National Aeronautics and Space Administration

tech bytes

AMES' EMERGING TECHNOLOGIES

Flying on Mars

A Rotorcraft Aeromechanics Journey

SUMMER 2021

In this issue:

Chief Technologist's Corner

Center Chief Technologist (CCT) Corner:

After a lengthy postponement in publishing due to the Covid pandemic, we are pleased to release this 2021 edition of Techbytes, which highlights FY20 Early Career Initiative (ECI) awardee, Haley Cummings, Principal Investigator of the Rotor Optimization for the Advancement of Mars eXploration (ROAMX) project. ROAMX received funding to pursue the computational optimization of rotor blades for flight on Mars and the experimental validation of improved rotor performance. The work ROAMX is conducting will help enable the future exploration of Mars by rotorcraft. This edition also features a synopsis of the FY20 Center Innovation Fund (CIF) portfolio. Fraught with challenges due to the lockdown, the Ames CIF teams have come up with innovative ways to complete many project goals without access to labs and other anticipated support. This past year has been a year like no other for both ECI and CIF. Looking ahead, the FY21 ECI call was released on March 1, down selects occur in June and the two final proposals will be submitted to HQ July 16. FY22 CIF Request for Proposals have been released with proposals due July 16.

- ***Dr. Harry Partridge**, Center Chief Technologist*

ABOUT THE COVER

Principal Investigator Haley Cummings in the Aeromechanics Office was awarded STMD Early Career Initiative funding to pursue the computational optimization of rotor blades for flight on Mars and the experimental validation of improved rotor performance.

Flying on Mars: The Rotorcraft Aeromechanics Journey

The Aeromechanics Office (ARC-AV) is awaiting with excitement the "Wright Brothers" moment when the Ingenuity Mars Helicopter makes its first flight on Mars.

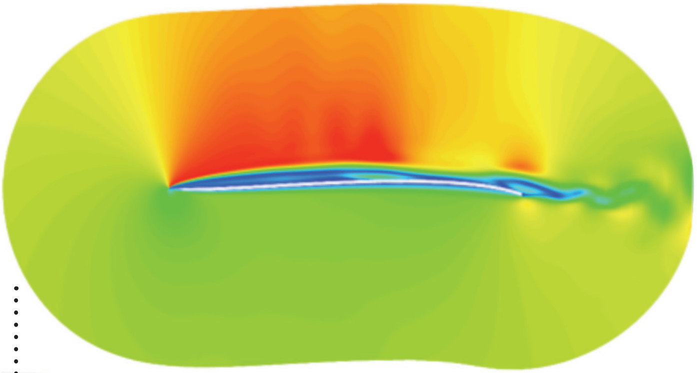
Larry Young (center), Mars rotorcraft pioneer.

Since the late 1990's the Aeromechanics Office has been pursuing research to enable rotorcraft flight on Mars, with Larry Young conducting the first-ever hover test of a rotor at reduced density to simulate Mars atmospheric conditions in 2002.

Since 2015, the Aeromechanics Office has contributed to the design of Ingenuity through controls design and testing supported by Dr. Carlos Malpica, vehicle performance analysis by Dr. Wayne Johnson, computational analysis by Witold Koning, and experimental facility

Flying on Mars: The Rotorcraft Aeromechanics Journey **(cont.)**

Witold Koning, Computational Lead for ROAMX.



Preliminary optimized airfoil for low Reynolds, high subsonic Mach number aerodynamics like that experienced with flight on Mars

development and analysis supported by Larry Young. However, the excitement in Code A V will not end when Ingenuity demonstrates flight.

The Aeromechanics Office is already looking towards the future of Mars rotorcraft and is investigating the development of vehicles for a Mars Science Helicopter, jointly led by JPL and by Shannah Withrow of Code AV. Recently, the Rotor Optimization for the Advancement of Mars eXploration (ROAMX) team led by Principal Investigator Haley Cummings in the Aeromechanics Office was awarded STMD Early Career Initiative funding to pursue the computational optimization of rotor blades for flight on Mars and the experimental validation of improved rotor performance. Since October, ROAMX has enhanced the optimization algorithm and has begun optimization of the airfoils. Optimization is still in progress, but initial results obtained by the computational team led by Witold Koning show that airfoil aerodynamic efficiency can be greatly improved, with early results already showing increases in section lift-to-drag ratios in excess of 30%. This level of improvement will enable future Mars rotorcraft to carry significant science payload (at least 2 kg) and fly at least 6 km in distance, opening up the exploration of Mars in a way that has previously been impossible.

Natalia Perez Perez (right), Experimental Lead for ROAMX, directing experimental testing in the N242 Planetary Aeolian Laboratory with Hannah Dromiack (center) and Shannah Withrow-Maser (left)

Comprehensive analyses (CAMRADII) has begun and is being conducted by Haley Cummings and Dr. Wayne Johnson to estimate loads for safety of flight and hardware sizing. Future work includes using comprehensive analyses to optimize rotor blade twist and chord distribution. Following optimization of the 2D airfoils and 3D rotor blade shape, a 3D CFD model of the rotor blade will be

Flying on Mars: The Rotorcraft Aeromechanics Journey **(cont.)**

generated and analyzed to compare against experimental results.

To validate predicted performance results of optimized rotors from 2D CFD and comprehensive analysis, the experimental team led by Natalia Perez Perez has utilized the results from the comprehensive analysis to design test hardware and identify equipment required for the experiment that can survive the extreme Mars flight testing conditions.

Ms. Perez Perez has also been coordinating with Code TS and N242 Planetary Aeolian Laboratory (PAL) testing facility to ensure experiments occur smoothly later this year. The PAL has the capability to pump down the chamber density to match the air density on Mars, which is about 100 times less than on Earth. Aerodynamic parameters of importance to match during experimental testing include density) and Mach number (which is affected by rotor tip speed). Thus, by testing in the PAL at reduced air densities to math Reynolds number and increased tip speed to match Mach number, flight on Mars can be adequately represented to validate predicted computational aerodynamic performance.

