NASA STTR 2021-I Solicitation

PROPOSAL NUMBER: 21-1- **T8.06-2067**

SUBTOPIC TITLE: Quantum Sensing and Measurement

PROPOSAL TITLE: Opto-Atomic Quantum Squeezer

Small Business Concern

Firm: **Hedgefog Research, Inc.**
Address: **1891 North Gaffey Street, Suite 224, San Pedro, CA 90731 - 1270**
Phone: **(310) 935-2206**

Research Institution:

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Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3

Technical Abstract (Limit 2000 characters, approximately 200 words):

Hedgefog Research Inc. (HFR) proposes to develop an Opto-Atomic Quantum Squeezer (OAQS) generating squeezed states of light resonant to a target atomic transition. Squeezed light offer exciting new opportunities in the field of quantum metrology, but available light sources delivering these exotic quantum properties are often bulky, complex, and highly susceptible to environmental perturbations and thus, not suitable for field applications. In addition, most squeezed light sources do not operate near an atomic resonance and do not offer strong light-atom interaction. HFR's OAQS will be a high-power quantum light source packaged in a low size, weight, and power (SWaP) unit compatible with operation on NASA's aerospace platforms. In Phase I, HFR will design system components of OAQS, evaluate their performance in squeezed light generation, and down-select key components and enabling technologies for future development. We will also conduct a preliminary design of the fully-packaged OAQS prototype.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Quantum states of light, such as entangled photons and squeezed light, are one of the key enabling ingredients in a number of applications associated with quantum sensing, quantum communication, and quantum computation. Narrow-band, resonant entanglement/squeezing source will enable an efficient, on-demand interaction between photons and atomic ensembles, which will enhance sensitivities of atom-based quantum sensors and make it possible to preserve/store quantum properties of squeezed light in atomic media.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Quantum metrology, taking advantage of quantum mechanical behavior of quantum particles, is expected to significantly boost sensitivity of various sensor modalities used in numerous applications, including inertial sensing, time keeping, EM-field sensing, and gravity sensing. Squeezed light sources allow to fully exploit quantum-mechanical nature of atoms and ions in these applications.

Duration: **6**

PROPOSAL NUMBER: 21-1- **T10.05-1207**

SUBTOPIC TITLE: Integrated Data Uncertainty Management and Representation for Trustworthy and Trusted Autonomy in Space

PROPOSAL TITLE: Machine Learning Explainability and Uncertainty Quantification to Support Calibration of Trust in Automated Systems

Small Business Concern

Firm: **Mosaic ATM, Inc.**
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Phone: **(800) 405-8576**

Research Institution:

Name: **Universities Space Research Association**
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Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 1
End: 3

Technical Abstract (Limit 2000 characters, approximately 200 words):

Mosaic ATM proposes an innovative approach to providing information about automated system trustworthiness in a given context, which will support humans in appropriately calibrating trust in such systems. Appropriately calibrated trust will, in turn, inform the scope of autonomy humans grant to the system to perform independent decision making and task execution. We communicate system trustworthiness through a combination of an innovative approach to explainable machine learning (ML) and representation of confidence in model results based on a quantification of uncertainty in those results given the available input data. We demonstrate our approach in the context of automated support for monitoring and managing crew wellbeing and performance in deep space exploration missions, where astronauts will be subject to the physical and psychological stress of performing in an isolated, confined, and extreme (ICE) environment. In Phase I, we will demonstrate our approach to support human assessment of automated system trustworthiness through a generalized method for explainable ML and representation of uncertainty in ML model results and situate them in a prototype system that will support evaluation of their effect on human calibration of trust. This prototype system will be based on our concept for automated support for monitoring and managing crew wellbeing and performance, which we will document in Phase I.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

- Several NASA applications will benefit from a generalizable approach to supporting appropriate calibration of trust in automated systems built upon ML models, including deep space exploration, air traffic management, and aviation safety.
- For example, NASA will benefit from an automated system to support monitoring and management of crew wellbeing and performance in deep space exploration.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

- Organizations performing in isolated, confined, or extreme (ICE) environments can use an automated system to support crew wellbeing, e.g., National Science Foundation, Department of Defense.

- Explainable computer vision can enhance automated labeling of drone equipment inspection images, flagging assets with visible defects, drawing inspector attention to the most relevant elements for analysis.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T10.03-1470**

SUBTOPIC TITLE: Coordination and Control of Swarms of Space Vehicles

PROPOSAL TITLE: Space Vehicle Swarm Coordination and Control using Temporal Logic

Small Business Concern

Firm: **Aster Labs, Inc.**
Address: **155 East Owasso Lane, Shoreview, MN 55126 - 3034**
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Research Institution:

Name: **The Regents of the University of Minnesota**
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Principal Investigator:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

This program will develop an innovative software tool for optimizing control of heterogeneous swarming systems using Swarm Signal Temporal Logic (SSTL) specifications. The proposed solution will enable task prioritization and scheduling, and distributed optimization of heterogeneous multi-agent systems (MAS) with the ability to scale the agent team, environment, and degree of heterogeneity with minimal effects to the computational complexity. The SSTL framework enables swarm time- and spatial-based task definitions and scheduling. Methods for coordination and control of agent behavior, in terms of desired robustness and total energy consumption, will be implemented using game theoretics and gradient descent in a distributed manner. Inter-agent communication methods will be developed, based on the nearest-neighbor communications models for use in the logic framework. SSTL algorithms developed will be implemented into a set of MATLAB language modules capable of declaring mission and objective requirements based on definitions of agents, tasks, and scheduling. The SSTL has a broad application range, including sets of multiple spacecraft, unmanned aerial/ground vehicles, and maritime vessels coordinating and cooperating in a MAS. Agent properties, such as dynamics models, mass, charge level, energy efficiency, communication range, and control update rates will be modeled. Software demonstrations will be performed to illustrate the feasibility and capabilities of the temporal logic approach to control numerous types of MAS vehicles and applications using SSTL specifications. Simulation valuations will determine algorithmic performance in terms of control convergence, energy consumption, and rates of successful task completion. System use cases will be outlined via CONOPS development, detailing the potential utility and benefits of SSTL algorithms for NASA and commercial applications.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Applying SSTL to NASA programs involving MAS enables definition of complex mission tasks for heterogeneous swarms with strict requirements for objectives in terms of time, duration, and cardinality. Specific applications include cooperative scouting activities and path planning, autonomous multi-objective scientific exploration, and communications networking. Task prioritization, time- and event-

based scheduling, and distributed convergence optimization via SSTL has broad applicability to swarms of space, aerial, sea, and ground vehicles.
Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The SSTL algorithms apply to a variety of MAS that benefit from coordinated task planning and distributed optimization. Non-NASA applications include commercial or defense UAS/UGV, seacraft, or space vehicles used for exploration, transit, or surveying. The SSTL framework is applicable to artificial intelligence, system design verification, linguistics, and task management systems.
Duration: **13**

PROPOSAL NUMBER: 21-1- **T10.04-1550**

SUBTOPIC TITLE: Autonomous Systems and Operations for the Lunar Orbital Platform-Gateway

PROPOSAL TITLE: REALISE - Remote Experimentation and Analysis Laboratory In SpacE

Small Business Concern

Firm: **Intelligent Imaging Innovations**
Address: **3575 Ringsby Court, Suite 102, Denver, CO 80216 - 5016**
Phone: **(303) 638-8914**

Research Institution:

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Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 4
End: 6
Technical Abstract (Limit 2000 characters, approximately 200 words):

We are proposing the fully autonomous science facility REALISE for suspended biological cultures that can both incubate organisms over long periods of time (30 days to 9 months) but also perform in-situ analysis of samples using bright-field and three-color fluorescence microscopy. REALISE will be based heavily on functionality, components, and experience from past Shuttle, ISS, and Orion heritage flight hardware but is intended to set new standards for in-situ scientific analysis, long-term cell culturing, as well as automation. The in-situ automated microscopy compartment will set new standards in characterizing cell adaptations in space over time as opposed to only start and end conditions. The fluorescent analysis -in addition to bright-field microscopy for morphological changes- will be used to characterize microbiological processes such as cell metabolism, cell health, and cell function. While REALISE is developed specifically for the Lunar Orbital Platform Gateway, it will have future applications also on commercial space stations and lunar surface habitats both manned and unmanned as well as for more automated and less crew-intensive experiments onboard the International Space Station. REALISE is proposed to be a two locker system that will be permanently deployed onboard the Lunar Orbital Platform Gateway and can store and actively support cell cultures fully thermally-controlled for up to 9 months. Once an experiment or production is terminated, REALISE is designed to be serviced on-orbit while the crew is present for consumable swap out so that the unit can initiate another autonomous operation cycle. Potential applications are radiation studies over multiple generations to characterize the response of organisms or the effectiveness of countermeasures for future long-term human spaceflights as well as cell production facilities for unique terrestrial cell culture treatments that can only be grown in the space environment.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

REALISE will provide NASA the capability to conduct autonomous long-term cell culture studies ranging from microbiology (yeast, protein crystals,) to mammalian cell cultures (bone cells, heart cells, blood cells, stem cells) in deep space. As REALISE is specifically designed for the Gateway Lunar Orbital Platform, novel radiation studies over multiple generations under long-term exposure to the space environment are imminent examples that are critical to inform NASA about the risks and mitigation of future human space exploration missions.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

REALISE will provide autonomous large scale cell culture productions for commercial companies that can produce unique cell culture lines onboard the Gateway in the deep space environment. However REALISE is expandable to ISS, commercial space stations, and/or planetary surfaces. Subcomponents such as automated manufacturing as well as in-situ analysis methods can also be individually marketed.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T14.01-1369**

SUBTOPIC TITLE: Advanced Concepts for Lunar and Martian Propellant Production, Storage, Transfer, and Usage

PROPOSAL TITLE: Robust, high-performance, contaminants-tolerant, reversible protonic ceramic electrochemical cells for producing Lunar and Martian propellant and generating power

Small Business Concern

Firm: **Special Power Sources LLC**
Address: **930 W Ely St, Suite M1, Alliance, OH 44601 - 1500**
Phone: **(330) 806-2671**

Research Institution:

Name: **Kansas State University**
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Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

Special Power Sources (SPS) will harness the advanced proton-conducting electrolyte developed at Kansas State University (KSU) and will deliberately design a novel, robust, tubular, high-performance, contaminants-tolerant, fuel-flexible, reversible electrochemical cells for producing Lunar and Martian propellants (H_2, CH_4, and O_2), generating power, and thus supporting critical NASA missions. This proton-conducting electrolyte exhibits excellent conductivity (>0.02 S-cm) and thereby enables ultrafast and efficient propellants

production and power generation. The reversible protonic ceramic electrochemical cells (PCECs) operate in electrolysis mode, converting H_2O into H_2 and O_2 via H_2O electrolysis or directly co-converting CO_2 and H_2O into CH_4 and O_2. These chemicals can be used as the Lunar and Martian propellants. When additional electricity is needed, it functions as a fuel cell in its reversed mode to produce electricity and water. PCECs display excellent fuel flexibility and contaminants tolerance and thus can directly produce and use multiple propellants including H_2, CH_4, kerosene, and O_2.

The Team will demonstrate a novel tubular cell architecture by leveraging the capabilities at SPS. This effort will be the first time in the U.S. that PCECs are translated from planar form to tubular cells; this represents a significant achievement in and of itself. A tubular cell architecture is typically more robust in terms of its ability to handle thermal, chemical, and mechanical stresses and thus is more appropriate for NASA missions. We will determine how this tubular architecture can improve its robustness and reliability. Furthermore, we will test the full cell under extreme conditions, such as superfast charge/discharge rate, to determine its durability. In Phase I, we will demonstrate an electrical current density of > 500 mA/cm^2 and transient currents >750 mA/cm^2 for at least 30 sec.
Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Reversible PCECs can be used for:

1. Directly producing Lunar and Martian propellants (H_2, CH_4, and O_2) through electrolyzing H_2O or co-electrolyzing CO_2 and H_2O. Additionally, the produced chemicals can be used as the chemical building blocks and energy sources, which are necessary ingredients for life on Moon or Mars.

2. Generating power in fuel-cell mode by directly converting chemicals (H_2, CH_4, kerosene, and O_2) into electricity.

2. Long-duration energy storage designed for NASA missions.
Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Protonic ceramic electrochemical cells can serve to efficiently produce renewable H_2. After integrating with fossil power plants, PCECs can function as the fossil energy storage device to convert captured CO_2 and H_2O into methane. PCECs can be deployed to support DoD remote operations as reliable and distributed power sources increasing the warfighters' ability to remain on station.
Duration: **6**

PROPOSAL NUMBER: 21-1- **T12.07-1562**

SUBTOPIC TITLE: Design Tools for Advanced Tailorable Composites

PROPOSAL TITLE: An Efficient High-fidelity Design Tool for Advanced Tailorable Composites

Small Business Concern

Firm: **AnalySwift**
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Phone: **(801) 599-5879**

Research Institution:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

Tailorable composites have been proposed to further lightweighting space structures with improved performance. However, no existing design tools are capable of exploiting the full potential of these advanced material systems. The theory underpinning existing design tools was originally developed for traditional composites with straight fibers while tailorable composites usually have curved fibers with varying orientations or more complex microstructures. To harness their full potential, it is imperative to develop theories and design methodologies for tailorable composites and integrate them into commercially available design tools.

We propose to develop an efficient high-fidelity design tool for tailorable composites featuring the following three innovations:

- Mechanics of structure genome (MSG) based composite models for calculating the location-dependent stiffness and strength of tailorable composites, which can rigorously predict effective stiffness and strength as well as layerwise stress/strain/displacement distributions.
- A versatile parameterization method that can expand the design space to achieve better design for tailorable composites along with general-purpose optimizers to produce highly tailorable designs with optimized load path.
- An integrated design framework with user-friendly GUI plug-ins in MSC.Patran/Nastran and Abaqus for the design of tailorable composite structures to leverage the versatile modeling capability in MSC.Nastran and Abaqus.

This project will benefit NASA and related agencies/industries by exploiting the potential of tailorable composites for designing better lightweight structures. The resulting efficient high-fidelity design tool developed in this project will shorten the design and analysis period of structures made of tailorable composites. Such a tool will ultimately reduce the cost associated with using tailorable composites and accelerate affordable space exploration by NASA and the private sector.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

- Lightweight structures for satellite buses, landers, rovers and other exploration vehicles, solar arrays, and antennas.
- Cryogenic tanks, pressurized habitats, other primary space structure components, including dry & unpressurized, such as lander truss cages, landing gears.
- Next-generation airframe tech (hybrid/blended wing body); highly flexible wings.
- Highly fatigue and damage tolerant structures for revolutionary vertical lift aircraft.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

- Better engineering and qualification of broader composite lightweight structures (with improved predictive capabilities).
- Validated design and analysis tools for the industrial realization of tailorable composites (aerospace, energy/wind, auto, marine, etc.).
- Improved designs for high-performance tailorable structures (prosthetics, fishing rods, golf clubs, tubes, etc.) with reduced cost & time.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T6.06-2093**

SUBTOPIC TITLE: Enabling Spacecraft Water Monitoring through Nanotechnology

PROPOSAL TITLE: Monitoring Systems for Inorganic and Organic Analytes in Spacecraft Water Streams

Small Business Concern

Firm: **TDA Research, Inc.**
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Phone: **(303) 422-7819**

Research Institution:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

Water recovery from wastewater is considered required for long-duration human exploration missions away from Earth. Without substantial water recovery, life support systems launch weights are prohibitively large. To insure the quality of this water, NASA is seeking miniature analytical systems i.e., sensor suites capable of simultaneous measurement of inorganic or organic species in potable and waste water.

