to have a direct view of the sky
- ► Recovers lost data rate from previous larger laser beams

Firm Contact

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Proposal number: H9.05-9570

An Ultralow Power Fast-Response Nano-TCD CH4 Sensor

For UAV Airborne Measurements

In this project, KWJ proposes to develop a low power, fast response, lightweight miniature CH_4 measurement system based on KWJ nano-TCD sensor for airborne measurement operation. KWJ has developed patented sub-½m dimension TCDs, with ultra-low power consumption, fast response time, very high stability, all coupled with simple electronic circuits and algorithms. In Phase I, KWJ will fabricate nano-TCD CH4 sensor, improve the sensitivity such that 5ppm accuracy will be obtained, and characterize the sensor on a bench-top testing system to demonstrate CH4 detection with all target specifications. In Phase II, the prototype sensing system will be built and integrated with NASA UAVs for field testing. The proposed sensor will be ideal for airborne gas surveys. This work has synergy within NASA and can collaborate with ongoing NASA SiC sensor developments in Phase II.

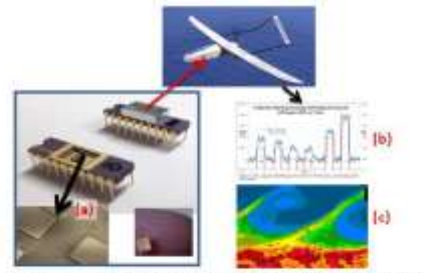
Applications

NASA

- Support for NASA's airborne science missions
- Accurately map the spatial and temporal distribution of CH4 in atmosphere using unmanned aircraft
- Other gas detection for NASA's earth and space applications

Commercial

- Low cost long lifetime gas detection, including:
  - Home CH4 alarms
  - Pipeline monitors and fenceline monitors
  - Leak detectors in the rapidly growing oil and gas "fracking" industry



Low power miniature CH_4 sensor that can be deployed by UAVs for qualitative, quantitative and spatial measurement and mapping of atmospheric gas. (a) 1x50µm sensing bridge; (b) example response to 100-500ppm CH_4; (c) example aerial mapping data

Phase II Objectives

- Demonstrate the feasibility of the nano- TCD based CH4 measurement system, measured against target specifications
- Design, optimize and fabricate nano-TCD sensor platform for CH4 sensing
- Optimize the sensitivity of the CH4 sensor Characterize the nano-TCD CH4 sensor and demonstrate CH4 sensing

Benefits

- A more cost effective alternative sensor
- Has a wide range of applications
- Low Power
- Fast response
- Small Size

Firm Contact

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Proposal number: S1.07-8865

Finite Internal Temperature Slide for Use with Colloid Experiments

Hollow microscope slide capable of taking temperature measurements without significant optical interference

The Light Microscopy Module (LMM), developed and managed by NASA Glenn Research Center (GRC), is producing fascinating results. LMM will yield even more astonishing results with the addition of enhancing subsystems. Techshot proposes development of a Finite Internal Temperature Slide (FITS) — a hollow microscope slide capable of taking temperature measurements of a sample along the length of a slide without significant optical interference. Additionally this technology will apply heating to the sample by passing a current through the resistive path used for temperature measurement. This allows for more accurate, varied and controlled temperature gradients to be applied across a sample volume while maintaining optical clarity. FITS is a direct result of a need expressed by current NASA funded Principal Investigators who intend to use the LMM for experiments in which temperature, and/or temperature gradients, must be precisely controlled.

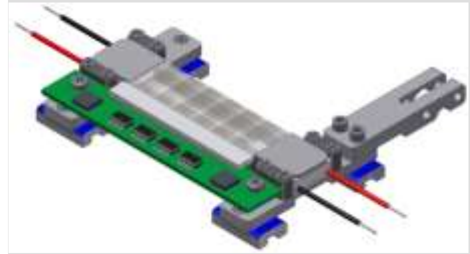
Applications

NASA

- ► Improved capabilities for the Light Microscopy Module when coupled with FITS
- ► Processing for large quantities of high-value materials for NASA

Commercial

- ► Lease FITS flight hardware to commercial entities for their use in conducting advanced scientific research and processing in space
- ► Procter & Gamble has interest in using Techshot technologies such as FITS to advance several of their consumer products by learning more about how materials behave in microgravity



Phase II Objectives

- ► Define design requirements
- ► Design FITS module
- ► Build and test technology demonstrators
- ► Identify applicable design requirements by canvassing a representative list of realistic users, identifying user requirements, characterizing interfaces with the LMM, and writing and reviewing requirements document
- ► Design FITS Module by investigating technical feasibility, developing preliminary circuity design, and developing a preliminary system software architecture
- ► Develop a functional demonstrator by documenting each FITS module design, selecting the best suited fabrication method, and fabricating and assembling each FITS module
- ► Test the technology demonstrator

Benefits

- ► Capable of taking temperature measurements of a sample without significant optical interference
- ► More accurate, varied and controlled temperature gradients can be applied across a sample volume while maintaining optical clarity

Firm Contact

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Proposal number: H10.02-8884

Measurement of Trace Gases in the Atmosphere of Venus

Using in-situ balloon-borne measurements

Southwest Sciences proposes to develop small, lightweight, low power instrumentation for the in situ balloon-borne measurement of several trace gases of importance in the atmosphere of Venus. Using low power vertical cavity diode lasers (VCSELs) at carefully selected wavelengths in the 2400 nm region, the instrument will be capable of simultaneous measurements of carbon monoxide, water vapor, hydrogen fluoride, carbonyl sulfide, and possibly sulfur dioxide. The Phase I effort will concentrate on identifying the best wavelength regions for measurement of multiple trace species with a minimum number of lasers (ideally no more than two), while establishing important design parameters for development of more rugged prototype instrumentation in Phase II.

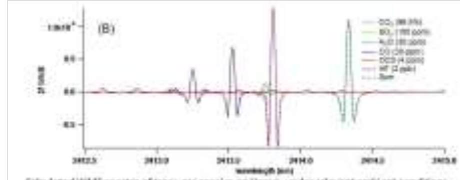
Applications

NASA

- ► Instrumentation for direct use by NASA in planetary measurements, particularly atmospheric measurements of Venus
- ► Measurements of other atmospheres, including Titan or Mars
- ► Environmental monitoring on-board manned spacecraft

Commercial

- ► Industrial process monitoring
- ► Atmospheric chemistry and environmental monitoring
- ► Workplace safety monitoring
- ► Medical diagnostic applications



Calculated WMS spectra of trace gas species on Venus, under relevant ambient conditions.

Phase I Objectives

- ► Identify optimal spectral regions for measuring several trace gases
- ► Assemble a Phase I laboratory prototype instrument to be used for near-infrared measurement of several of the trace gases
- ► Establish expected detection limits for the gases
- ► Estimate the expected design parameters for a small, low power instrument targeting in situ measurement of trace gases in the Venus atmosphere
- ► Identify the size, weight, and power requirements as well as its expected measurement capabilities

Benefits

- ► Small and lightweight
- ► Low power requirements
- ► Measures gases of importance in atmosphere of Venus
- ► Simultaneously measures multiple gases

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