While there are many aspects of flying on Mars that are challenging, increasing the aerodynamic performance of the rotors has the biggest impact on what science a Mars rotorcraft can conduct, and what distances that rotorcraft can travel. Thus, the work ROAMX is conducting is helping enable the future exploration of Mars by rotorcraft. Mars rotorcraft open up a new "golden era" of aviation and allow the advancement of science exploration of Mars in a way that has never been done before. ■

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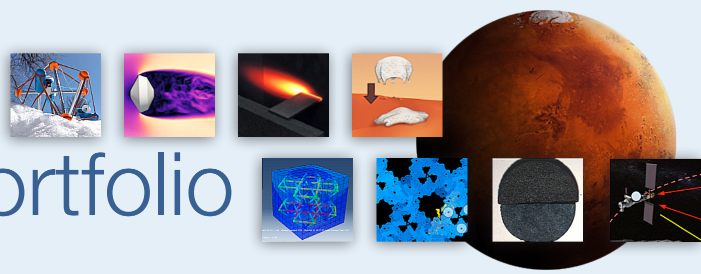
Ames FY20 Center Innovation Fund Portfolio



Like almost everything else, the lockdown due to Covid made FY20 a challenging year for the ongoing Center Innovation Fund (CIF) projects. Researchers were unable to access their labs, conduct experiments, secure much needed interns and collaborators, and/or complete procurements necessary for the success of project objectives. This coupled with some funding arriving late in the cycle made for a challenging year for all. The Ames Research and Technology Showcase (ARTS), which generally occurs in October, was cancelled. As a consequence, CIF and IRAD teams were unable to present their year-end accomplishments to the center. Many of the FY20 CIF projects were unable to fully complete project objects and have deferred project completion until labs reopen. None-the-less, some projects were able to complete project objectives in a remove environment. Here we present project overviews for all 26 CIF projects supported in FY20. ■

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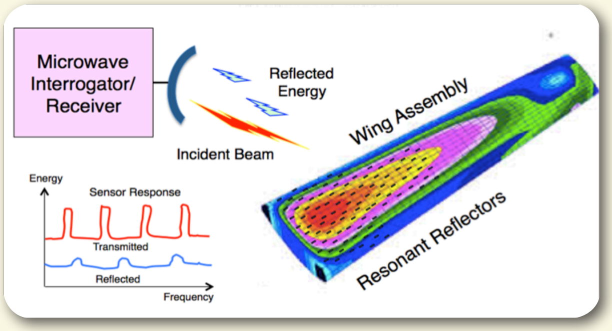
Radar for Smart Structures

Principal Investigator: *Richard Alena, Code TI*

Radar for Smart Structures develops an innovative radar-based structural monitoring system to demonstrate a "smart structure" able to dynamically sense its state of load and deformation. These novel sensors can be embedded during manufacturing and used for quality control. The same sensors can be used for hazard and failure detection and life-cycle management for production aerospace vehicles. The capability of assessing aerodynamic state geometrically may be particularly useful for rotorcraft and adaptable aeronautic concepts employing flexible surfaces. The key innovation is the construction of subminiature radar reflectors able to respond to a simple low-power radar beam over distances of

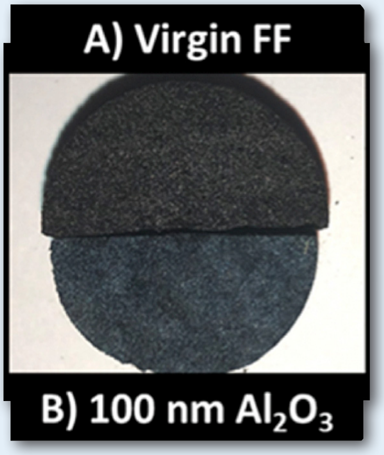


meters. Resonant radar reflectors can provide a distinct, single frequency signal, allowing detection and range measurement of specific reflectors with high accuracy. Each reflector can be tuned to a slightly different frequency allowing the construction of complex arrays for accurate multiple point measurements. ■

Enhancing TPS Performance with Atomic Layer Deposition (E-TPS)

Principal Investigator: *Brody K. Bessire, Code TSM*

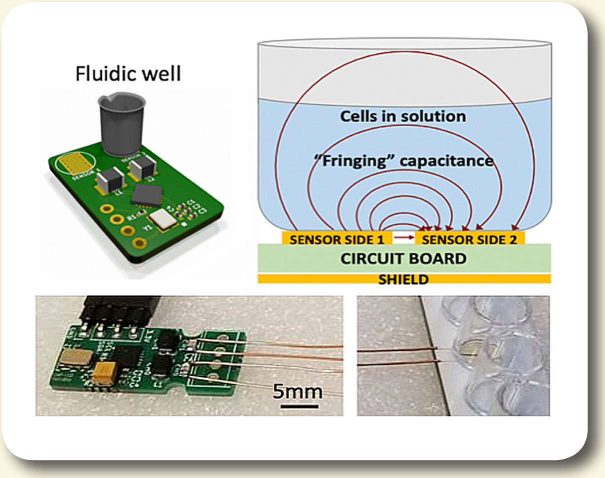
The E-TPS project investigates the application of nanocoatings to carbon-based thermal protection system (TPS) materials via atomic layer deposition (ALD). Nanocoatings of inorganic oxides functionalized with hydrophobic compounds may obviate the need for silicone-based coatings (e.g., NuSil) that are required to mitigate water uptake and particle shedding during storage and handling. ALD nanocoatings are expected to enhance the performance of TPS materials by increasing the onset of oxidation and lowering the effective thermal conductivity of carbon-based TPS materials. Thin coatings (e.g., 50-100 nm) of alumina were successfully applied to FiberForm using an ALD reactor, then cross-sections were analyzed with energy dispersive x-ray spectroscopy. Thermogravimetric analysis revealed the onset of oxidation of FiberForm is increased by 250 °C after applying 50 nm of an alumina coating. ■



Continuous Monitoring of Biological Radiation Response Using a Miniature Dielectric

PI: *Sharmila Bhattacharya, Code SCR;*
Co-I: *Sergio R. Santa Maria, Code SCR*

This project develops a miniaturized instrument for continuous monitoring of the biological response to deep space radiation. Given that the biological effects of the deep space radiation environment are critical gaps in our knowledge and that those conditions cannot be replicated using terrestrial facilities, small and sensitive technologies capable of monitoring transient biological changes can conduct high-impact science to inform future crewed missions to deep space. The instrument can be miniaturized and complement autonomous small satellites and missions to interplanetary space and to the lunar surface. Here, a technique known as dielectric spectroscopy is used to quantify the electrical signatures generated by living cells. The continuous cell changes and electrical signatures generated by the exposure to ionizing radiation can thus be investigated by using this approach and provide new information on the activity and physiology of cells like the budding yeast Saccharomyces cerevisiae. ■



2020 CIF Portfolio

Tensegrity Underwater Robot for Traversing Liquid Environments (TURTLE)