In this proposed STTR project TDA Research, in collaboration with the University of Puerto Rico Mayaguez (UPRM), will develop a miniature device that can quickly analyze mineral and organic species in water. The device will provide near-real-time analysis with increased sensitivity and signal to noise ratio for metal cations and organic species such as the dimethanesilanediol, chloroform, dichloromethane, benzene etc. in water at low concentrations.

In Phase I we will carry out a proof-of-concept demonstration in a breadboard device and complete the design for a high fidelity device to minimize the monitor's footprint and overall dimensions, elevating the TRL to 4. In Phase II we will build a high-fidelity prototype with reduced dimensions, and demonstrate the analysis of various mineral and organic constituents, elevating the TRL to 6.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Potential NASA applications would be technologies that fill specific gaps in capabilities needed for spacecraft water management in the area of environmental monitoring. NASA is looking for technologies that identify and quantify inorganic and organic species in water for use during long-duration human missions away from Earth

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The water monitoring market is very large, and is projected to reach USD $7.54 Billion by 2027. There is a need to have one portable device that can quantity both mineral and organic species with minimal sample preparation and ease of use.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T9.02-1625**

SUBTOPIC TITLE: Rapid Development of Advanced High-Speed Aerosciences Simulation Capability

PROPOSAL TITLE: Rapid and Robust Analysis of High-Speed Environments Using Inviscid Output-Based Adaptive-Mesh Solvers

Small Business Concern

Firm: **Pointwise, Inc.**
Address: **213 South Jennings Avenue, Fort Worth, TX 76104 - 1107**
Phone: **(817) 377-2807**

Research Institution:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

We propose an adaptive-mesh, real-gas Euler finite-element solver for rapid prediction of high speed environments. Mesh adaptation is output-based, providing reliable control of numerical errors associated with quantities of engineering interest, such as drag or integrated wall temperature. The adaptation provides a feedback loop to automatically produce anisotropic meshes that are aligned with shocks, reducing errors induced by mesh-shock mismatch, and eliminates laborious human-in-the-loop mesh generation.

Robust simulation of the strong bow shocks associated with high-speed flows is achieved through the use of a PDE-based artificial viscosity augmenting the conservation equations. The PDE-based artificial viscosity provides superior dissipation for shock capturing by distributing artificial viscosity in a smooth manner between neighboring elements. The capability effectively reduces entropy noise in the post-shock region compared to shock operators based solely on local quantities.

Metric-conforming mesh adaptation will be incorporated into the industry leading Pointwise mesher using established local cavity operators and mesh curving procedures. The metric-conforming meshing algorithm will first be performed under the assumption of linear elements (Q1). For higher order solves, the mesh will then be curved to better approximate the geometry.

Existing finite-rate and multi-species non-equilibrium chemistry models will be analyzed as to their suitability for the higher order mesh adaptation. A specific challenge to be addressed in this project is adjoint compatibility (i.e. well posedness of adjoint PDEs) of the non-equilibrium relations and adjoint consistency of the resulting discretization. Essential to this process is establishing consistency between the mathematical and physical entropies associated with the models, and may require minor adjustments to modeling correlations.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

NASA applications include high-speed air vehicles, space vehicle launch, assent, and entry, parachute deployment, and complex multi-species reacting flows.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Military applications include vehicle aerodynamics and store separation. Civil applications include vehicle aerodynamics, low sonic boom aircraft, propulsion integration, rotorcraft, medical device, power generation, and complex reacting flows. There is essentially no market limitation for output-based mesh adaptation coupled with a robust solver.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T8.06-2232**

SUBTOPIC TITLE: Quantum Sensing and Measurement

PROPOSAL TITLE: Single Photon Generation by Functionalized Quantum Dots on Carbon Nanotube Arrays for Single Photon Detector Calibration and Quantum Entanglement Applications

Small Business Concern

Firm: **Lambda Consulting/Advanced Nanophotonics**
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Phone: **(240) 678-9475**

Research Institution:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

Generation of single photons is of great interest to NASA for several applications, chief among them is for calibration of single photon sensing detectors such as superconducting edge sensors or nanowire detectors. Single photon sources that produces photons that are entangled are also needed for quantum communications. The development of a carbon nanotube electrode by the SBIR firm during unrelated SBIR Phase III work related to an E-Nose for detection of VOC's in COVID-19 infected patients, provides a new avenue for the development of single photon sources. By implanting functionalized quantum dots (QD) on activated carbon nanotube (CNT) sites we can generate single photons by three different processes. 1) Electrical stimulation of quantum dots embedded in a dielectric 2) Optical stimulation using a laser of a different wavelength 3) Opto-electric stimulation of the quantum dots by providing a bias voltage and then providing optical pumping. The use of CNTs as both the support structure and electrode provides an ultra dark background for absorbing light from the pump laser to allow easier viewing of the emitted photon. CNTs freely share electrons within their matrix, also making them appear as an electron gas, which may also enhance the QD photon generation pump process. The QD's will be implanted using a nano plotter on an array of 16 pixels that are derived from the E-Nose chip design, this could allow for the implantation of a variety of QD types to provide different colors of emitted photons from each pixel. During Phase I will focus on demonstrating that we can generate single photons by these modalities. A pump laser will be passed through a fast optical fiber switch and collimated to illuminate the pixel array; the 1x2 switch will be operated to allow the illumination and collected photons to be isolated, with the emitted photons captured by the collimator array and output by the fiber switch to a fast detector for measurement.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Generation of single photons and many of them is a key technology to applying quantum entanglement to quantum computing, communications and cryptology. Single photon generation will allow the adaptation of existing technology and infrastructure to this new and powerful means of communication. Free space quantum communications would enable near instantaneous command and control of NASA assets in deep space by manipulation of entangled photons on the ground that have been delayed in a fiber optic loop and a paired receiver on the probe.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Single photon generation and entanglement at telecom wavelengths would allow adaptation of existing infrastructure for instantaneous communications on the ground that is impervious to interception because it is impossible decode the transmission without access to the paired entangled photon. Quantum communications, cryptology and computing all depend on the ability to generate single photons.

Duration: **6**

PROPOSAL NUMBER: 21-1- **T5.04-2355**

SUBTOPIC TITLE: Quantum Communications

PROPOSAL TITLE: Entangled Photon Transceiver Leveraging Photonic Integrated Circuit Technology

Small Business Concern

Firm: **Freedom Photonics, LLC**
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Research Institution:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

The development and scaling of a nationwide fault-tolerant quantum network is of crucial interest to both the domestic and international scientific community. To achieve large scale quantum networks, quantum teleportation, the technique in which quantum information (a.k.a. qubits) is transferred between a sender and receiver, needs to be realized in a low-cost, size, weight and power (low-CSWAP) form factor. Extending quantum teleportation technology to photonic integrated components, which significantly reduces CSWAP and increases environmental stability can allow for a scalable space-deployable quantum network. A key component to this system is the entangled photon-pair source. Recent developments in quantum communications have successfully demonstrated quantum communications link in space by the Chinese Micius satellite for quantum studies and quantum communication. Freedom Photonics is exploring photonic integrated circuit (PIC) solutions for entangled photon sources in satellite applications. The PICs that will be developed here will allow the low-CSWAP implementation of high-brightness quantum transmitters in LEO satellites to allow for enhanced quantum communications.

Photonic quantum communication devices currently have stringent system level requirements that are still being explored. Freedom Photonics LLC and our RI team member are partnering to combine high-performance photonic technology for entangled photon sources.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Exploring photonic integrated technology that is readily available in telecommunications has become imperative for space-based and airborne quantum communication systems in order to further Nasa's goal of a U.S. Global Quantum Network by 2032. Additionally, the photonic integrated circuit (PIC) technology being developed can extend to technology needs for other flight missions needing PIC technology for classical communication links and sensors.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

A US Government study in 2017 estimated quantum encryption products have a market of $50M to $500M [K. W. Crane *et al.*, IDA Paper P-8567 (2017)]. Also, due to stringent requirements for quantum communications, this technology can be used in classical communication systems, which is a trillion-dollar industry (USTelecom).

Duration: **13**

PROPOSAL NUMBER: 21-1**- T6.06-1195**

SUBTOPIC TITLE: Enabling Spacecraft Water Monitoring through Nanotechnology

PROPOSAL TITLE: New-generation spacecraft water monitoring with flight ready solid state nanopores

Small Business Concern

Firm: **GOEPPERT, LLC**
Address: **2200 Arch Street, Unit 504, Philadelphia, PA 19103 - 1343**
Phone: **(267) 713-2662**

Research Institution:

Name: **University of Connecticut**
Address: **438 Whitney Road Extension, Unit 1133, CT 06269 - 1133**
Phone: **(860) 679-3951**

Principal Investigator:

Name: **Zehui Xia Ph.D**
E-mail: **zx@gppert.com**
Address: **2200 Arch Street, Unit 504, PA 19103 - 1343**
Phone: **(443) 240-3618**

Business Official:

Name: **Vanya Buvac**
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Address: **2200 Arch Street, Unit 504, PA 19103 - 1343**
Phone: **(267) 687-9996**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

In order to provide a fast, simple and reliable way of identifying inorganics and organics present in the water systems aboard the ISS (and potentially other spacecraft), we propose to develop a robust, portable and easy-to-use sensor system based on solid-state nanopore technology. The system would enable in situ detection and quantification of analytes of interest by utilizing a low noise and low capacitance glass chip with an ultrathin silicon nitride (SiN) material which has flight heritage. The signal recording system would be designed to be compact (cm-scale) and easy to operate, and we would provide detailed instruction on its use, data collection and analysis. The instrument would enable determination of inorganic and organic species present in water samples, and establish a miniaturized analytical laboratory for future NASA missions. Sensor's specifications will be outlined and developed to satisfy the detailed and stringent NASA mission requirements, in consultation with NASA scientists. The proposed deliverable will be a solid-state pore chip integrated to corresponding miniaturized electronics for high signal-to-noise ratio and multiple analyte detection, together with the data acquisition and analysis software featuring current and time analysis, voltage-pulse-based pore de-clogging button and other advanced features. We will document the proposed innovation, evaluate its strengths and weaknesses compared to the state-of-the-art and propose further development to be performed in a subsequent Phase II. In order to deliver the advanced instrument and based on the current state of the market, state-of-the-art and Goeppert's previous endeavors, we articulate and propose the following Technical Objectives: 1) Fabricate ultrathin and sensitive SiN nanopore chips, 2) Measure a wide range of pure analytes of interest to NASA and 3) Establish a database for NASA with all measurement parameters and results.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Our technology features a novel single-molecule detection method designed for water monitoring in spacecraft. This advanced instrument can be crucial to support the life of crew residing in the ISS for months at a time. The ISS is a highly controlled, stable and isolated environment. The maintenance of safe living conditions in ISS is important to support the scientific activities of the crew, and to ensure their safe and unharmed return to Earth upon mission completion.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed nanopore sensor architecture, with its miniaturized and robust design has potential in a wide variety of terrestrial applications ranging from DNA sequencing, point-of-care diagnostics, human pathogen surveillance to agricultural. Additionally, the small molecule analysis capability can be applied to the EPA and USDA needs for measuring water quality.

Duration: **6**

PROPOSAL NUMBER: 21-1- **T11.05-1825**

SUBTOPIC TITLE: Model-Based Enterprise

PROPOSAL TITLE: Digital Twin Data Acquisition System for Institutional Facility Management

Small Business Concern

Firm: **Emerging Technology Ventures Inc.**
Address: **1300 Lavelle Rd, Alamogordo, NM 88310, Alamogordo, NM 88310 - 7627**
Phone: **(575) 483-6002**

Research Institution:

Name: **Navajo Technical University**
Address: **Lower Point Road, State Road 371, NM 87313 - 0849**
Phone: **(505) 786-4370**

Principal Investigator:

Name: **Mr. Gary Bullock**
E-mail: **gary.bullock@etvamerica.com**
Address: **1300 Lavelle Rd, Alamogordo, NM 88310, NM 88310 - 7627**
Phone: **(812) 277-9233**

Business Official:

Name: **Mr. Eugene Hudson**
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Phone: **(575) 446-9337**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 4
End: 6

Technical Abstract (Limit 2000 characters, approximately 200 words):

Emerging Technology Ventures Inc. and its research and development partners, Navajo Technical University and New Mexico Institute of Mining and Technology , are proposing to develop and demonstrate a “Digital Twin (DT) Data Acquisition System for Institutional Facility Management”. The innovation addresses Industry 4.0 digital transformation initiatives in Building Information Modelling (BIM) and Facility Management (FM) which have created critical demand for up-to-date digitized building assets for effective implementation in predictive, condition-based maintenance (CBM) strategies in FM. The team’s proposed use of autonomous, multi-modal systems and analytics to create DTs representing near real-time status of the built environment for FM offers an opportunity for responsive, labor efficient CBM.

The effort responds to NASA's digital transformation goals for model-based solutions in the area of “Digital Twin” Institutional Management of Health/Automated Decision Support of Agency Facilities that would greatly enhance operational efficiencies in its aging facilities.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The effort responds to NASA's digital transformation goals for model-based solutions in the area of “Digital Twin” Institutional Management of Health/Automated Decision Support of Agency Facilities that would enhance operational efficiencies in its aging facilities. The proposed solution will support localized and distributed management of NASA's facility constellation providing near real-time status of the facility environment for predictive condition based maintenance and offer possible adaptation for application in space environments.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Grandview Research reports that the global non-destructive inspection market size for this vertical was valued at USD 4.19 billion in 2017. It is projected to expand at a Cumulative Annual Growth Rate of 6.2% over the forecast period (2018-2025). The commercial real estate and industrial manufacturing markets offer excellent opportunities for expansion.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T8.07-2178**

SUBTOPIC TITLE: Photonic Integrated Circuits

PROPOSAL TITLE: Heterogeneous Silicon Photonics Magnetometer and Laser System-on-Chip

Small Business Concern

Firm: **Luna Innovations, Inc.**
Address: **301 1st Street Southwest, Suite 200, Roanoke, VA 24011 - 1921**
Phone: **(540) 769-8400**

Research Institution:

Name: **The Regents of the University of California, Santa Barbara**
Address: **3227 Cheadle Hall, 3rd Floor, CA 93106 - 2050**
Phone: **(805) 893-4034**

Principal Investigator:

Name: **Dr. Hongliang "Joe" Liang PhD**
E-mail: **liangj@lunainc.com**
Address: **3155 State Street, VA 24060 - 6604**
Phone: **(540) 953-4259**

Business Official:

Name: **Mr. John Forester**
E-mail: **foresterj@lunainc.com**
Address: **706 Forest Streeet, VA 22903 - 5231**
Phone: **(434) 220-9449**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

Luna, teamed with Dr. John Bowers of UCSB, will develop an integrated chip-scale optical magnetometer with an integral Silicon/III-V laser. This innovative product will enable new levels of performance for in situ and remote sensing in NASA's space missions. The coupling of a silicon based optical magnetometer with an on-chip light source using heterogeneous silicon photonics drastically minimizes device size, weight, and power (SWaP) while maintaining high performance magnetic field sensing. Benefitting from wafer-level fabrication, monolithically processed components allow for a sensing instrument with no moving parts which can be hardened to endure the harsh conditions of space missions. A heterogeneous Si/III-V laser eliminates the need for a bulky, external light source by coupling light directly into the optical magnetometer either via butt-coupling or directly integrated on-chip.