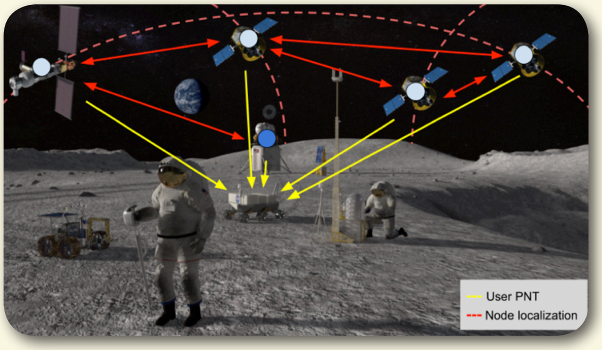
Principal Investigator: *Maria Bualat, Code TI*

The Tensegrity Underwater Robot for Traversing Liquid Environments project explored the feasibility of a lightweight, compact, and resilient waterproof tensegrity robot for surface and underwater science missions, which require observations at and across surface/liquid environment boundaries. New features were added to the NASA Tensegrity Robotics Toolkit (NTRT) to enable active buoyancy control for a tensegrity structure in simulation. A physical robot prototype was designed, built, and tested in different environments, including dry soil, snow, and water. ■

Lunar Autonomous Positioning System (LAPS)

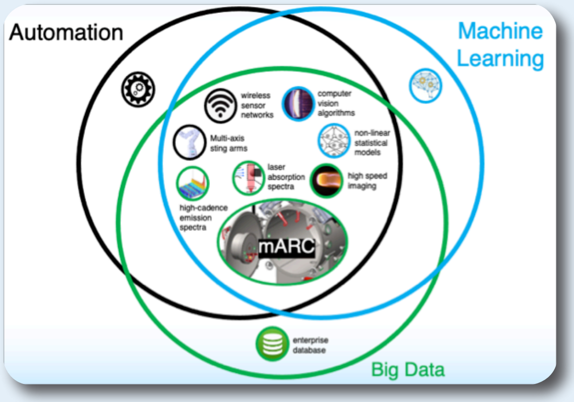
Principal Investigator: *Kelley Hashemi, Code TI*

LAPS helps construct an orbital and ground resource network that provides Position, Navigation, and Timing (PNT) services for lunar surface operations. While functionally similar to Global Navigation Satellite Systems (GNSS) for Earth, this system will instead build an automated PNT framework utilizing limited infrastructure on board orbiting assets along with a controlled number of highly accurate assets, or anchor nodes. The goal is to use advanced algorithms to autonomously coordinate on demand or as needed asset participation to achieve orbit determination and time synchronization of accuracy sufficient for end-user localization. Other proposed lunar PNT solutions, such as weak signal GPS, will not meet many mission localization requirements without additional user INS augmentation and a dedicated GNSS constellation would require prohibitive infrastructure development. LAPS instead offers a design that could be deployed in the near term and is facilitated by accessible hardware technology. ■



Global Approach to Uncertainty Reduction (GATUR)

PI: *Megan E. MacDonald, Code TSF;*
PI: *Magnus A. Haw, Code TSM*

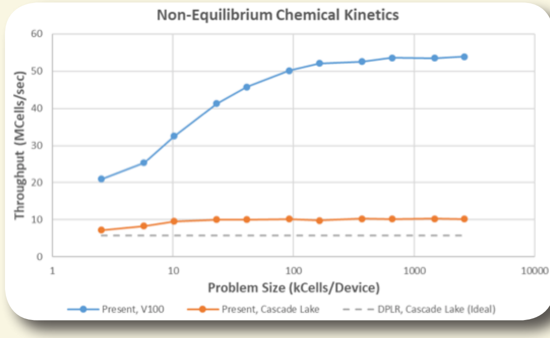


GATUR addresses the critical absence of multi-dimensional diagnostics and scalable data infrastructure in arc jet ground test facilities, which is now a limiting factor as 1D facility characterization is insufficient for validation of the latest multi-dimensional CFD and materials models. Addressing this gap will improve facility characterization, material and CFD model validation, and reduce ground-to-flight extrapolation uncertainties. The diagnostics planned for multi-dimensional characterization include a new multichannel spectral array diagnostic (16-50 channels) for 2-3D reconstruction of flow properties and several fast cameras for material sample photogrammetry. 2020 work focused on building new intelligent & scalable data infrastructure software suitable for automated acquisition, storage and processing of terabytes of data. Software development produced a scalable data infrastructure with built-in statistical tracking, machine learning modeling, search capability, and data visualization, which lays the groundwork for multi-dimensional validation by supporting the acquisition of critical diagnostic hardware and development of advanced data infrastructure software. ■

Towards GPU-Accelerated Flow Solvers for Planetary Entry

Principal Investigator: *Jeffrey Hill, Code TSA*

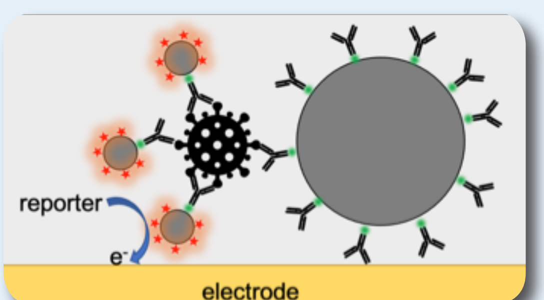
This work demonstrates viability of using the Kokkos Performance Portability Library to efficiently execute NASA-relevant aerothermodynamic computations on many-core accelerators such as the NVIDIA V100 GPU. Kokkos is a hardware abstraction library that enables high performance parallel computation on a variety of architectures without resorting to platform- or vendor-specific programming models. This is the first step towards enabling NASA's aerothermodynamics community to harness the benefits of exascale computing to accelerate entry system design and reduce mission risk. Three domain-specific computational kernels were extracted from the DPLR and LAURA aerothermodynamic flow solvers, the kernels were migrated from Fortran to C++, and miniapps developed to exercise the kernels on NVIDIA V100 GPUs using Kokkos. The resulting software is available on NASA's internal GitHub. Successful demonstration is complete for compute kernels that execute 5-10x faster on the V100 than on traditional compute nodes and deliver an order-of-magnitude improvement in throughput relative to the current state of the art. ■