Phase I will prove the feasibility of a silicon optical magnetometer based on interferometric principles which can measure both magnitude and direction of a magnetic field. Studies on the sensitivity and range of the magnetometer will be completed and the design refined through high-fidelity simulations. A laboratory demonstration of a silicon photonics device with an external laser will prove the feasibility of the sensing mechanism and the approach for future system-on-chip fabrication. During Phase II, the team will fabricate a prototype silicon optical magnetometer coupled to a heterogeneously integrated silicon laser to demonstrate a lightweight, rugged, and miniature magnetometer device suitable for NASA scientific missions in space. A successful project will result in significant commercial potential and will advance the state-of-the-art of silicon photonics.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The silicon based optical magnetometer will address NASA needs for in situ and remote sensing on small spacecraft platforms where low size, weight, power and cost (SWaP-C) are critical. Coupled with a laser system-on-chip, the magnetometer can support NASA missions ranging from recording the varying strength and direction of a planet's magnetic field to analyzing magnetic properties of materials to determine their identity. The silicon fabrication process leverages CMOS manufacturing techniques to allow for miniaturization at reduced costs.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Optical magnetometers offer superior sensitivity, resolution, and precision, in addition to immunity to electromagnetic interference compared to traditional fluxgate sensors. Applications range widely, including detection of archaeological sites, directional drilling of oil, underwatering monitoring of

Duration: **13**

PROPOSAL NUMBER: 21-1- **T6.07-1224**

SUBTOPIC TITLE: Space Exploration Plant Growth

PROPOSAL TITLE: Visual AI for Controlled Environment Agriculture

Small Business Concern

Firm: **Bloomfield**
Address: **2026 E Carson Street, 2nd Floor, Pittsburgh, PA 15203 - 1969**
Phone: **(412) 414-5003**

Research Institution:

Name: **Carnegie Mellon University**
Address: **5000 Forbes Ave., PA 15213 - 3890**
Phone: **(412) 268-2000**

Principal Investigator:

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Phone: **(412) 414-5003**

Business Official:

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Phone: **(412) 965-9301**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

Crop inspection is as essential today as it was at the birth of agriculture. Then and now, growers move among the fields to visually inspect plants, identifying and assessing the presence of infection and disease, deficiencies in water and nutrients, impact of environmental factors, the timing of harvests and predicting the expected yield.

However, human inspection is subject to the limitations of human attention, varying levels of skill and knowledge, and the biases of the person doing the inspection. Bloomfield built Flash to allow specialty crop growers to inexpensively, easily and continuously inspect their crops, plant-by-plant, to gain the benefits of close inspection while reducing and eliminating the deficiencies of human inspection. To date, Bloomfield has inspected grapes in 12 vineyards across 4 states, with plans to inspect vineyards in the EU and apple orchards in the US and UK.

Bloomfield will adapt its' existing deep learning, camera-enabled, cloud-based plant assessment tool, Flash, to design and build a self-contained, computing at the edge variant for Controlled Environment Agriculture (CEA) to meet NASA's needs that will determine:

(1) Plant stresses and/or infestation
(2) Plant performance against expectations
(3) Recommendations for improving plant health and performance in the unique and challenging environment of space

These will require the achievement of three objectives:

(1) Prove continuous, precise, accurate and reliable deep learning image-based plant health and performance assessment works in CEA
(2) Prove a novel multi-spectral imaging tool also capable of capturing precise images for deep learning analysis
(3) Prove a plant inspection tool using multi-spectral imaging under controlled lighting conditions capable of functioning reliably and

continuously on the edge

This STTR provides Bloomfield with the opportunity to meet NASA's needs while advancing Bloomfield's product road map of providing value not just outdoors but also CEA.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Variations in ambient lighting make image-based AI difficult. But in CEA regulating the lighting solves this problem. Our camera will convert incident irradiant energy into discrete pixel values. Incident photons convert to electrical charges and quantize the analog signal to digital data. Utilizing LEDs in use on the ISS APH growth chamber for multi-spectral imaging is novel and a filter wheel on the camera will be synched with the in-situ growth LEDs and used as a flash to control the exposure and inspect for biotic and abiotic plant stress.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

An acute need exists in specialty crops – which require frequent and intensive inspection – to objectively, precisely and consistently provide actionable reporting on the health of every plant in real-time. The deep network detection pipelines, edge processing capacity and novel camera system developed here will be ideally suited and commercialized in specialty crops grown in CEA settings.

Duration: **12**

PROPOSAL NUMBER: 21-1- **T7.04-1573**

SUBTOPIC TITLE: Surface Construction

PROPOSAL TITLE: Structural Printing of Solar Melted Regolith

Small Business Concern

Firm: **Physical Sciences, Inc.**
Address: **20 New England Business Center , Andover, MA 01810 - 1077**
Phone: **(978) 689-0003**

Research Institution:

Name: **Massachusetts Institute of Technology**
Address: **77 Massachusetts Avenue, MA 02139 - 4307**
Phone: **(617) 253-3906**

Principal Investigator:

Name: **Dr. Richard Wainner**
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Business Official:

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Phone: **(978) 689-0003**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

Physical Sciences Inc., in collaboration with the Massachusetts Institute of Technology and Lios Design, proposes to investigate and develop a system to enable molten lunar regolith printing of structures to support human activities on the surface of the moon. In support of the greater "Moon to Mars" campaign and the lunar stepping stone Artemis project, NASA needs the capability for adaptable and efficient robotic construction of robust lunar base structures on the surface of the moon. The proposed approach completely

leverages *in situ* resource utilization (ISRU) for both power and construction materials. Various important structures, including landing pads, blast shields, roads and habitats will be constructed from direct solar sintering, melting, and 3D printing of lunar regolith. The concept takes advantage of recent technology developments in the delivery of concentrated solar power, as well as additive manufacturing (printing) with metal oxide (glassy) materials. The proposed Phase I project will address the specific challenges of merging these technologies into a viable construction tool on the surface of the moon. The outcomes of the effort will be detailed physical modeling of critical physical processes, (including experimental tests on regolith surrogate material), and the generation of a Phase II prototype design that can be built and tested on Earth for vetting of the manufacturing concept in ambient, and then lunar simulated, conditions. This project will advance the state of the art in both utilization of concentrated solar power, and "glass printing" using lunar raw materials. Technical success of the prototype, and follow-on lunar-specific robotic manufacturing platforms will provide an extremely versatile tool for structure fabrication in current and future planetary exploration campaigns.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The most important and near-term NASA mission and market for the technology proposed here is the Artemis project, which aims in its current timeline to put men and women back on the moon by 2024. Continued activity in the polar region of the moon in this effort encompasses the construction of a lunar base, comprising a variety of structures, ideally with as much ISRU as possible. Lessons learned in robotic fabrication in this environment will help guide the designs of next step goals of putting humans on Mars for extended periods.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Extension markets include: commercial terrestrial (remote e.g.) and space operations needing solar thermal power; additive manufacturing from local materials such as sand (military, humanitarian); versatile large-scale (architectural) construction from affordable and insulative materials; and small-scale construction with affordable and various glassy materials (research fabrications, art).

Duration: **9**

PROPOSAL NUMBER: 21-1- **T10.03-1622**

SUBTOPIC TITLE: Coordination and Control of Swarms of Space Vehicles

PROPOSAL TITLE: On-board Swarm Control for Autonomy and Responsiveness (OSCAR)

Small Business Concern

Firm: **Orbit Logic, Inc.**
Address: **7852 Walker Drive, Greenbelt, MD 20770 - 3208**
Phone: **(301) 982-6232**

Research Institution:

Name: **Regents of the University of Colorado**
Address: **3100 Marine Street, Room 450, CO 80303 - 1058**
Phone: **(303) 735-6738**

Principal Investigator:

Name: **Ken Center**
E-mail: **ken.center@orbitlogic.com**
Address: **7852 Walker Drive, MD 20770 - 3208**
Phone: **(240) 391-3310**

Business Official:

Name: **Ella Herz**
E-mail: **ella.herz@orbitlogic.com**
Address: **7852 Walker Drive, MD 20770 - 3208**
Phone: **(301) 982-6234**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

Orbit Logic is teamed with the University of Colorado (CU) to develop the On-board Swarm Control for Autonomy and Responsiveness (OSCAR) solution. OSCAR will leverage Orbit Logic's heritage Autonomous Planning System (APS) onboard planning/response framework and CU's heritage satellite formation flying and orbit control algorithms to develop a capability that will allow a swarm of planetary-orbiting satellites to dynamically adapt their configuration to accommodate varying mission needs. OSCAR will be capable of determining, planning and orchestrating the relative movement of each swarm element to meet a variety of needs, including "convoys" allowing events detected by leading satellites to trigger follow-up responses by following satellites, or single/multiple synthetic apertures enabling coordinated collection of space-resident or planetary surface data by multiple asset elements.

OSCAR will be validated and matured through simulation runs performed against the Basilisk Astrodynamics Framework, developed jointly by the University of Colorado AVS Lab and the Laboratory for Atmospheric and Space Physics (LASP). Basilisk will host models of satellite subsystem-oriented functionality representative of previously flown science and exploration missions. Runs will be performed on computing elements representative of contemporary satellite flight processors to confirm that the software solution is suitable for execution in constrained processing and memory environments.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

OSCAR will be highly applicable to exploration missions targeting Mars and the outer planets. Significant communication delays to and from Earth makes it essential that individual swarm assets coordinate with each other to maintain the orbits required to achieve mission objectives and to rapidly respond to emerging events that might be missed using a traditional mission control paradigm. OSCAR will allow operators to express mission objectives such as; seeking and tracking volcanic events, dust storms or weather features.
Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

OSCAR approaches are relevant to collaborating teams of commercial imaging satellites, autonomous air vehicles supporting ground survey or goods delivery, and underwater vehicles performing military missions (such as bottom survey and feature inspection) where changing/maintaining relative vehicle locations without collision are required.
Duration: **13**

PROPOSAL NUMBER: 21-1- **T11.04-1711**

SUBTOPIC TITLE: Digital Assistants for Science and Engineering

PROPOSAL TITLE: Augmented Intelligence & Cognitive Support Ecosystem (AICSE)

Small Business Concern

Firm: **STEM Resources**
Address: **1700 Main St #165874 , Little Rock, AR 72216 - 8001**
Phone: **(505) 369-6427**

Research Institution:

Name: **Fayetteville State University**
Address: **1200 Murchison Rd, NC 28301 -**
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Principal Investigator:

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Business Official:

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Phone: **(505) 369-6427**

Summary Details:

Estimated Technology Readiness Level (TRL) :
Begin: 1

End: 9
Technical Abstract (Limit 2000 characters, approximately 200 words):

Scientific discovery today depends as never before upon ease of access to data, associated sophisticated tools and applications, to enable research, education. Researchers who once worked in local, isolated laboratories now collaborate routinely and on a global scale.

Specialized instruments that werespread across multiple locations can now fit into a single lab connected via cyberinfrastructure resources and residing in big data. However, the sheer volume and heterogeneity of data bring a multitude of problems.

The primary intellectual merit of the proposed project comes from its vision of providing an augmented intelligence and cognitive support ecosystem (AICSE) assistants that enhances the capability of scholars and researcher in examining research topics, data and assists the user in understand its relevance to their goals. The expected result of this feasibility study will be a new resilient architecture for an agent-driven tool that is capable of ingesting any structured or unstructured data provided by the NASA and providing actionable insights. The project will produce a software design document or specification document that is composed of several layers that compass NASA-domain specific research areas . In particular the design will include, (1) a cross-platform user interface or agents, (2) natural language understanding functionality that maps tokens or words, sentences, paragraphs or documents to their respective meaning. As well as, produce document-specific sentiment, tone and intent information based on document corpuses. (3) Several open-source NLP models that can produce document-level or corpus themes, identifies relationships among themes and aggregate analysis. Also, the proof of concept, phase I effort will be limited to Google Scholar, because of its diverse research publication types, as well as the restricted timeframe of the project.
Potential NASA Applications (Limit 1500 characters, approximately 150 words):

This feasibility study will examine agent-driven technologies from the standpoint of low-level cognitive tasks , thereby, reducing the cognitive workload of its end-user around concepts and ideas within the corpuses. The expected result of this feasibility study will be a new resilient architecture for an agent-based research assist tool that is capable of ingesting any structured or unstructured data provided by the NASA staff and providing actionable insights.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The work in this project will form the foundation for possible smart artificial agents designed to provide mentoring services in diverse commercial areas, in terms of connecting diverse to resources, such as (1)social service benefits, like SNAP and Medicaid, (2) employment assistance, (3) education/job training, (4) housing, (5) mental, behavioral/ physical services (6) substance abuse treatment

Duration: **8**

PROPOSAL NUMBER: 21-1- **T10.03-1245**

SUBTOPIC TITLE: Coordination and Control of Swarms of Space Vehicles

PROPOSAL TITLE: Autonomous Swarming for Teams of Exploration Robots (ASTER)

Small Business Concern

Firm: **Charles River Analytics, Inc.**
Address: **625 Mount Auburn Street, Cambridge, MA 02138 - 4555**
Phone: **(617) 491-3474**

Research Institution:

Name: **Worcester Polytechnic Institute**
Address: **100 Institute Road, MA 01609 - 2280**
Phone: **(508) 831-6853**

Principal Investigator:

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Business Official:

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Phone: **(617) 491-3474**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

NASA will use swarms of robot vehicles for future planetary exploration, including Moon explorations in support of a sustained lunar presence. Advanced robotic and autonomous systems can overcome challenges inherent in navigating extreme terrain. Other tasks, such as obtaining mineral or ice samples from a wide area of a planetary surface or exploring terrain that blocks the transmission of signals to Earth or satellites (e.g., canyons, caves, lava tubes), lend themselves to robotic systems composed of multiple vehicles working in a coordinated fashion (i.e., multi-robot swarms). In addition to sharing work across the team, these swarms can adapt to changing exploration needs, and provide resiliency to failure of single vehicles while being scalable to accept additional vehicles when needed. Charles River Analytics and the Novel Engineering for Swarm Technologies (NEST) Laboratory at Worcester Polytechnic Institute will design and demonstrate Autonomous Swarming for Teams of Exploration Robots (ASTER). We introduce three compelling innovations to swarm systems: (1) the use of composable behavior primitives to achieve tasks and that can respond autonomously to unexpected situations; (2) the design of behavior primitives that use heterogeneous capabilities on swarm vehicles to achieve tasks; and (3) the design of behavior primitives that enable the swarm to manage faults as swarm vehicle capabilities degrade over time. ASTER will use three technologies: Charles River's Swarm Coordination Framework for rapid prototyping and analysis of behaviors, the Buzz swarm programming language for coordinating behaviors among physical robots, and the ARGoS multi-physics simulation engine. We will develop three scenarios consistent with NASA's Lunar Exploration Program Overview (September 2020), and perform thorough evaluations to support future research and transition opportunities. Our Phase I results will allow us to deploy this work on advanced hardware platforms in Phase II.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The innovations proposed under ASTER are relevant to the NASA Small Spacecraft Technology Program (SSTP) and the 2018 NASA Strategic Plan's focus on advanced robotic and autonomous systems. Plans to use Commercial Lunar Payload Services to return humans to the Moon and establish a sustained lunar presence will depend on exploring the lunar surface for resources necessary to maintain operations. Lessons learned from using robot swarms on the Moon will inform future voyages to planets (e.g., Mars) and asteroids.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The Army's Air Launched Effects (ALE) program, US Navy's RAIDER, DARPA's OFFSET, and work at other Government agencies will benefit from these innovations, as will commercial companies working with the Government (e.g., AeroVironment). The use of swarms in precision agriculture, commercial delivery systems, factory floor automation, and construction are other avenues we will pursue.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T6.07-2911**

SUBTOPIC TITLE: Space Exploration Plant Growth

PROPOSAL TITLE: Spectroscopic System for the Accurate Determination of [O2], [CO2], d18O-O2, and d13C-CO2 in Plant Chambers

Small Business Concern

Firm: **Nikira Labs Inc.**
Address: **1074 Wentworth St. Unit B, Mountain View, CA 94043 - 4629**
Phone: **(650) 906-0274**

Research Institution:

Name: **COLORADO STATE UNIVERSITY**
Address: **601 S Howes St, Ste 500, 2002 Campus Delivery , CO 80523 - 2002**
Phone: **(970) 491-6904**

Principal Investigator:

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Business Official:

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Phone: **(650) 906-0274**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

The National Aeronautics and Space Administration (NASA) has long studied plant growth in space for environmental management and food production aboard the International Space Station and future, extraplanetary human colonies. These studies have shown that microgravity impedes plant growth in a variety of ways, and NASA actively seeks new technologies to measure plant health in space as a function of externally controlled variables. In this Small Business Technology Transfer (STTR) program, Nikira Labs Inc. and Colorado State University (CSU) will collaborate to develop an analyzer that measures oxygen (O_2), carbon dioxide (CO_2), oxygen isotope ($d^{18}O$-O_2), and carbon isotope ($d^{13}C$-CO_2) fluxes in plant chambers for direct quantification of photosynthesis, respiration, and plant health.

In Phase I, Nikira Labs will develop and test a prototype analyzer to measure these key gases and their isotopes. After extensive laboratory testing to empirically determine its analytical performance, the unit will be deployed at Colorado State University to study gas fluxes from plant chambers. These plants will be subject to various stressors and the measured quantities will be directly correlated to an independent measure of photosynthetic efficiency to evaluate the STTR analyzers application for plant health monitoring. Finally, the Phase I results will be used to develop a Phase II instrument for application and delivery to NASA.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Growing plants in space has several advantages in life support systems. Plants can be used for future extraplanetary colonies and provide fresh vegetables for missions. Thus, NASA has developed plant growth chambers including the Advanced Plant Habitat. Researchers have found that plant growth in microgravity is impeded by several factors. In order to compensate for this, NASA must actively measure plant health. The STTR analyzer will provide a real-time measure of plant health, allowing for both active monitoring and control.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

In addition to its application in space-based programs, the proposed system can also be used for research and wastewater management. A preliminary market analysis suggests a cumulative 5-year revenue of $29M - $48M from these two markets alone.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T10.04-2457**

SUBTOPIC TITLE: Autonomous Systems and Operations for the Lunar Orbital Platform-Gateway

PROPOSAL TITLE: Lunar FLAPPER

Small Business Concern

Firm: **Orbit Logic, Inc.**
Address: **7852 Walker Drive, Greenbelt, MD 20770 - 3208**
Phone: **(301) 982-6232**

Research Institution:

Name: **University of Maryland**
Address: **7809 Regents Drive, 3112 Lee Bldg., MD 20742 -**
Phone: **(301) 405-8108**

Principal Investigator:

Name: **Kenneth Center**

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Address: **7852 Walker Drive, 20770 - 3208**
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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

Orbit Logic (OL) and the University of Maryland College Park (UMd) are teaming to develop a machine learning solution, Lunar FLAPPER (Fault Learning Agent for Prediction, Protection and Early Response), that is able to operate in two modes: 1) a fully autonomous operations monitoring mode with fault detection, correction and reporting, and 2) a semi-autonomous mode, which can request approval for corrective actions and which can utilize human (ground operator) inputs to learn ideal operating conditions through positive re-enforcements of solution selections. OL will be leveraging and extending the work of our original FLAPPER SBIR research initiative to include operator in-the-loop training. We will enhance our already mature Autonomous Planning System (APS) product by adding Specialized Autonomous Planning Agents (SAPAs) to accommodate these new use cases.

The end-vision includes both ground- and space-resident software components and tools. Lunar FLAPPER infrastructure on the ground will integrate with emulation, simulation, and real hardware instances to interact with mission data sources (telemetry and commands) - then observe data activity when mission operational scenarios are executed. Machine Learning (ML) techniques (already prototyped in previous NASA-funded efforts) will be utilized to learn what constitutes both nominal and off-nominal system behaviors, building both a library of “detection kernels” (usable to recognize and characterize anomalous behavior) and a library of appropriate responses to correct faults and restore nominal operations. The goal is an eventual transition to as much onboard autonomy and fault management as possible, such that the station and all of its onboard systems are fully sustained with minimal or no intervention from Earth-based operators when it is not inhabited.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Space stations and habitats such as the proposed Lunar Gateway. Any space mission where human operators directly interact with system capabilities and a path is desired to reduce operator workload by training autonomy to perform missions and resolve faults autonomously, including Earth-orbiting single satellites and constellations, inter-planetary missions, or planetary orbiting/exploration missions. Systems involving autonomously acting drones or surface robots, with or without humans in-the-loop.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Collaborative Earth observing satellite constellations, coordinated space/ground sensor systems supporting enhanced space situational awareness, coordination of data chain orchestration for data analytics, collaborative autonomous maritime (surface and underwater) missions, coordination of teams of ground orbits and/or air vehicles for science, search/rescue.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T14.01-2398**

SUBTOPIC TITLE: Advanced Concepts for Lunar and Martian Propellant Production, Storage, Transfer, and Usage

PROPOSAL TITLE: Robust and Reversible Metal Supported Solid Oxide Cells for Lunar and Martian Applications

Small Business Concern

Firm: **NexTech Materials, Ltd.**
Address: **404 Enterprise Drive, Lewis Center, OH 43035 - 9423**
Phone: **(614) 842-6606**

Research Institution:

Name: **Washington State University**
Address: **PO Box 641060, Lighty 280, WA 99164 - 1060**
Phone: **(509) 335-9661**

Principal Investigator:

Name: **Dr. Emir Dogdibegovic Ph.D.**
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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

To support NASA's challenging space exploration goals for the next few decades, reliable power generation and energy storage technologies are needed. NASA is considering multiple approaches for using residual propellants from space travel or those generated via In-Situ Resource Utilization technologies for onsite power generation on the Moon and Mars. Solid oxide cells are well suited for NASA's applications due to their high efficiency and performance, ability to operate reversibly in power generation and electrolysis modes, and flexibility to operate at wide temperature ranges with a variety of fuels. However, traditional cell architectures are limited in their ability to recover from high slew rates and rapid thermal changes and electrolyte hermeticity often suffers.

Metal-supported solid oxide cells (MSCs) are a game-changing technology for NASA. With a thin ceramic electrolyte enabling high electrochemical performance and porous metal supports providing unprecedented mechanical robustness, MSCs are well-suited for environments with high fluid pressures and vibration loads and extreme thermal changes. Nexceris' MSC technology has been demonstrated to meet NASA current density targets at atmospheric conditions and has been scaled to large active areas without performance losses. In this Phase I STTR project Nexceris will work with Washington State University to demonstrate the capabilities of its highly robust and reversible planar MSCs under pressure and with pure oxygen.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Metal-supported solid oxide cells have the potential to meet multiple needs for NASA's missions to the Moon during the Artemis program and future exploration of Mars. MSCs can use residual propellants (cryogenically stored oxygen and methane) to generate power for lunar landers, exploration rovers and life support technologies. The electrolysis capabilities of MSCs may be used for in-situ resource utilization by providing oxygen for life support and generating additional propellants from existing mineral resources.
Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The technology developed in this project will be directly applicable to unmanned underwater vehicle applications for the Navy. With the focus on robustness, power density, and rapid cycling capability, MSCs will also add considerable value for aviation applications and multiple nearer term applications, including portable power sources, military power systems, and automotive range extenders.
Duration: **9**

PROPOSAL NUMBER: 21-1- **T11.05-1297**

SUBTOPIC TITLE: Model-Based Enterprise

PROPOSAL TITLE: T11.05

Small Business Concern

Firm: **Global Technology Connection, Inc.**
Address: **2839 Paces Ferry Road, Suite 1160, Atlanta, GA 30339 - 5770**
Phone: **(770) 803-3001**

Research Institution:

Name: **Georgia Institute of Technology-Main Campus**
Address: **225 North Ave, GA 30332 -**
Phone: **(404) 894-8055**

Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

Global Technology Connection, Inc. and its university partners propose a structured, model-based approach to the definition and development of Institutional Management Digital Twins that is guided by architectural and Model-Based Systems Engineering (MBSE) practices and principles. The proposed technical approach identifies a series of steps aimed at guiding engineers through such digital twin development tasks. Such capability would provide multiple benefits including having optimal level and granularity of information and better problem understanding for critical decision making, model and knowledge reuse to reduce digital twin development time frames, improved operations, communication, and collaboration among several stakeholders. In Phase I, we will identify users and use cases, scope and context, data sources and types, modeling needs and its details, and the final product and its views. Access to ongoing Digital Twin proof-of-concept studies and the team's breadth of experience in modeling languages like SysML and MBSE solutions in the field of Digital Twin Institutional Management to support Health/Automated Decision Making at multiple scales across buildings and campuses will be leveraged in this effort. In phase II, we will expand on the Phase I developed Digital Twin architectures to develop commercial level prototypes and apply them on identified industry/partner's buildings.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

NASA's infrastructure and buildings across multiple campuses vary in age, technological capabilities, and connectivity. The proposed technical approach identifies a series of steps aimed at guiding engineers through digital twin development tasks. This provides benefits including having optimal information for critical decision making, enabling model reuse to reduce development costs, and improved operations. Building management tools result in identifying, prioritizing, and achieving significant cost savings across NASA campuses.
Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The cost savings and operational benefits of Institutional Management Digital Twins is universal. Due to the flexible nature of our technology that utilizes architectural and MBSE practices and principles, digital twins for non-NASA government and private facilities can be easily developed and implemented to minimize inefficiencies and improve operations.
Duration: **12**

PROPOSAL NUMBER: 21-1- **T5.05-2304**

SUBTOPIC TITLE: Solar and Electric Sail Embedded Technologies for Communications, Control, or Ancillary Functions

PROPOSAL TITLE: Embedded Fiber-Optic Sensing for Solar and Electric Sails

Small Business Concern

Firm: **Luna Innovations, Inc.**
Address: **301 1st Street Southwest, Suite 200, Roanoke, VA 24011 - 1921**
Phone: **(540) 769-8400**

Research Institution:

Name: **The University of Alabama in Huntsville**
Address: **301 Sparkman Drive, VBRH E26, AL 35899 - 0001**
Phone: **(256) 824-2651**

Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

Luna, teamed with Ms. Sue O'Brien at The University of Alabama Huntsville, is proposing to utilize High-Definition Shape Sensing (HD-Shape) to optimize the control of solar and electric sails. Solar and electric sails use lightweight material with large cross-sections to transfer momentum of solar radiation into directional thrust. Control is performed by adjusting the center of mass (CM) with respect to the center of pressure (CP). Utilizing the technology proposed here, the shape of a sail can be controlled using feedback regarding its actual position to align CM and CP and achieve the desired direction of thrust. HD-Shape enables the position and orientation of a multi-core optical fiber to be measured independent of the structure it is attached to, with the advantage of being immune to the electromagnetic and radiation environment present in space. During Phase I the team will demonstrate boom arm curvature measurements for providing active feedback to boom controls systems and begin designing an architecture for a low mass, low power system suitable for space deployment. Phase II will begin prototyping the electronics resulting in a system that can be tested by NASA.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed solution will provide NASA with solar and electric sail embedded fiber-optic sensors for control and ancillary functions. The fiber system used to measure curvature in this Phase I is expected to be advanced to provide full 3-D shape along the fiber length for Phase II. This technology has many applications for NASA in tether management and endpoint identification for marsupial robots, non-destructive inspection, and human space walks.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Under water tethered diving for both divers and unmanned underwater vehicles.

Tether management and endpoint identification for marsupial robots.

End point identification for automation of non-destructive inspection systems
Duration: **12**

PROPOSAL NUMBER: 21-1- **T12.05-3097**

SUBTOPIC TITLE: Use of Additive Manufacturing for Thermal Protection Systems

PROPOSAL TITLE: 3D Printing of High Temperature Thermoset Foams for Space Vehicular Thermal Protection Systems

Small Business Concern

Firm: **RE3D Inc**
Address: **1100 Hercules Ave, Suite 220, Houston, TX 77058 - 2758**
Phone: **(512) 730-0033**

Research Institution:

Name: **The University of Tennessee-Knoxville**
Address: **201 Dougherty Engineering Building 1512 Middle Drive, TN 37996 -**
Phone: **(865) 974-8006**

Principal Investigator:

Name: **Matthew Fiedler**
E-mail: **matthew@re3d.org**
Address: **1100 Hercules Ave, Suite 220, TX 77058 - 2758**
Phone: **(832) 305-5293**

Business Official:

Name: **Michael Strong**
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Address: **1100 Hercules Ave, Suite 220, TX 77058 - 2758**
Phone: **(732) 580-8754**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

We propose to create an open-source modification of our commercially available, affordable, industrial 3D printer, and in conjunction develop printable, high temperature hybrid thermoset (HT^2) materials in partnership with the University of Tennessee at Knoxville (UTK) during this Phase 1 NASA/STTR.

In addition to additive manufacturing's (AM) benefits of low-cost prototyping, efficient low volume manufacturing, and unparalleled ability to create complex geometries, utilizing the Gigabot platform offers scalability as research progresses to enable affordable and large-scale printing of TPS. The methodology proposed will have the potential of expanding the thermoset extrusion material library and significantly decrease the time spent on previous TPS systems.