Electrochemical Antigen Sensor for Pathogen Detection

Principal Investigator: *Jessica Koehne, Code TSS*

This work develops an electrochemical sensor platform to detect pathogens from human specimen samples. Potential benefits of this technology to NASA include crew health diagnosis of disease, environmental monitoring and food safety monitoring. The goal is to develop an approach for pathogen detection that could utilize in-space manufacturing for on-demand manufacture of pathogen sensors in microgravity. The platform consists of an interchangeable sensor and reusable cartridge and electronic hardware. The sensor is based on a printable electrochemical enzyme-linked immunoassay (ELISA) consistent for in-space manufacturing. The modular nature of the platform allows for a high level of sensor tunability and could include additional biosignature detection to encompass a wider range of human health diagnostic applications. The image shows a schematic of pathogen sensor design. ■

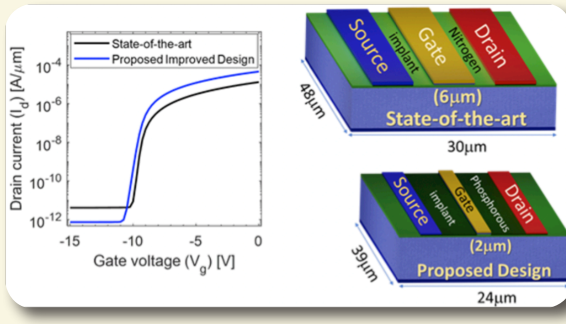


2020 CIF Portfolio

Computational Device Designer for High-Performance SiC Electronics for Harsh Space Environments

Principal Investigator: : *John W Lawson, Code TI*

Robust, high performance electronics are required for harsh space environments, and SiC based devices can potentially provide solutions; however, current SiC device densities are severely limited in the range of onboard computational tasks that can be performed. Application of existing silicon based terrestrial simulation tools to SiC electronics for high temperature and heavy radiation environments requires models to be modified and recalibrated to capture the correct physics and experimental behavior seen in these devices. Detailed semiconductor modeling and simulation capability developed in this project allow experimentalists and circuit designers to explore a dramatically expanded design space. A simulation framework was applied to the case of an n-type 4H-SiC JFET operating at high temperatures (460C), which is a crucial building block for more complex ICs. Results show that successful switching may be achieved by reducing the gate length down to 1 micron, which if confirmed would represent a 6X performance increase relative to the SOA SiC technology. ■



2020 CIF Portfolio

Biological Nanowires: Self-Assembly of Complex Nano-electronic Components from Biologically-Derived Precursors

Principal Investigator: : *Lynn Rothschild, Code SST*

The BioWires project utilizes metal base pairing in DNA to self-assemble one-dimensional (1D) conductors consisting of single metal ions inside precisely defined nonlinear nanostructures for the development of biologically derived nanoelectronics. Modern nanoelectronics involve photon lithography and nanofabrication processes that are prohibitively wasteful and massive in a mission context. By contrast, DNA self-assembly allows for nanometer resolution and liberation from top-down lithographic patterning. This work verified that the variant of DNA chemistry involving silver(I)-mediated base pairing is highly conductive and assembled periodic 2D arrays of biological nanowires. Results are significantly ahead of the state-of-the-art in terms of resolution, conductance, and scalability. Many groups have considered the use of DNA as a scaffold for conductive materials, but this work utilizes intrinsically functional molecular electronics based on DNA architectures. The image shows pseudo-infinite molecular array of DNA with metal-mediated base pairs (red circles), and motif assembles from DNA oligomers into microscale crystals (inset) via self-assembly. ■

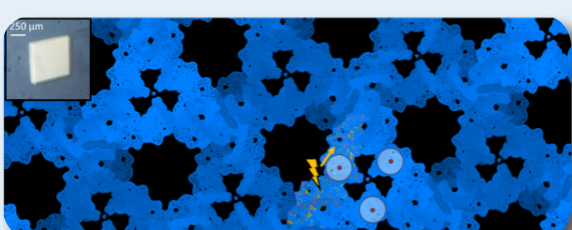
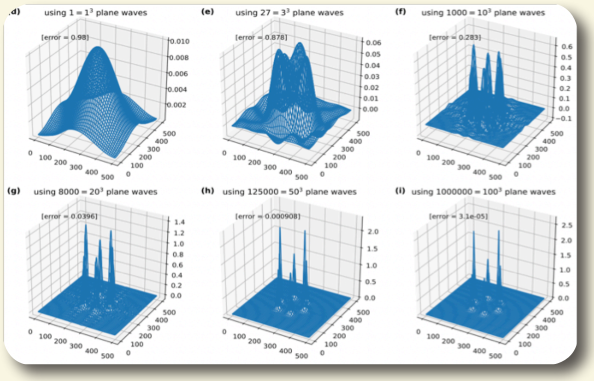


image credit: Simon Vecchioni, Columbia U

Quantum Computing to Accelerate High Fidelity Computational Materials Modeling

Principal Investigator: *Norman Tubman, Code TI*

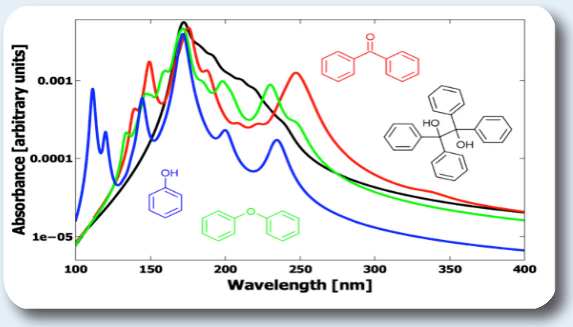
This work develops quantum algorithms for material science simulations based on new ideas recently proposed on plane wave basis sets. Many body simulations are not generally performed in plane wave basis sets on classical hardware, but with newly proposed quantum algorithms, it is possible this will be a highly efficient basis set to run quantum simulations on quantum hardware. Using state of the art classical simulations, small test simulations were run to estimate the resources that will be needed to run such plane wave algorithms on quantum hardware. The approach was demonstrated for a series of atoms and molecular systems. The figure shows convergence of a core orbital of benezene with increasing plane waves. The number of plane waves and overlap errors are given in each plot. The convergence of the core orbitals is one of the key bottlenecks in planewave approaches, as many plane waves are needed for convergence. ■



Surface Treatment for Bond Reliability and Strength (STARBURST): Technologies to Enhance Lightweight Exploration Missions