In collaboration between re:3D and UTK, HT^2 Materials will be developed, and 3D printed with the target application of TPS for space vehicles. The TPS materials and methods will allow for optimum performance of extreme materials, making it possible to print them in more complex and contoured geometries to enable maximum heat shielding performance in space vehicular applications in launch and recovery. This will involve the formulation of a three-phase, low-density, epoxy-polysilazane based syntactic foam, including high-alumina cenospheres and nanoclay reinforcement. The optimum material formulation will be paired with the CNC controlled movement of an extrusion head to enable tailored density and porosity control coupled with long pot life and several curing options to meet post-processing constraints. Various geometries will then be tested to demonstrate the optimized 3D printing parameters and resolution. The various parts that will be designed and fabricated will then be tested for their thermo-mechanical properties, extreme heat and flame resistance, and charring and ablation properties.
Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The development of a variety of termoset materials capable of withstanding the rigors of space for use in TPS creation. The ability to use open-source additive manufacturing tools for the creation of tool-path algorithms, for printing directly onto the face of three dimensional objects for the creation of TPS. Time and Money savings from using additive manufacturing for TPS creation. Scalability of the solution as the project progresses to incorporate large build/surface areas.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Private-commercial space industry is growing exponentially, and TPS creation through Additive Manufacturing, would prove to be useful for customers in this sector. TPS creation could be useful to other space agencies and DoD partners. There are also a whole host of opportunities to learn more within the R&D effort for technologies to be incorporated into future iterations of re:3D's 3D printers.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T8.06-2455**

SUBTOPIC TITLE: Quantum Sensing and Measurement

PROPOSAL TITLE: Quantum Light Source for On-Site Detector Calibration

Small Business Concern

Firm: **Qubitekk**
Address: **1400 Norris Road, Bakersfield, CA 93308 - 2232**
Phone: **(760) 599-5100**

Research Institution:

Name: **University of New Mexico-Main Campus**
Address: **1700 Lomas Blvd NE, NM 87131 - 0001**
Phone: **(505) 277-0810**

Principal Investigator:

Name: **Dr. Duncan Earl**
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Business Official:

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Phone: **(760) 599-5104**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

Ongoing R&D into quantum computing, quantum communications, and quantum networking solutions requires optical detectors that can detect a single photon with high efficiency. For many experiments, it is critical to know the precise detection efficiency of these detectors. Calibrating these detectors is currently a challenge as these detector are often large, complex, and fragile and must be shipped to a calibration facility for measurement. We propose an alternate method of detector calibration that permits on-site detector calibration using a small, rugged quantum bi-photon source. These bi-photon sources can be used with a calibration method previously reported and demonstrated by NIST (the Klyshko method).

As part of our proposed Phase I project, a proof-of-principle demonstration of the Klyshko calibration method will be implemented using a commercial-off-the-shelf (COTS) bi-photon source offered by Qubitekk. The calibration accuracy achievable with this non-optimized COTS source will be demonstrated and documented. This COTS source design will then serve as the starting point for an optimized, enhanced stability, prototype bi-photon source for on-site detector calibration. The performance improvements of this prototype source design will be estimated through optical modeling and experimental measurements and compared against the COTS source specs and testing data. The suitability of the prototype for various environments (both space-based and terrestrial) will be evaluated through modeling and comparison with prior testing data. The ability of the prototype source to characterize SPD efficiency across a broad wavelength spectrum will be evaluated and any spectral gaps or range limitations identified. The design and anticipated performance improvements related to this prototype, optimized bi-photon source will be detailed in the project's final report and its construction and testing proposed as part of any follow-on Phase II effort.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed technology has applications related to the NASA mission, including secure satellite communication networks, deep space laser communications (using terrestrial single photon counting arrays), quantum sensors for atmospheric measurements, and a large number of applications enabled by quantum computers. The proposed technology is in direct response to NASA STTR solicitation and its request for quantum sources "needed for system calibration of single-photon counting detectors and energy-resolving single-photon detector arrays."

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed technology has wide application across the emerging quantum technology markets. These markets - which consist of products related to quantum computing, quantum communications, and quantum sensing solutions – have seen rapid growth over the past decade. The largest of these non-NASA applications include cybersecurity for critical infrastructure and quantum computing for data mining.

Duration: **9**

PROPOSAL NUMBER: 21-1- **T14.01-1649**

SUBTOPIC TITLE: Advanced Concepts for Lunar and Martian Propellant Production, Storage, Transfer, and Usage

PROPOSAL TITLE: Continuous Correlations for Complete Boiling Curves of Cryogenic Fluids

Small Business Concern

Firm: **Creare, LLC**
Address: **16 Great Hollow Road, Hanover, NH 03755 - 3116**
Phone: **(603) 643-3800**

Research Institution:

Name: **Case Western Reserve University**
Address: **10900 Euclid Ave., OH 44106 - 7015**
Phone: **(216) 368-2000**

Principal Investigator:

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Phone: **(603) 640-2405**

Business Official:

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Phone: **(603) 640-2487**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

Future space exploration missions will rely on in situ production, storage, and transfer of cryogenic rocket propellants. Engineers need accurate and efficient modeling tools to design the next generation of lightweight, efficient cryogenic propellant management devices and processes. Predictive models for key fluid dynamics and heat transfer behavior must be tailored for use with cryogenic propellants and easily implemented in existing modeling frameworks. We propose to develop a suite of pool boiling correlations developed specifically for common cryogenic fluids and propellants, including hydrogen, oxygen, and methane. We will create a database of existing cryogen pool boiling data from the literature and augment it with new data collected from our cryogenic pool boiling test apparatus. In Phase I, we will focus on pool boiling critical heat flux and demonstrate our approach to database generation, experimental pool boiling data collection, and correlation optimization. In Phase II, we will produce new data and correlations that are piecewise smooth across all pool boiling regimes.
Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Improved pool boiling correlations tailored for cryogenic fluids will help with design of propellant tanks to minimize chilldown times and minimize liquid venting during propellant fill. They will also help model propellant boiloff due to static heat gain during operations. Outside of propellant management, our correlations may be used in design of low-temperature cooling systems for use with electronics or science instruments.
Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Cryogenic fluid management is also important for directed-energy weapons cooling and liquid natural gas production and transport. Our pool boiling heat transfer correlations will be useful in designing these systems.
Duration: **13**

PROPOSAL NUMBER: 21-1- **T7.04-2835**

SUBTOPIC TITLE: Surface Construction

PROPOSAL TITLE: Low-Energy Additive Construction for the Moon and Mars

Small Business Concern

Firm: **Masten Space Systems, Inc.**
Address: **1570 Sabovich Street, Mojave, CA 93501 - 1681**
Phone: **(888) 488-8455**

Research Institution:

Name: **Pacific International Space Center for Exploration Systems (PISCES)**
Address: **99 Aupuni St. Ste 212-213, HI 96720 - 4273**
Phone: **(808) 896-6550**

Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

Dust mitigation on the lunar surface is an early priority for permanent or long-term lunar and Martian outposts. The physical characteristics of regolith on the lunar surface, along with its lack of an atmosphere and low gravity make the fine particles a hazard for equipment and operations on the moon. Mars presents similar hazards with its low-pressure atmosphere and reduced gravity. Regolith ejected from landers upon landing or taking off represent the highest risk due to the high exhaust velocities.
To mitigate high-velocity regolith from being ejected into adjacent areas, landing and launch pads require surface stabilization. Due to the large mass required and high payload costs, methods that incorporate ISRU have the potential to present a lower-cost and more efficient option for planetary construction.
Past work by PISCES, in conjunction with NASA SwampWorks and Honeybee robotics, has focused on sintering basalt without binders. This method has proven successful, but the high energy and the need for consumable high-temperature molds would incur substantial energy and payload costs.
Recent work done by PISCES evaluated the use of a binder in an aqueous solution that eliminates the problem of high energy input required for the process. The use of this binder has allowed for a reduction of the sintering temperature of the basalt, but most importantly, it cures into a structurally viable material under a vacuum and in CO_2. This can be a game changer that allows for the regolith binder mix to be used in additive construction operations without the need for additional heat or consumable molds.
This proposal leverages Masten Space Systems' work on the effects of PSI on surface erosion with their hot plume sample interaction testing and PISCES' work on basalt-binder composites.
This proposal will advance and validate this novel binder-regolith composite for surface construction and develop an effective composite extruder for the relevant environments.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed innovation addresses a number of NASA objectives.This proposal addresses several technologies relevant to NASA as outlined in the 2020 NASA Technology Taxonomy. The process fits within TX07.2.3 Surface Construction and Assembly. Additionally, this proposal directly addresses TX13.4.6 Ground Analogs for Space/Surface Systems, touches upon TX12.1.4 Materials for Extreme Environments, and SKG Theme 3. The primary use would be for the Artemis program supporting human landings.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Potential non-NASA markets include lunar and Martian infrastructure for commercial providers, , non-terrestrial production of heat shields and radiation shielding. Potential terrestrial markets are tiles and countertops, and as a sintered product, refractory tiles for launch pads and furnaces.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T11.05-1182**

SUBTOPIC TITLE: Model-Based Enterprise

PROPOSAL TITLE: Model-based Intelligent Decisions for Higher Innovation Value and Efficiency (MINDHIVE)

Small Business Concern

Firm: **EdgeDweller Inc**
Address: **1917 E. Wildcat Rd., Clarkesville, GA 30523 - 0359**
Phone: **(404) 310-4214**

Research Institution:

Name: **Georgia Tech Research Corporation (GTRC)**
Address: **926 Dalney St NW, GA 30332 - 0420**
Phone: **(404) 385-2080**

Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

Through many applications of EdgeDweller's (EDI) Intentional Innovation® (II) problem-solving process, a core insight was discovered: **When organizations concurrently evaluate multiple challenges they are facing regarding their impact on organizational strategic goals *in addition to* the technical requirements for an improved process, product or service, they develop and implement more efficient, effective solutions to the challenges.**

EDI will prove that a decision-making hierarchy which starts at the agency level and permeates the entire organization to the tech. efficiency level, will produce higher value results for NASA's FRED than decision-making that is limited to the tech. efficiency level.

Project MINDHIVE integrates multiple technologies and methods to create a SaaS solution that enhances NASA's ability to manage decisions across multiple levels and functional domains of the agency, including FRED. MINDHIVE builds on prior EDI projects with NASA where we linked these hierarchies to our II® process to significantly increase the value of new solutions and reduce solution concept-to-use case time to 3.5 months.

In order to deliver FRED insights at tech. levels requested, we have assembled an informal consortium of experts with backgrounds in Decision Intelligence, AI, Machine Learning, Digital Twin models, and NASA Facilities management. We will apply this decision model to FRED, simulating the impact of different solutions to clearly demonstrate variations in value and performance.

We will use this Phase 1 contract to show how this approach can yield;

- Higher performing future states

- Reduced risk through solutions that evolve over a series of multi-level assessments with milestone launches from the current to future state
- Higher performance at multiple levels (agency, mission directorate, program, tech.)
- Longer lasting performance through technical solutions designed to evolve over time
- Rapid deployment of solutions agency-wide where applicable.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

NASA Applications - Multi-Level Decision Support to Advance Missions, Enhance Technical Effectiveness, Advance Innovation Adoption:

-Mission Directorates - With SaaS need to integrate multi-level decisions hierarchies at agency, mission directorate, program and technology levels
-Mission Directorates seeking to evaluate nascent technologies
-Artemis and future extraterrestrial facilities
-Continued NASA HQ Innovation Ecosystem support
-HQ Digital Transformation support

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Priority Non-NASA Addressable Markets Include:

-Other government agencies with similar facilities management challenges (Ex. DoD, USAF, DARPA, NSF, GSA)
-Selective Companies in the Aerospace Industry
-Selective Healthy Building Targets
-EdgeDweller Client Targets
-Healthcare
-Fortune 1000s in Banking, Financial Services, Insurance (BSFI)

Duration: **13**

PROPOSAL NUMBER: 21-1- **T10.04-2151**

SUBTOPIC TITLE: Autonomous Systems and Operations for the Lunar Orbital Platform-Gateway

PROPOSAL TITLE: HEART - Habitat ECLSS Analytics for Resilience Tool for Real Time Habitability Management

Small Business Concern

Firm: **Space Lab Technologies, LLC**
Address: **5455 Spine Road, Suite ME, Boulder, CO 80301 - 3312**
Phone: **(720) 745-9321**

Research Institution:

Name: **Regents of the University of Colorado**
Address: **3100 Marine Street, Room 481, 572 UCB, CO 80309 - 0001**
Phone: **(303) 735-6692**

Principal Investigator:

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Business Official:

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Phone: **(720) 309-8475**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

HEART (Habitat ECLSS Analytics for Resilience Tool) is an environmental health monitoring platform that addresses the need for autonomous technologies to manage space habitats. Spacecraft crew on deep space exploration missions will need to manage, plan, and execute a mission independently of mission control on Earth, because of communication time lags or outages. Due to complexity of spacecraft systems, operations management will be prohibitively time consuming and computationally intensive. Off-nominal events may occur that limit crew activity or capacity. Furthermore, space habitats like Lunar Gateway may operate without crew for weeks, months, or even years at a time, necessitating autonomous operations. When a space habitat is unoccupied, unexpected events may require immediate autonomous detection and response. HEART assesses ECLSS robustness in real time for autonomous habitat health management. It provides state estimation, model-based anomaly detection, prioritized anomaly reporting, and managed transitions to different operating modes (dormant, quiescent, and active) in space habitats like Lunar Gateway. The benefits of HEART over state-of-the-art ECLSS health management applications include improved situational awareness, model-based anomaly detection for dynamic systems, early degradation detection, risk assessment for prioritized reporting, state transition readiness, and adaptability. This Phase I project will show proof of concept for the enabling functions of HEART. In support of NASA's priorities for sustained human exploration of deep space the HEART concept will be a major step towards autonomous systems that enable spacecraft operation independent of Earth-based mission control. The design will be readily transferable to terrestrial applications, including management of any complex controlled environment supporting life forms, such as submarines, plant growth chambers, greenhouses, or even biomanufacturing facilities.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

HEART will be an asset for autonomous operations in space habitats envisioned by NASA for deep space exploration, such as Lunar Gateway, lunar surface habitats, Mars transit vehicles, or Mars surface habitats. HEART has the potential for infusion into the Advanced Exploration Systems program under the Human Exploration and Operations Mission Directorate (HEOMD) including the habitations systems and foundational systems domains, especially the Autonomous Systems and Operations project.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

HEART can provide autonomous environmental health management for any complex controlled environment supporting life forms, including human spacecraft and space habitats, space suits, deep space diving suits, submarines, underwater habitats, smart greenhouses, or even microbial reactors used for bio manufacturing processes.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T15.04-1416**

SUBTOPIC TITLE: Full-Scale (2+ Passenger) Electric Vertical Takeoff and Landing (eVTOL) Scaling, Performance, Aerodynamics, and Acoustics Investigations

PROPOSAL TITLE: Full-Scale eVTOL Aircraft Performance and Aeroacoustic Test, Evaluation, and Modeling

Small Business Concern

Firm: **Continuum Dynamics, Inc.**
Address: **34 Lexington Avenue, Ewing, NJ 08618 - 2302**
Phone: **(609) 538-0444**

Research Institution:

Name: **Pennsylvania State University**
Address: **233D Hammond Building, PA 16802 -**
Phone: **(814) 865-6433**

Principal Investigator:

Name: **Dr. Todd Quackenbush**
E-mail: **todd@continuum-dynamics.com**
Address: **34 Lexington Avenue, NJ 08618 - 2302**
Phone: **(609) 538-0444**

Business Official:

Name: **Ms. Melissa Kinney**
E-mail: **melissa@continuum-dynamics.com**
Address: **34 Lexington Avenue, NJ 08618 - 2302**

Phone: **(609) 538-0444**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 4
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

The recent upsurge in development and prospective applications of Electric Vertical Takeoff and Landing (eVTOL) vehicles has the potential to transform the landscape for vertical flight. Among the several classes of aircraft under development for projected Advanced Air Mobility (AAM) missions and activity are vehicles with distributed multiple-rotor systems. Such multicopters offer potential benefits in simplified flight control, redundancy, and conversion between vertical lift and forward flight. However, multirotor systems pose considerable design challenges in terms of quantifying the effect of rotor-rotor interactions on integrated performance, rotor/airframe interactional aerodynamics, flight mechanics, vibratory loads, and noise. Computational models exist that can analyze these vehicles, however high-quality, full-scale experimental data to validate these models is not currently available. To address this need, NASA is seeking design and execution of experiments on multrotor VTOL systems that would generate data suitable for validating aerodynamic and acoustic analyses of full-scale multicopter systems. The proposed collaborative STTR effort will address this need by providing both a computational model and a body of aerodynamic data for a full scale multirotor eVTOL aircraft with an initial tranche of full-scale performance modeling, simulation and test data to be provided in Phase I. An ambitious timeline is proposed by leveraging the advanced state of development of models and resources available to the proposing team, including both a full-scale multicopter that has already undergone low altitude hover flight tests and industry-standard modeling and analysis software currently in use by NASA and eVTOL AAM aircraft developers performing vehicle concept evaluation, analysis and design.
Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed research effort will provide performance, aerodynamics and acoustics flight test data and computational modeling for full-scale eVTOL AAM multicopters, directly supporting NASA's ARMD Strategic Thrust 4: Safe, Quiet, and Affordable Vertical Lift Air Vehicles by addressing the increasing demand for knowledge about how to design, build and fly these types of vehicles. The test data obtained in this effort helps fill a vital, missing link impeding the progress of those at NASA and in industry developing eVTOL AAM vehicles.
Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

CDI provides engineering services and analysis software to numerous eVTOL AAM air taxi vehicle developers. The test data and analysis enhancements produced will be instrumental to the success of this new generation of entrepreneurial organizations who have an immediate need for the proposed full-scale, flight test data and the improved modeling and analysis it will engender.
Duration: **13**

PROPOSAL NUMBER: 21-1- **T6.07-2266**

SUBTOPIC TITLE: Space Exploration Plant Growth

PROPOSAL TITLE: A Smart Spectral Polarimetric Imager for Autonomous Plant Health Monitoring

Small Business Concern

Firm: **Space Lab Technologies, LLC**
Address: **5455 Spine Road, Suite ME, Boulder, CO 80301 - 3312**
Phone: **(720) 745-9321**

Research Institution:

Name: **University of Florida**
Address: **207 Grinter Hall, PO Box 115500, FL 32611 - 5500**
Phone: **(352) 392-9267**

Principal Investigator:

Name: **Adam Escobar**
E-mail: **adam@spacelabtech.com**
Address: **5455 Spine Rd, Ste ME, CO 80301 - 3312**
Phone: **(720) 309-8475**

Business Official:

Name: **Christine Escobar**
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Phone: **(720) 309-8475**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

For future long-duration space exploration missions, NASA expressed the need for plant systems that may provide a nutrient dense supplement to crew diet and possibly other life support functions, such as CO2 removal, O2 production, water recovery, and waste recycling. Current and future infrastructure for plant growth include chambers with controlled environments. To ensure optimal growing conditions in these chambers, the plants will require precise monitoring of health throughout the plant life cycle. These monitoring systems will need to operate autonomously with little crew involvement. Current plant monitoring instruments include multispectral and hyperspectral sensing that require post-process algorithms to detect physiological phenomena. Space Lab Technologies (Space Lab) and the Space Plants Lab at the University of Florida (UF) propose an improved approach for monitoring space plant health using a smart spectral polarimetric imager to monitor morphological features and stresses. The Phase I work investigates not only sensing bandlimited reflectance as do current space plant imagers, but also study the polarization flux reflected from the plant surfaces. The polarization information conveys electric field direction of the reflected light. Spectral polarization studies of plants are an emerging method for plant health monitoring with related published works within the past few years. The proposed innovation expands upon this current research, where the biological and physical science for plant spectral polarimetry is still being researched. In addition to spectral polarization imaging, real-time image processing using digital signal processing techniques within the on-board FPGA provide autonomous plant health monitoring. Combining the use of spectrum, polarization, and real-time image processing in instrumentation enables optimal control for producing healthy plants or crops for space exploration.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

- Plant Health Monitoring in Space Habitats
- Space Crops Food Safety
- Spacecraft Structural Stress or Fracture Detection
- Remote Sensing of Earth
- Planetary Science
- Photosynthetic Microbe Detection

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

- Agriculture - Crop Health
- Controlled Environment Agriculture
- Food Processing and Safety
- Mechanical Stress and Fracture Detection
- Industrial Process Monitoring
- Photosynthetic Microbe Life Detection
- Research Polarized Spectrometer

Duration: **13**

PROPOSAL NUMBER: 21-1- **T7.04-1428**

SUBTOPIC TITLE: Surface Construction

PROPOSAL TITLE: Induction Furnace-Nozzle for Forming and Placing Lunar Regolith Bricks for Landing Pad Construction

Small Business Concern

Firm: **Astroport Space Technologies, Inc.**
Address: **110 E. Houston Street, 7th Floor, San Antonio, TX 78205 - 2990**
Phone: **(210) 404-2981**

Research Institution:

Name: **The University of Texas at San Antonio**
Address: **One UTSA Circle, TX 78249 - 1644**
Phone: **(210) 458-6472**

Principal Investigator:

Name: **Sam Ximenes**
E-mail: **info@explorationarchitecture.com**
Address: **110 E. Houston Street, 7th Floor, TX 78205 - 2990**
Phone: **(210) 404-2981**

Business Official:

Name: **Sam Ximenes**
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Phone: **(210) 404-2981**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

Proposed is an integrated induction furnace and nozzle for in-situ 3D printing and landing pad construction using lunar regolith. Through applied research, we combine two elements into one "innovation":

- The furnace element uses an induction heater for reducing regolith feedstock into a fluid melt, which can be applied to a variety of solidification applications.
  - Inductin heater advancements include automatic frequency tuning to the composition and properties of the feedstock.
- The nozzle element enables single-step lunar regolith melting, brick production and placement for landing pad creation or any flat hardened surface area such as roads or foundations.

Our proposed solution is based on the principles of additive construction processing in-situ materials (regolith) into construction bricks. At the system level, basic components include a 3D printer using an Induction Furnace-Nozzle mounted onto a mobility platform for single step brick production and placement. The applied research focus for this proposal is on integration of the induction furnace and nozzle (an Induction Furnace-Nozzle) for regolith brick production.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

- Lunar landing pad construction
- Lunar road and berm construction
- Lunar dust mitigation
- Planetary infrastucture foundational elements

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Technology has the potential to be utilized for low cost & rapid construction on earth (IP & operational know-how; material processing; assembly automation; remote operations). In-situ resource utilization of locally sourced material could have potential terrestrial applications, for low cost housing for low income indigenous housing and/or next-gen, ecological advanced construction applications.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T8.07-1939**

SUBTOPIC TITLE: Photonic Integrated Circuits

PROPOSAL TITLE: High-Performance On-chip Spectrometer for Space Applications

Small Business Concern

Firm: **LyteChip Inc.**
Address: **292 Nevada St., Newton, MA 02460 - 1458**
Phone: **(302) 563-5402**

Research Institution:

Name: **Massachusetts Institute of Technology**

Address: **77 Massachusetts Ave Rm 13-4054, MA 02139 -**
Phone: **(302) 766-3083**

Principal Investigator:

Name: **Dr. Tian Gu**
E-mail: **gutian@lytechip.com**
Address: **292 Nevada St., MA 02460 - 1458**
Phone: **(302) 563-5402**

Business Official:

Name: **Dr. Tian Gu**
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Phone: **(302) 563-5402**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

We aim to pioneer a high-performance on-chip infrared spectrometer in response to Topic T8.07 Photonic Integrated Circuits (PIC). The technology will directly address space applications such as surface and atmospheric analysis on CubeSats and planetary landers, mineralogy, monitoring of volatile organic compound contaminants in spacecraft cabin atmospheres, and point-of-care diagnostics for astronauts, etc.

Miniaturized spectrometers are highly demanded by aerospace and other markets with growing needs for compact in-line, on-field and point-of-use measurement systems. PIC technologies have emerged as a promising solution for spectrometer miniaturization. However, existing mini-spectrometers are largely limited by trade-offs between size down-scaling and critical performance metrics and thus cannot offer performances comparable to classical benchtop instruments. This proposal builds on and will significantly advance an on-chip spectrometer design pioneered by the MIT group, digital Fourier Transform (dFT) spectrometer, which offers major performance, SWaP, robustness and scalability benefits—all highly needed features for space applications.

In Phase I, we will focus on developing a full-fledged, tapeout-ready PIC design for the proposed spectrometer, as well as fabrication, assembly and experimental validation of first generation electronics for spectrometer control and testing. We will also mature spectral data acquisition and processing algorithms. The spectrometer design features an ultra-broad bandwidth covering 1.26 – 2.4 um wavelengths (scalable to other bands such as mid-IR), a high spectral resolution of 0.14 nm, a spectral channel count exceeding 8000, and an ultra-compact on-chip footprint of 10 mm^2. We'll leverage Si photonics foundry to demonstrate the spectrometer -- an essential path towards scalable and cost-effective manufacturing with a projected 100X cost reduction compared to commercial high-end benchtop instruments with similar performances.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

Atmospheric and surface analysis, mineralogy, biomarker detection, monitoring of volatile organic compound contaminants in spacecraft cabin atmospheres, life-support system monitoring, point-of-care diagnostics for astronauts, in situ monitoring of scientific experiments, astronomical spectroscopy, Raman/fluorescence sensing, non-destructive structure evaluation, etc. The miniaturized, low-power, rugged optical module can be integrated with CubeSat, rover or balloon platforms, or sensor networks. Relevant NASA programs: PICASSO, IIP, ACT, etc.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Spectroscopic sensing, hyperspectral imaging, optical network monitoring, optical coherence tomography, etc. For example, the technology can be used for pharmaceutical process monitoring, petrochemical and agrochemical manufacturing control, environmental monitoring, wavelength monitoring in telecom systems, fiber optic sensing, nondestructive structure testing and medical imaging using OCT, etc.

Duration: **6**

PROPOSAL NUMBER: 21-1- **T8.07-1991**

SUBTOPIC TITLE: Photonic Integrated Circuits

PROPOSAL TITLE: Ultra-narrow Linewidth Lasers for Deployed Quantum Timing Applications

Small Business Concern

Firm: **Vescent Photonics, Inc.**
Address: **14998 W 6th Ave, Suite 700, Golden, CO 80401 - 5025**
Phone: **(303) 296-6766**

Research Institution:

Name: **Lincoln Laboratory**
Address: **244 WOOD STREET LEXINGTON, MA 02420 - 9108**
Phone: **(781) 981-1547**

Principal Investigator:

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Phone: **(303) 296-6766**

Business Official:

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Address: **4865 East 41st Avenue, CO 80216 - 4401**
Phone: **(303) 296-6766**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3

Technical Abstract (Limit 2000 characters, approximately 200 words):

Vescent Photonics, LLC in collaboration with the Massachusetts Institute of Technology Lincoln Laboratory proposes to develop a compact, chip-scale ultra-narrow linewidth laser for next-generation fieldable quantum sensor applications including optical atomic clocks, two-way time transfer, and precision inertial force and gravity sensing. Atomic clocks represent the most precise and accurate instruments developed by scientists to date, offering measurement instabilities below $1x10^{-16}$ in a second. This level of accuracy enables the application of optical atomic clocks to a whole host of precision sensors, including the measurement of weak gravitational fields in near-zero gravity as well as accurate positioning, navigation, and timing onboard a spacecraft. However, high performance optical atomic clocks currently only exist in laboratory settings due to requirements of an ultra-narrow-linewidth (< 10 Hz) interrogation laser used as an optical flywheel for the atomic clock transition. The solution presented here for the development of an ultra-narrow linewidth laser is an extension to the initial investigations of Dr. William Loh at MIT-LL with chip-scale stimulated Brillouin scattering (SBS) cavities. Recent measurements conducted by the MIT-LL team have shown that chip-based photonic waveguide cavities can support ultranarrow-linewidth lasers; this effort seeks to increase the integration of necessary chip-scale components to move towards a design where the entire laser system is contained on a chip-scale device. This effort will focus on a design for chip-based SBS laser cavity with integrated frequency doubling for direct laser light generation at 674 nm for a $^{88}Sr^{+}$ optical atomic clock. Packaging will also be designed to integrate easily with the near-infrared pump laser at 1348 nm.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The ultra-narrow linewidth laser will be suitable for NASA's next generation chip-scale optical atomic clocks (timing, navigation, and magnetometry), ultra-low phase-noise microwave generation for RADAR detection of slow-moving objects with low RADAR cross-sections (timing, navigation, and sensing), and high precision remote sensing technologies such as dual comb spectroscopy (atmospheric sensing, molecular species identification).

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Department of Defense and commercial applications include optical atomic clocks, time and frequency transfer (of precision timing signals), ultra-low phase-noise microwave generation, dual comb spectroscopy, precision optical metrology, and astronomical spectrograph calibration.