Principal Investigator: : *Lauren Abbott, Code TSM*

STARBURST aims to advance laser surface treatment and analysis technologies that improve process control for bonded joints required for composite structures in space missions. Surface treatment is performed with a picosecond laser, which removes surface contamination and increases surface energy via laser ablation. The surface chemistry is probed by laser-induced breakdown spectroscopy, which measures optical emissions from the laser-induced plasma. Molecular modeling techniques are leveraged to improve understanding of the chemical changes taking place at the surface during laser ablation, using polyether ether ketone composites as a case study. Highly accurate quantum calculations using time-dependent density functional theory are used to compute

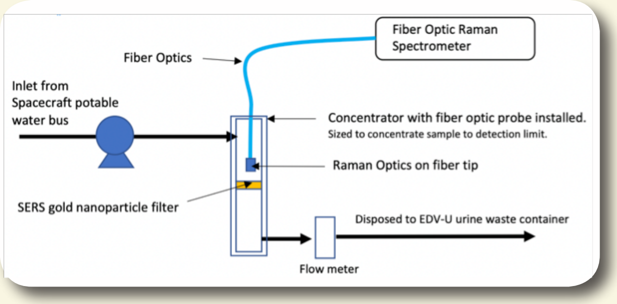


electronic excitations, as well as absorption and emissions spectra, for representative molecular fragments expected in the surface and plasma. Results from these calculations will be used to propose likely surface and plasma reactions and chemistries, insights gained will help accelerate optimization of the laser surface treatment process and improve sensitivity of the laser surface analysis technique. ■

Viral Sensor

PI: *Michael Flynn, Code SCB;* **Co-I:** *Rocco Mancinelli, Code SSX;*
Co-I: *Amber Paul, Code SCR*

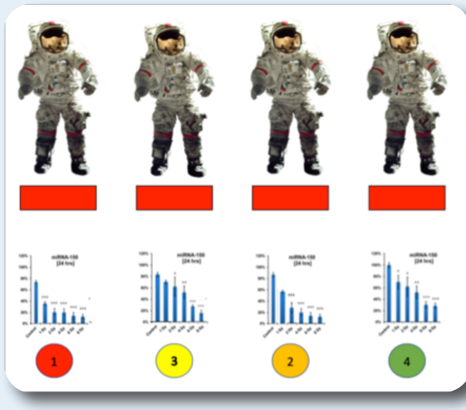
Viral Sensor evaluates the feasibility of developing a reusable viral sensor for potential use by crew members as a medical diagnostic tool, and for monitoring the spacecraft environment, such as recycled or stored water supplies. In 2020, proposed laboratory demonstration project became a paper concept study, but laboratory work will resume when access to the Ames' laboratories is allowed. Work to date determined that the initial instrument design did not meet all of the research objectives. Specifically, the regeneration approach used for the sensor limited its reusability because it was viral strain specific. The sensor could not be reprogramed in-flight to detect a new or different viral strain. As a result, the sensor design evolved to include a Raman spectrometer and a gold nanoparticle concentration device. The resulting updated sensor design is fully regenerable and can be modified in the field (during flight) to screen for any viral strain in the library. The proposed viral test uses Raman spectrometry to identify spectral fingerprints of viruses that have been filtered out of solution by a nano-filter. ■



2020 CIF Portfolio

Solar Particle Event Rapid Triage using miRNA Biomarker Radiation Biodosimetry

Principal Investigator: *Lauren Friend, Code RE*

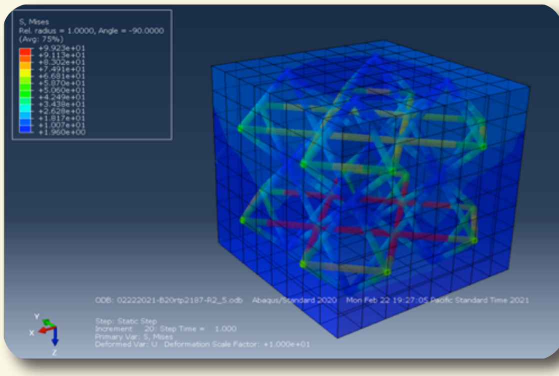


The severity of radiation exposure by crew is determined by the dose and type of radiation and an individual's unique physiological response. The current gold standard for determining risk from radiation exposure is physical dosimetry, which measures radiation dose; individual physiological responses are not considered. Radiation biodosimetry is critical in measuring an individual's physiological response. Jacob Laboratory developed a qPCR enabled biomarker assay for radiation biodosimetry sensitive at the level relevant for a Solar Particle Event (SPE); and Columbia University developed a Point of Care (POC) compatible qPCR device. However, no technology exists that allows the two to interact. This work develops a sensitive POC biodosimetry device that determines the unique response of crew members to SPE by modifying the assay developed at Jacob Laboratory for use with the Columbia University POC qPCR device and spaceflight heritage sample preparation methods from Wetlab and Wetlab-2. This tool proves a faster POC qPCR technology requiring less training and crew time, with a wide range of qPCR applications, including blood-based diagnostics for crew members, model organism experiments, microbiology, plant biology, and planetary protection. Here, four crew members experience the same event have the same physical dosimetry reading (red bar) but have very different reactions (miRNA graphs). ■

Lattice Reinforced Stabilized Regolith for Lunar Surface Infrastructure

Principal Investigator: *Christine Gregg, Code RM*

This project envisions a lunar regolith construction methodology that uses autonomously assembled lattices (NASA ARMADAS project) and panels to reinforce lunar concrete and provide integral formwork. By relying on structure optimized for autonomous robotic assembly, the usually labor-intensive processes of adding



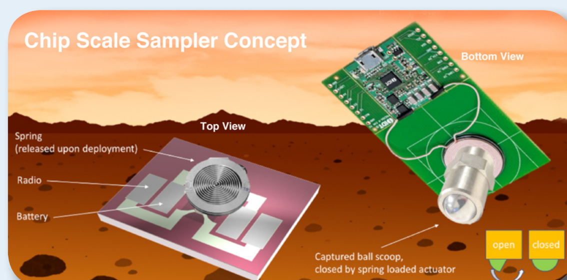
continuous reinforcement and formwork can be fully automated and integrated with a wide range of potential ISRU materials and processes. This capability will allow the autonomous construction of strong and safe lunar concrete structures using a broad range of ISRU chemistries and methodologies. Simulation results show that cuboctahedral lattice structures can effectively increase concrete strength. These models were then used to determine optimal lattice stiffness and geometry to provide effective reinforcement while maintaining relatively low mass. These results will guide future redesign of the reinforcement lattice for experimental validation, which was delayed due to lack of laboratory access during the pandemic. ■