Duration: **12**

PROPOSAL NUMBER: 21-1- **T6.06-1513**

SUBTOPIC TITLE: Enabling Spacecraft Water Monitoring through Nanotechnology

PROPOSAL TITLE: Multi-Analyte Microfluidic Colorimetric Sensor for Inorganic Ions

Small Business Concern

Firm: **Lynntech, Inc.**
Address: **2501 Earl Rudder Freeway South, College Station, TX 77845 - 6023**
Phone: **(979) 764-2200**

Research Institution:

Name: **Clemson University**
Address: **230 Kappa Street Suite 200, SC 29634 - 5702**
Phone: **(864) 656-8972**

Principal Investigator:

Name: **Angelo Kirchon**
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Address: **2501 Earl Rudder Freeway South, TX 77845 - 6023**
Phone: **(979) 764-2200**

Business Official:

Name: **Darla Hisaw**
E-mail: **darla.hisaw@lynntech.com**
Address: **2501 Earl Rudder Freeway South, TX 77845 - 6023**
Phone: **(979) 764-2219**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

This proposal aims to support NASA needs expressed in 2020 NASA Technology Taxonomy, TX06 Human Health, Life Support, and Habitation Systems, to develop “Next-Generation Water Monitoring Systems with Nanotechnology”. The proposed STTR project aims to develop a nanoparticle based microfluidic colorimetric sensor for the detection and quantification of metal ions. The desired sensitivity, selectivity and stability of the device will be achieved through the combination of chemical selective and sensitive functionalized metal nanoparticles, paired with a novel in-situ formation of the functionalized nanoparticles onto microfluidic paper-based pads, as well as a simple and compact RGB colorimetric reader. Overall, the proposed technology will be a reliable, robust and compact microfluidic based colorimetric sensor that requires extremely small sample volumes, no sample prep, has fast measurement times (less than 5 min), is easy-to-use, and most importantly has the capability to measure metal ions currently of intertest to NASA (Ag, Zn, Mn, Pb, Hg, Ni). In addition, the proposed technology would be gravity agnostic due to the use of microfluidic channels.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed microfluidic colorimetric sensor will provide an on-demand, easy-to-use measurement of metal ions for NASA’s water systems. The proposed technology would be applicable for both crewed missions beyond low-earth orbit as well as future habitation mission on both the moon and other celestial bodies (ex. Mars). The proposed technology is also relevant to the International Space Station, where it could be used in the short term, to support on-going research and testing in order to develop systems for monitoring water quality.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Non-NASA commercial applications of the proposed microfluidic colorimetric detection of metal ions includes the use in municipal water treatment plants and the residential and commercial market segments. This technology may also find applications in pharmaceutical, medical and electronic industries for quality monitoring of the metal-ion free water.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T13.01-1326**

SUBTOPIC TITLE: Intelligent Sensor Systems

PROPOSAL TITLE: Intelligent Photonic Micro-Sensor Network for Rocket Propulsion Ground Testing

Small Business Concern

Firm: **Intelligent Fiber Optic Systems Corporation**
Address: **4425 Fortran Drive, San Jose, CA 95134 - 2300**
Phone: **(408) 565-9004**

Research Institution:

Name: **Stanford University**
Address: **3160 Porter Drive, Suite 100, CA 94304 - 8445**
Phone: **(650) 723-0719**

Principal Investigator:

Name: **Mr. Joe Kramer**
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Address: **4425 Fortran Drive, CA 95134 - 2300**
Phone: **(408) 565-9000**

Business Official:

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Phone: **(408) 565-9004**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3

Technical Abstract (Limit 2000 characters, approximately 200 words):

NASA's requirements for improved measurement and analysis techniques for propulsion system performance characteristics for rocket propulsion systems. IFOS is developing a scalable, wirelessly networked, photonic instrumentation solution for measurement of strain and temperature, and derived acoustics, pressure, and heat flux. IFOS' chip-scale solution leverages the latest advances in photonic integrated circuits (PIC) and highly confined Brillouin sensing for ultra-fine localization of structural and environmental events of interest. IFOS' sensors will address NASA's need for instrumenting inaccessible measurement locations on rocket propulsion test structures. The concept of operations includes both wireless sensor network operation and fiber-connected networking where cybersecurity and/or EMI/RFI are a concern. In Phase I, IFOS and Stanford University will demonstrate concept feasibility of the innovative sensing network concept. In Phase II, field demonstration will occur with rocket propulsion system prime integrator. IFOS will leverage synergistic work on self-healing networks, built-in test, and distributed in-fiber Brillouin sensing. The concept can later be extended to SHM of in-flight systems, autonomous vehicle operation, or instrumenting inaccessible measurement locations.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

This innovation meets NASA's requirements for improved measurement and analysis techniques for propulsion system performance characteristics for rocket propulsion systems. The technology can also be used to provide information to safely expand the flight and test envelopes of rocket vehicles and components.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Commercial markets stand to benefit from IFOS' technology for testing and validation of highly integrated/synergistic structures including COPVs in the aerospace, automobile, and infrastructure industries, and photoacoustics and ultrasonics in medicine. Commercial aviation, the oil and gas industry, and land and marine vehicles will significantly benefit.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T15.04-1254**

SUBTOPIC TITLE: Full-Scale (2+ Passenger) Electric Vertical Takeoff and Landing (eVTOL) Scaling, Performance, Aerodynamics, and

Acoustics Investigations

PROPOSAL TITLE: Prediction and Validation of High Lift Performance with Strong Wing Propulsor Interactions

Small Business Concern

Firm: **Electra Aero Inc**
Address: **218 North Cherry Street, Falls Church, VA 22046 - 3520**
Phone: **(540) 660-2917**

Research Institution:

Name: **University of Southern California**
Address: **3720 S. Flower St. 3rd Floor, CA 90089 - 0701**
Phone: **(213) 740-6064**

Principal Investigator:

Name: **Amanda Reguengo**
E-mail: **amandas@usc.edu**
Address: **3720 S. Flower St. 3rd Floor, CA 90089 - 0701**
Phone: **(213) 740-6064**

Business Official:

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Phone: **(540) 660-2917**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 4
End: 5

Technical Abstract (Limit 2000 characters, approximately 200 words):

Numerous efforts are under way to develop aircraft for Advanced Air Mobility (AAM). Efficient flight for Urban Air Mobility (UAM) and short inter-city transportation promises to alleviate urban congestion and revolutionize air travel, while the use of Distributed Electric Propulsion (DEP) promises to do so in a safe, quiet, and energy-efficient manner. Many promising concepts are highly integrated electric vehicles with strong coupling between DEP system and airframe. One such concept is Electra's hybrid electric Short Takeoff and Landing (eSTOL) vehicle which uses blown-lift technology to achieve substantial range-payload capacity while operating with a 100-ft ground roll. Such an eSTOL vehicle is an alternative to eVTOL that can meet similar AAM requirements safely and efficiently. All these DEP-enabled integrated concepts would benefit from improvements in aerodynamics design and analysis tools, but the lack of full-scale validation data remains a barrier.

Electra and the University of Southern California propose to address the need for such validation data via the design in Phase I, and execution in Phase II, of experiments to gather in-flight aerodynamic data specifically targeting tool validation. The overall program is envisioned to cover acquisition of full-scale flight data and improvement of state-of-the-art design and analysis tools via development of advanced aerodynamic models for vehicles with closely integrated DEP systems. Included in Phase I are estimation of in-flight performance and DEP-wing interactions using high-fidelity numerical tools, and development of an experimental test plan for the acquisition of high-quality detailed flight data using Electra's full-scale 2-passengers eSTOL Technology Demonstrator vehicle. By complementing a test vehicle whose construction is already funded, the proposed STTR program will be able to use best-in-class instrumentation and gather a significant amount of data in a cost-effective and time-efficient manner.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

- o Advanced Air Mobility (AAM) National Campaign (eVTOL, eSTOL flight demonstrations)
- o Regional Air Mobility (RAM) (eCTOL & eSTOL general aviation and commuter aircraft)
- o NASA X-Planes (X-57, TTBW, EPFD)

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

- o General Aviation, Commuter, and Regional Aircraft with Distributed Propulsion
- o eVTOL and eSTOL Air Taxis

o Air Force Agility Prime “Air Race” ORBS

o Military Applications (logistics at austere fields, special forces deployment, quiet Stealth)

o Disaster response at austere sites and damaged airfields

Duration: **10**

PROPOSAL NUMBER: 21-1- **T12.07-2597**

SUBTOPIC TITLE: Design Tools for Advanced Tailorable Composites

PROPOSAL TITLE: Design Tools for Advanced Tailorable Composites

Small Business Concern

Firm: **M4 Engineering, Inc.**
Address: **4020 Long Beach Boulevard, Long Beach, CA 90807 - 2683**
Phone: **(562) 981-7797**

Research Institution:

Name: **Virginia Tech**
Address: **245 Goodwin Hall, VA 24061 - 0001**
Phone: **(540) 231-6653**

Principal Investigator:

Name: **Daniel Hammerand, Ph.D.**
E-mail: **dhammerand@m4-engineering.com**
Address: **4020 Long Beach Boulevard, CA 90807 - 2683**
Phone: **(561) 981-7797**

Business Official:

Name: **Kevin Roughen**
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Phone: **(562) 981-7797**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 5
Technical Abstract (Limit 2000 characters, approximately 200 words):

With the advent of automated tow placement and additive manufacturing, a designer of composite structures must deal with an enormous design space. Fortunately, advances in high-performance computing and software have enabled such design space exploration provided that an appropriate design environment is available. M4 Engineering, Inc., in partnership with Virginia Tech (RI) and San Diego State University (subcontractor), will develop such software for design of complex aerospace composite structures with variable fiber tow steer and curvilinear stiffeners. Previous research has shown that achieving optimal designs requires optimizing tow steered composite panels together with curvilinear stiffeners, an approach pioneered at Virginia Tech under NASA funding. Prior research developments by project team will be leveraged in creating a computationally efficient design optimization methodology. Critical to practical success will be the inclusion of realistic manufacturing constraints for achievable fiber tow paths with reasonable manufacturing times. Different parameterizations with user-specified flexibility for increasing design degree of freedoms will be implemented for optimizing fiber angles directly in the primary top-level optimization. Constraints on primary fiber path parameters to enforce manufacturability will implemented in the top-level optimization. Computational efficiency will be achieved using efficient reduced order models and convex approximations within the optimization. In order to deliver a capability that is primed for widespread utilization, the software tool will be formed as a plug-in to a major commercial software suite. Meaningful demonstration problem execution will be used to assess the robustness and efficiency of the approach and to identify future enhancements. During Phase I, the essential numerical elements of the software tool will be implemented and a comprehensive plan for GUI integration will be developed.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

NASA applications include primary and secondary structures a range of aeronautical and space applications where substantial performance stiffness and weight improvements would be highly beneficial. More specifically, the design methodology and software tool will have applications in space vehicles including the Artemis/HLS programs, aircraft fuselage, wings, and control surfaces including advanced concepts such as blended wing bodies, fuel tanks for launch vehicles, cryogenic tanks and satellites.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Non-NASA applications include military aircraft, trucks, tanks, missiles, automobiles, aircraft engine nacelles, wind turbine blades, medical protective equipment, prosthetic devises and marine structures. The design tool will also enable design of novel structures in emerging aerospace sectors for personal mobility and drones.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T12.05-1948**

SUBTOPIC TITLE: Use of Additive Manufacturing for Thermal Protection Systems

PROPOSAL TITLE: Microwave Assisted Deposition of Cyanate Ester Composites

Small Business Concern

Firm: **Raven 3D, LLC**
Address: **415 Elm Ave. Apt. 1, Norman, OK 73069 - 5736**
Phone: **(918) 645-2776**

Research Institution:

Name: **University of Oklahoma-Norman Campus**
Address: **865 Asp Ave Rm 212, OK 73019 - 1029**
Phone: **(405) 325-3663**

Principal Investigator:

Name: **Mr. Blake Herren**
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Phone: **(918) 645-2776**

Business Official:

Name: **Mr. Blake Herren**
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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

To automate the fabrication of ablative Thermal Protection Systems (TPS), a novel in-situ curing additive manufacturing (AM) technology and high-performance composite materials will be developed. The state-of-the-art in-situ curing nozzle utilizes localized volumetric heating of the extrudate to rapidly cure the polymer and adhere it to the flight structure. Rollers following the thermoset printhead will consolidate the materials reducing voids and eliminating previously necessary repairs on fabricated TPS before launch. The composition of the composite materials will be easily varied to gradient the material properties through the thickness of the TPS. Highly insulative materials closer to the flight structure and highly structural materials closer to the stagnation point of the vehicle will be critical for high-performance TPS. Future implementation of a continuous fiber 3D printhead will allow printing of the honeycomb or iso-grid reinforcement to stop potential crack propagation in high shear environments. Additionally, a highly robust outer layer of continuous carbon fiber will be 3D printed on the TPS for enhanced mechanical reinforcement. The unique combination of the novel in-situ curing nozzle, high-performance thermoset composite materials, and a multi-axis robotic arm will enable automated and time-efficient

fabrication of TPS with minimal defects. This technology will facilitate future NASA missions to the Moon and Mars by initializing an assembly line for atmospheric entry vehicles of the future.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The primary NASA application of the proposed technology will include full automation of the ablative TPS manufacturing process. The current fabrication methods used for ablative TPS are outdated requiring extensive time, manual labor, and costly repairs before launch. The innovation will enable automated rapid fabrication of TPS to facilitate the organization of an assembly line for atmospheric entry vehicles for NASA's future missions to the Moon and Mars.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

In-situ curing technologies for extrusion-based additive manufacturing (AM) are widely applicable to 3D print many thermoset materials. These thermoset materials have advantageous key materials properties over traditional polymer-based AM, enabling significant manufacturing freedom of highly versatile polymers in many fields including biomedical, aerospace, defense, automotive, and many more.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T5.04-2489**

SUBTOPIC TITLE: Quantum Communications

PROPOSAL TITLE: Entangled Photon Pair Source Based On Thin-Film Lithium-Niobate-On-Insulator Photonic Integrated Circuits

Small Business Concern

Firm: **Phase Sensitive Innovations, Inc.**
Address: **116 Sandy Dr., Newark, DE 19713 - 1187**
Phone: **(302) 286-5191**

Research Institution:

Name: **University of Delaware**
Address: **210 - E Hullihen Hall, DE 19716 - 0000**
Phone: **(302) 831-8626**

Principal Investigator:

Name: **Dr. Peng Yao**
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Phone: **(302) 286-5191**

Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

Herein, PSI propose a system-on-chip (SoC) solution for an entangled photon pair source (EPPS) based on thin-film lithium niobate on insulator (TFLNOI) photonic integrated circuits (PIC). Using integrated photonic devices such as fiber coupler, waveguide, modulator, splitter/combiner and micro-ring, the proposed EPPS can generate and process the entangled photons with high efficiency and speed. In phase I effort, we will study and model the proposed EPPS at the system level and layout specs for key components and systems. We will develop the periodic poling process for the target TFLNOI platform. And we will design and experimentally demonstrate high-

efficiency spontaneous parametric down conversion (SPDC) photon pair generation at telecommunication wavelength toward the end of the phase I work. In addition, a variety of PIC components such as waveguide, splitter/coupler, switch, modulator and filter will also be investigated theoretically and/or experimentally leveraging other ongoing government funded projects. The end result of the phase I work includes a demonstrated SPDC structure on a TFLNOI substrate, a system model and a system PIC design leveraging PSI existing PIC components, which will pave the path toward a full SoC prototype in phase II. Based on our pioneer work in TFLNOI PICs development and with our successful experiences in commercialization of SBIR research efforts, PSI is poised to develop, package, qualify and commercialize the proposed EPPS chip for tomorrow's quantum communication demands.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

High quality entangled photon pair is needed almost in all quantum technologies from quantum communication to quantum computing. As NASA explore deep space in the next decades, reliable, secure and high volume data communication is in urgent demands. Having a high-efficiency, high-speed, low SWaP-C, reconfigurable, integratable PIC-based entangled photon source will not only meet the challenge for many current system, but will also enable many new applications such as quantum internet, high-sensitive sensing and quantum computation.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Rapid development in quantum information technology demands high-efficiency, reliable and integrated quantum light source. Similarly, photon-based quantum computing also requires entangled photon generation as well as complicated processing. The potential commercial market of the proposed PIC chip is vast.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T13.01-1411**