2020 CIF Portfolio

Novel Energy-Based Approach for In Situ Life Detection

PI: *Yuri Griko, Code SCR;* **Co-I's:** *Luke Idziak, Code RE, Jing Li, Code TSS, Heather Smith, Code SST, Sanaz Vahidinia, Code SST*

This work introduces and tests a new energy-based approach and instrumentation suitable for in situ life detection with high sensitivity and probability. The approach is based on the proposed hypothesis that structural complexity and metabolic energy consumption of life forms, both manifestations of energy, are the most essential and sufficient attributes of life to be used for its detection. Using a variety of simple microorganisms (B. subtilis, Sulfolobus acidocaldarius, L. bulgaricus) and more complex life forms (Tardigrade), the work demonstrates that modern calorimetry consists of isothermal and scanning operational modes and represents a powerful method to directly monitor the biological activity of such living systems, as well as to characterize differences between the structural organiza-

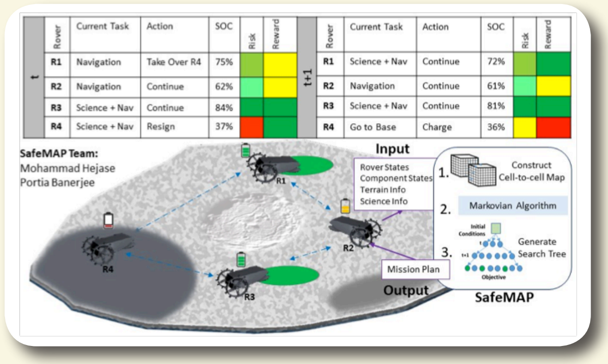


tion and complexity of measured life forms and inorganic environmental compounds. The instrumentation can be compact with relatively low power requirements and be fully automated for its incorporation into a space exploration platform as a life-detection instrument. A radically new architecture for space exploration and science missions is envisioned which uses numerous small and inexpensive networked sensors dispersed over large areas to ingest samples and perform in situ analyses over long time periods. ■

Safe Multi-Agent Autonomous Planning (SafeMAP)

Principal Investigator: *Mohammad Hejase, Code TI*

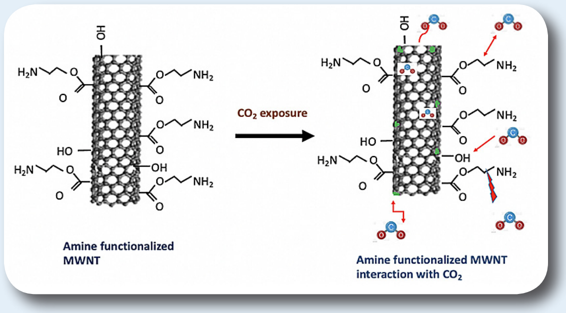
SafeMAP develops a software tool that unifies disparate models for multi-agent systems in a Markovian framework that allows for simultaneous system health monitoring, decision making under uncertainty, and multi-agent system collaboration. Multi-agent cyber-physical systems offer the potential of increased efficiency, resiliency, and mission capabilities for applications such as multi-rover terrain operations, distributed satellite operations, and management of smart lunar habitats. SafeMAP uses physics-based models, probability models of the environment and component operational states (nominal, degraded), and reward models for mission-specific objectives such as scientific task completion or resource consumption. SafeMAP is a set of mission plans that satisfy the mission objective under specified risk/reward constraints. A readable interpretation generated mission plans is provided as an additional output. This tool is being implemented in simulation on a case study involving a four-rover system performing surface mapping and science tasks. The case study is used to assess SafeMAP in terms of efficiency and resiliency. Efficiency is demonstrated through the generation of mission plans that increase reward and minimize risk, whereas resiliency is demonstrated through dynamic task allocation under off-nominal conditions. ■



Carbon Nanotubes for Selective Removal of CO_2 in Crew Cabin and Future Habitats on Moon and Mars

Principal Investigator: *Jing Li, Code TSS*

With access to the lab prohibited, this project looked state-of-the-art CO_2 removal technologies, their shortcoming, and analyzed possible options for solving known issues. Current ISS technology utilizes various zeolite sorbent-based temperature-swing adsorption process for CO_2 removal, which suffers from degradation of sorbent capacity and thus limited operational life span. Nanotubes-based sorbents not only show better CO_2 adsorption (≈30% higher) but also better regeneration at much lower temperature compared to the traditional Zeolite sorbents. Pristine nanotubes are not effective by themselves, but surface modified nanotubes show much higher absorption of CO_2. Eight different nanotubes-based sorbents have been identified that will be tested once allowed to return to the lab. Recipes to synthesize these materials were either found in the literature or originally proposed.



An assessment of required materials and equipment was completed, and procurement will commence as soon as work is permitted to move forward. A work plan was prepared for materials synthesis and their application process, including: 1) synthesis of five materials, and 2) measuring their absorption characteristics on Micromeretics apparatus. Micromeritics is used for materials characterization, such as surface area, physisorption and chemisorption characteristics of the synthesized materials for this particular application. ■

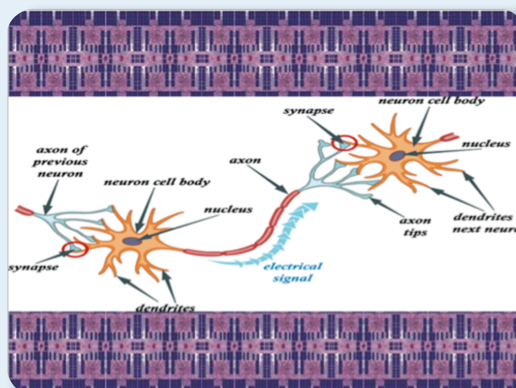
Resource Ingesting Soft Robotic Skins for In Situ Regolith Sampling

Principal Investigator: *Darlene S. S. Lim, Code SST*

This project demonstrates proof-of-concept of In Situ Resource Ingesting (ISRI) robots for regolith recovery and manipulation. ISRI robots are made from robotic skins - conformable sheets with embedded sensing, actuation and rigidity control. An empty ISRI robot will be transported as a lightweight and compact system that, upon arrival at a target planetary surface, will autonomously ingest material into itself and leverage its increased inertial properties for locomotion and material transport. This project's objectives are to design an existing robotic skin technology for proof-of-concept prototypes, and to test the prototypes with representative materials of varying geotechnical properties. The figure shows the basic concept of ISRI soft robots (from left to right): deployment, embedding, ingestion of regolith, and manipulation of the material to perform locomotion. ■

Neuromorphic Learning for Adaptive Control

Principal Investigator: *Mike Lowry, Code TI*

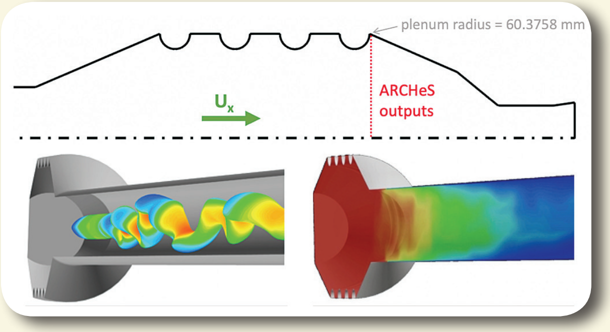


In contrast to CPUs that employ many auxiliary circuits such as caches and pipelines to provide the appearance of a very fast serial processor, neuromorphic processors devote a large percentage of their circuits to execute massive numbers of arithmetic operations in parallel. Typical algorithms are neural nets and convolutional digital signal processing, such as for computer vision. Like the brain, some Neuromorphic processors are capable of learning, either in batch mode (e.g., deep learning) or adaptively in-situ online. For today's space missions, adaptation is done by sending sensor data to Earth mission control for human engineers to update the control algorithms. For future space missions, adaptation could either be done by the spacecraft/rover in situ, or through Earth-based process that could be completely or partially automated. The project made an assessment of the energy requirements for transmitting sensor data back to Earth versus batch mode processing on the spacecraft. This energy tradeoff varies by distance and data volume, and the complexity of processing. The second part of this project is considering the on-line option with incremental adaptation. For this part, the Intel Loihi processor will be used for adapting control through algorithms that are based on spiking neural nets, and then analyzing the energy requirements. ■

Arc Heater Simulator (ARCHeS) Toolkit

Principal Investigator: *Nagi Mansour, Code TS*

A unique simulation toolkit ARCHeS that solves the tightly coupled Magneto-Hydrodynamics equations tightly, equilibrium chemistry with variable elemental composition, and three-dimensional radiative transfer with 100's of bands has been developed within the open-source framework OpenFOAM. In addition, a Development of proportional–integral–derivative (PID) controller for time dependent modulation of electrode boundary conditions has been implemented. This yields a more physical constant voltage BC at a given timestep and modulates that value over time to reach the desired current set point. This replicates how the arc jet power supply physically operates and provides a smooth mechanism for ramping the current from zero to steady-state without substantial manual intervention. Previously, constant current was enforced using



a gradient BC which allows non-physical variation in the voltage across a given electrode. The figure shows the ARCHeS simulation of the plasma flow inside the AHF arc heater (1200A and 0.45 kg/s). The top shows the location of the ARCHeS outputs in the AHF plenum. The bottom left is the current density (surface) and magnetic field (color), and the bottom right is the Argon mass fraction. ■

2020 CIF Portfolio

Ames SpaceShop Rapid Prototyping Lab FY20

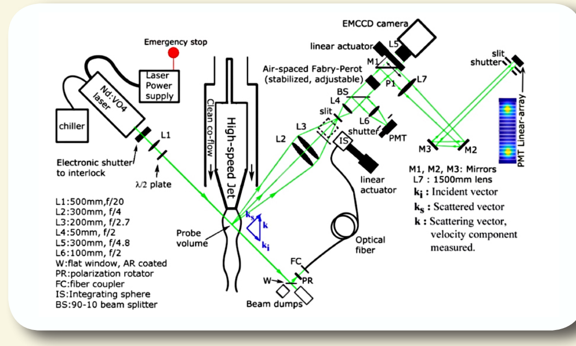
Principal Investigator: *Alex Mazhari, Code RM*

The SpaceShop Rapid Prototyping Lab supports the center's early concept ideation, fabrication, and testing requirements. In FY20, the facility supported over 100 projects resulting in hundreds of components ranging from those concerning aeronautics and experimental aircraft, to numerous small-spacecraft, ISS payloads, nanorobotics, life science concepts, and microfluidic instrumentation. SpaceShop also supported a Space Act with the USGS for rapid prototyping consultation and services. SpaceShop conducted R&D within the field of additive manufacturing (AM) automation, resulting in multiple conference contributions, pending journal papers, and a NASA patent-pending technology for augmented & automated AM. The facility's consolidation of polymeric AM equipment continues to develop a technical competency in the underlying material processes. As a function of this competency, the facility supported numerous Agency AM roles as the lead ARC representatives. These include but are not limited to NESC technical reviews for AM, NESC Materials Capability Leadership Team & Technology Discipline Team, the AM Standards and Qualifications Group, the NASA AM team, and the NASA Additive Manufacturing Working Group. ■

Spectrally Resolved Rayleigh scattering to Simultaneously Measure Fluctuations in Velocity Temperature and Density in High-Speed Flows

Principal Investigator: *Jay Panda, Code AOX*

Turbulence fluctuations that cause drag, structural vibration, sound generation, and efficient combustion are nearly impossible to measure at supersonic and hypersonic speed. This project advances a molecular Rayleigh scattering based technique to measure spectra of unsteady fluctuations in velocity, temperature and density over a frequency range of 0≤f≤10 kHz in supersonic flows. This work helps to create a measurement tool for the transonic and supersonic wind tunnels, which will enable measurement of shock unsteadiness, shock-plume interactions such as that found in sonic-boom mitigation tests of the commercial supersonic transports. This work also provides critical unsteady data for CFD validation. The project completed setup of the spectroscopic arrangement, incorporated a new 16-channel linear-array of photo-multiplier tubes, and photon-counting hardware. Preliminary data has been collected from a Mach 1.2 supersonic jet and measured velocity and density fluctuations spectra. ■



An Integrated Thermal Solution for Hypersonic Wing Leading Edge Applications

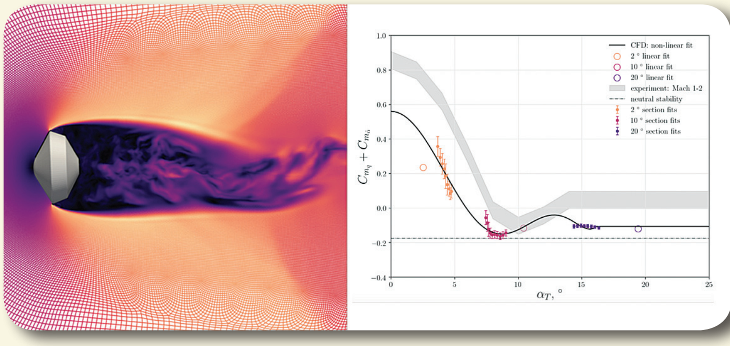
Principal Investigator: *Keith Peterson, Code TSM*