SUBTOPIC TITLE: Intelligent Sensor Systems

PROPOSAL TITLE: Wireless Networked, High Temperature, Wide Bandwidth Pressure Sensors for Propulsion System Monitoring

Small Business Concern

Firm: **Nanosonic, Inc.**
Address: **158 Wheatland Drive, Pembroke, VA 24136 - 3645**
Phone: **(540) 626-6266**

Research Institution:

Name: **Virginia Tech**
Address: **Virginia Tech MC 0238, VA 24061 - 0000**
Phone: **(540) 231-7274**

Principal Investigator:

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Business Official:

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Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

This NASA Phase I STTR program would develop wireless networked, high temperature, wide bandwidth pressure sensors for use in propulsion systems during ground test and launch operations. Both applications require broadband and in particular high frequency response for adequate diagnostics, and operation at very high temperatures in rocket engine environments. The team proposes major changes in pressure sensor fabrication and implementation to allow order of magnitude increases in their temperature range, from their current 125 °C upper temperature limit to 500 °C and above. The proposed approach involves the avoidance of conventional soldering processes to reach approximately 300 °C and the use of very high temperature polymer-derived ceramic potting and thermal barrier insulation materials to reach 500 °C and above. The team will transition the wireless networked, high temperature, high frequency pressure sensors from their current concept to prototype stage products of use for rocket engine applications.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed wireless networked, high temperature, wide bandwidth pressure sensors can be used in the propulsion systems during ground test and launch operations. Currently, there are no commercial pressure sensors that can cover the wide frequency bandwidth from DC to 5MHz, even without high temperature capacities. The advantage of the proposed sensors over these existing low temperature products is their DC to 5MHz frequency response.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Primary customers would be university, government laboratory and industry researchers. Customers for wireless networked, high temperature, high frequency pressure transducers will be the manufacturers of engines and of high speed vehicles and flight control systems. Broader commercial sensor opportunities include oil and gas down-hole measurements.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T11.05-2986**

SUBTOPIC TITLE: Model-Based Enterprise

PROPOSAL TITLE: Digital Engineering for Model Based Enterprise

Small Business Concern

Firm: **Ujima Digital**
Address: **1550 Wewatta, suite 200, Denver, CO 80202 - 6305**
Phone: **(904) 444-9000**

Research Institution:

Name: **United States Air Force Academy**
Address: **2304 Cadet Drive, Suite 3800, CO 80840 -**
Phone: **(719) 333-2207**

Principal Investigator:

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Business Official:

Name: **David Emanuel**
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Address: **1420 Oak Street, Apt 422, CO 80919 - 4413**
Phone: **(904) 444-9000**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 6
Technical Abstract (Limit 2000 characters, approximately 200 words):

Ujima Digital and the United States Air Force Academy are partnered to deliver a collaborative, SysML enabled model-based enterprise platform for operating and managing their numerous facility's product lifecycles. A model-based enterprise will not only give NASA

visibility into the operational consumption of their facilities, but it will also allow for teams to collaborate around engineering requirements such as preventative maintenance, resource planning, and sharing interoperable engineering requirements with internal teams and contractors. Our solution combines 3D digital twin technology, digital engineering, and model-based systems engineering to create “tangible” digital assets that can give real-world feedback on the performance health of a facility and facilitate automated decision support to those managing NASA’s aging infrastructure. We aim to provide facility managers, contractors, engineers, and all other stakeholders the ability to collaborate around the entire product lifecycle of a facility from a shareable, inspectable, digital, single source of truth.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

- Providing a data driven model-based enterprise to NASA’s field facilities to manage the day to day operations and systems engineering requirements.
- Provide a Building Information Management solution to NASA’s administrative building to manage the relationships with the numerous vendors they have, as well as support their cost saving initiatives.
- Supporting NASA’s research and development centers and provide a model-based approach to managing their research center’s assets and their utility.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

- Enterprises are currently undergoing a digital transformation and are currently looking for innovative ways to modernize their technology infrastructure, and digital engineering is at the forefront of thought for telecommunications, advanced manufacturing, and product-based technology companies such as Apple, Google, and Samsung.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T11.04-2736**

SUBTOPIC TITLE: Digital Assistants for Science and Engineering

PROPOSAL TITLE: LINUS: An Intelligent Digital Assistant for UAM Operators

Small Business Concern

Firm: **Intelligent Automation, Inc.**
Address: **15400 Calhoun Drive, Suite 190, Rockville, MD 20855 - 2814**
Phone: **(301) 294-5221**

Research Institution:

Name: **University of Maryland**
Address: **3112 Lee Building, 7809 Regents Drive, MD 20742 - 5141**
Phone: **(301) 405-6269**

Principal Investigator:

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Phone: **(240) 406-5506**

Business Official:

Name: **Mark James**
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Address: **15400 Calhoun Drive, Suite 190, MD 20855 - 2814**
Phone: **(301) 294-5221**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

Intelligent Automation, Inc. (IAI), along with its teammate University of Maryland propose to develop LINUS, an InteLligent DIgital AssistaNt for Urban Air Mobility (UAM) OperatorS. The key innovation of this project is the development and integration of Automatic Speech Recognition (ASR), Natural Language Understanding (NLU), and Text-to-Speech (TTS) along with their acoustic and UAM developed Language Models to create a digital assistant for UAM Operators. UAM is emerging as a viable alternative to ground and air transportation modes and the UAM Concept of Operations (UAM ConOps) describes a phased-in approach to UAM operations in the National Airspace System (NAS). The roles and responsibilities assigned to operators of UAM will require new technologies and capabilities to achieve this. The IAI Team proposes an intelligent digital assistant (IDA) to assist UAM Operators and Pilots-in-charge in the planning and execution of UAM operations. The core objective of our LINUS project is to develop a natural language artificial intelligence-powered interactive assistant to UAM operators for conducting UAM operations to help manage operator workload. Assistive tasks performed by LINUS will include flight planning, flight following, and contingency management. A secondary objective, is to develop a standard API to enable integration with future backend AI-based intelligent information systems. For this proposed project, we intend to leverage prior work that developed a chatbot for comfortably discussing and reporting symptoms, and Intelligent Digital Assistant (IDA) project that developed technology to ease operational pressures on Sailors interacting with complex Navy Combat Systems. IDA integrates state-of-the-art ASR, NLU, and TTS architectures coupled with domain specific neural acoustic models for ASR and domain specific language models for ASR, NLU, and TTS.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

NASA's UAM Sub-Project is working with the FAA and other industry stakeholders to integrate UAM into the NAS. A concept for a UAM Dispatcher or Fleet Manager position is presented by NASA et al in the paper "Urban Air Mobility Fleet Manager Gap Analysis and System Design." LINUS can be included in the UAM Dispatcher concept thus providing an intelligent assistant to UAM Operators to help manage workload in an increasingly complex operational environment.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The key commercial value for LINUS is its ability to perform speech-to-text and understand context and meaning on low-resource languages such as those within the NAS operational community. Commercialization revenue may come from technology licensing to product developers interested in more natural human-machine-interaction and product sales to universities and contractors.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T12.06-2998**

SUBTOPIC TITLE: Extensible Modeling of Additive Manufacturing Processes

PROPOSAL TITLE: Predictive Thermal Simulation for Laser Powder Bed Fusion

Small Business Concern

Firm: **Open Additive, LLC**
Address: **2750 Indian Ripple, Rd., Ste. A, Beavercreek, OH 45440 - 3638**
Phone: **(937) 306-6140**

Research Institution:

Name: **University of Pittsburgh-Pittsburgh Campus**
Address: **3420 Forbes Avenue, PA 15260 -**
Phone: **(412) 624-2052**

Principal Investigator:

Name: **Dr. Christopher Barrett**
E-mail: **cbarrett@openadditive.com**
Address: **2750 Indian Ripple, Rd., Ste. A, OH 45440 - 3638**
Phone: **(937) 306-6737**

Business Official:

Name: **Dr. Randall Pollak**
E-mail: **tpollak@openadditive.com**
Address: **2750 Indian Ripple, Rd., Ste. A, OH 45440 - 3638**
Phone: **(937) 306-6161**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 3
Technical Abstract (Limit 2000 characters, approximately 200 words):

The proposed innovation for this work is an efficient simulation software combined with in-situ sensing capability for use with laser powder bed fusion (LPBF) machines to detect defects before initiating the build; thus allowing abatement of the defects before they are materially created. The predictive thermal simulation capabilities developed by the University of Pittsburgh, to be combined with Open Additive's multi-sensor data collection and analytics suite (AMSENSE®) and transitioned into a commercial software framework, will provide a comprehensive solution for the development, validation, and transition of quality assurance strategies for additively manufactured metal parts for aerospace applications. The resulting toolset will provide an efficient simulate-before-build approach that will enable the ability to print low volume, highly critical complex geometric parts by LPBF at reduced timelines and cost compared to the current state of the art.
Potential NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed simulator in combination with AMSENSE sensing and analytics capabilities will provide a robust prediction and monitoring solution for low volume, highly critical parts. The effort will provide a method tosimulate-before-build for complex novel geometries to identify ideal laser processing parameters. This will accelerate the qualification of laser powder bed fusion (LPBF) processes and parts for use on NASA mission projects such as the Mars Oxygen In-Situ Resource Utilization Experiment (MOXIE) and other endeavors.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The proposed simulation tool combined with in-situ sensing/analytics will have wide applicability to defense and industrial needs for additively manufactured parts to support modernization and systems sustainment. The toolset will provide an integrated approach to reduce the costs and lead times involved in AM applications development, thus paving way for more materials and complex geometries.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T10.03-2297**

SUBTOPIC TITLE: Coordination and Control of Swarms of Space Vehicles

PROPOSAL TITLE: Communicationless Coordination via Intent Estimation and Intent-Expressive Motion Planning in Multiagent Exploration

Small Business Concern

Firm: **Geisel Software, Inc.**
Address: **67 Millbrook Street, Worcester, MA 01606 - 2846**
Phone: **(508) 936-5099**

Research Institution:

Name: **Arizona State University**
Address: **551 E. Tyler Mall, ERC 305, AZ 85287 -**
Phone: **(480) 965-7970**

Principal Investigator:

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Phone: **(480) 965-7970**

Business Official:

Name: **Brian Geisel**
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Address: **67 Millbrook Street, MA 01606 - 2846**
Phone: **(508) 936-5099**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 3
End: 4

Technical Abstract (Limit 2000 characters, approximately 200 words):

This project will design algorithms for communicationless coordination of multi-robot systems via intent estimation and intention-expressive motion planning. In collaboration with Geisel Software, Inc., the ASU team will explore the feasibility and design of these algorithms by building upon prior work on intent inference for dynamical systems, e.g., autonomous driving and swarm intent estimation. In particular, the ASU team will develop behavior and intent estimation/prediction algorithms that combine set-based and probabilistic model discrimination and estimation frameworks to detect a potential mismatch between intended and actual paths/trajectories of rovers. Moreover, the cooperative team will design intent-expressive (also known as 'legible') motion planning algorithms such that the intended paths/trajectories and tasks are more easily inferred without explicit communication. Furthermore, in this first phase, we will perform feasibility and test studies for the proposed communicationless coordination approach by developing a realistic simulation platform such as a Gazebo simulator and leveraging Geisel Software's prior experience and expertise in this area. To complement the roles of the collaborators at Geisel Software, Inc., Dr. Yong and his graduate student will assist with algorithm design and simulations.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

More efficient planning for independent autonomous swarms of robots performing science tasks in various space environments.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

Improved coordination and task allocation for autonomous swarms of robots performing science tasks in various deep sea/communication denied environments. Defense applications may include adversarial estimation of enemy intent.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T9.02-1964**

SUBTOPIC TITLE: Rapid Development of Advanced High-Speed Aerosciences Simulation Capability

PROPOSAL TITLE: GPU Acceleration of an Adjoint Enabled Real Gas Hypersonic Flow Solver

Small Business Concern

Firm: **Scientific Simulations, LLC**
Address: **1582 Inca Drive, Laramie, WY 82072 - 5007**
Phone: **(307) 399-0871**

Research Institution:

Name: **National Institute of Aerospace**
Address: **100 Exploration Way, VA 23666 - 6147**
Phone: **(757) 325-6700**

Principal Investigator:

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Phone: **(307) 761-3829**

Business Official:

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Phone: **(307) 399-8717**

Summary Details:

Estimated Technology Readiness Level (TRL) :

Begin: 2
End: 4
Technical Abstract (Limit 2000 characters, approximately 200 words):

The objective of this Phase 1 proposal is the Graphical-Processing-Unit (GPU) acceleration of a two-dimensional, unstructured, viscous Navier-Stokes (NS) solver for aerothermodynamic applications. The subject code employs a multi-species two-temperature chemically reacting real gas model and incorporates the exact discrete tangent and adjoint systems for the real-gas system, which has been used for uncertainty quantification in past work. Our approach is based on a hybrid OpenACC-CUDA strategy, which seeks to extract maximum performance while minimizing code re-writing with an eye towards code maintainability and portability. In the Phase 1 project, the entire 2D code will be ported to V100 or A100 GPUs using OpenACC directives. This will be followed with the development of specific optimized CUDA implementations for the most critical components of the code. In particular, we will investigate CUDA implementations of the implicit line solver, the chemical source term, and a representative real-gas adjoint kernel from the 2D code. The effect of the number of species and reactions, and solver block sizes will be investigated in these component CUDA implementations. Phase 1 will also investigate alternate solver approaches with reduced memory requirements for their suitability for use on GPUs. The CUDA optimized kernels will in turn be used to further optimize corresponding portions of the simpler OpenACC implementation in order to investigate the potential for performant implementations with minimal code disruption. In Phase 2, the most promising component implementations and solution techniques will be extended to three dimensions and incorporated into a fully functional three-dimensional multi-species aerothermodynamics CFD solver optimized for GPU architectures.

Potential NASA Applications (Limit 1500 characters, approximately 150 words):

There is a strong requirement within NASA for more accurate and efficient predictive numerical simulation tools for entry, descent and landing (EDL), particularly in view of the difficulties in testing at the extreme conditions and harsh environments associated with spacecraft re-entry. Efficient use of GPU architectures offers the possibility of lower cost simulations at higher resolution, using more complex and realistic physical gas models, and incorporating other effects such as ablation.

Potential Non-NASA Applications (Limit 1500 characters, approximately 150 words):

The development of a GPU accelerated aerothermodynamic simulation capability which lowers the cost and inreases the accuracy of hypersonic flow simulations will open new markets for commercial CFD in high speed flows. GPU implementation of chemically reacting gas species will also have application in combustion problems with the potential to open new markets in the aerospace propulsion industry.

Duration: **13**

PROPOSAL NUMBER: 21-1- **T8.07-1794**

SUBTOPIC TITLE: Photonic Integrated Circuits

PROPOSAL TITLE: Photonic Integrated Microwave Spectrometer for Hyperspectral Sounding

Small Business Concern

Firm: **Freedom Photonics, LLC**
Address: **41 Aero Camino, Santa Barbara, CA 93117 - 3104**
Phone: **(805) 967-4900**

Research Institution:

Name: **Purdue University-Main Campus**
Address: **155 South Grant Street, IN 47907 - 2114**
Phone: **(765) 494-6204**