The desire to increase the range and speed of hypersonic vehicles requires a sharp, shape-stable Wing Leading Edge (WLE) with performance capabilities well beyond that of the current state of the art. The advent of additive manufacturing makes available new and innovative integrated thermal management systems that were previously not possible. This project evaluated various two-phase heat transfer devices and selected an oscillating heat pipe due to its' unique ability to operate under high g-loads. The initial prototype used to demonstrate high temperature operation includes lithium as the working fluid, with an additively manufactured Niobium based alloy (C103) manufactured by Castheon Inc. Trials are currently underway at the E-Beam welder, IMG Precision, who will charge the heat pipe. To demonstrate operation of the oscillating heat pipe, an oxyacetylene torch test setup was designed. Initial testing using a graphite calibration with thermocouples placed at set distances from the front of the test article demonstrated sufficient heating to the oscillating heat pipe. ■

Daedalus: A Multi-Disciplinary Entry Vehicle Design and Optimization Platform

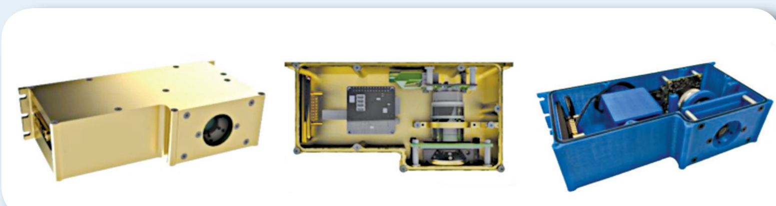
Principal Investigator: *Eric Stern, Code TSM*

Daedalus is a software development effort that leverages high-fidelity EDL modeling for a multi-disciplinary framework capable of delivering "simulate as you fly" analysis and design utility. This work further develops this concept on two fronts: advancing the topology optimization aspect through collaboration with our external partner and demonstrating end-to-end multi-disciplinary analysis and infusion into a flight project. Expertise in the topology optimization was leveraged from the Hypersonic Vehicles Interdisciplinary Research Team (HyVIRT) at CU Boulder. Support was also leveraged from the Entry System Modeling (ESM) project (STMD-GCD). Daedalus made progress in demonstrating the synthesis of high-fidelity multi-physics modeling products into design-ready reduced order models. Specifically, an approach for computing the so-called pitch damping coefficient from free-flight CFD (coupling dynamics and fluid flow) has been developed. The image shows an engineering pitch-damping curve derived from high fidelity CFD simulation. ■



Versatile 3D Microscopy in 100 Grams!

PI: *Uland Wong, Code TI;* **Co-I:** *Michael Dille, Code TI*



This work develops a new type of 3D microscope that allow scientists to not only view accurate and immersive soil granule models from afar, but also to understand geometric structure and infer material composition. Under development is a solid-state 3D microscopic imager consisting of a single programmable optical path, enabling the construction of a compact, lightweight, and ruggedized instrument. The design observes regolith in situ and forgoes the need for a sampling apparatus. This research matures and miniaturizes a recently constructed prototype 3D microscope combining techniques of photometric lightfield imaging and controlled illumination (gonioreflectometry). Initial data collected using this benchtop prototype has demonstrated resolution of 1 micron and was tested on an array of planetary simulant samples. Current work seeks to design and test a reduced-scale instrument compatible with micro-rover-scale payload bays. Iteration of the packaging will enable use in outdoor planetary analog testing and in review of high-risk, COTS components for flight and mission relevance. The project completed the design, fabrication and testing of miniaturized electronics, consolidating several disparate components of the larger prototype into one small printed-circuit board. The image shows renderings of the instrument packaging (left), internal top-view of electronics and optics (center), and 3D printed prototype assembly in progress (right). ■

Early Career Initiative (ECI)
FY 2022 Call for Proposals

The Space Technology Mission Directorate (STMD) released the Early Career Initiative (ECI) call for proposals on March 1. This is an annual call from STMD focused on professional development for early career NASA scientists, engineers and technologists. Centers must submit proposals through their Center Chief Technologists (CCT) to the STMD Program Executive for ECI. Two selections will be made per Center this year.

An early career civil servant (ECS) who has received their terminal degree (AA, BS/BA, MSc, or PhD), and is within the first 10 years of their early career is eligible to apply. CCT office received 11 Notice of Intent concept proposals.

The deadline for submitting to the ARC review process has passed. Two proposals will be sent to the STMD review panel July 16 with selection notification to the teams in August. Projects begin in October.

More information available at the Center Chief Technologist (CCT) website **https://www.nasa.gov/centers/ames/cct**

CONTACT Debra Reiss-Bubenheim
debra.bubenheim@nasa.gov

Center Innovation Fund (CIF) FY 2022 Call for Proposals

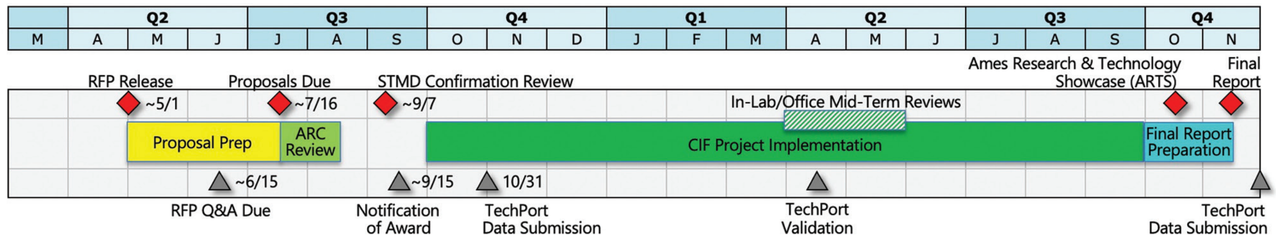
The NASA Ames CCT Office has released the Request For Proposals for the FY22 Center Innovation Fund. CIF focuses on technology investments that are longer-term, higher-risk, high-impact, and not necessarily tied to any specific future mission opportunity. For the FY22 CIF's, the Agency is particularly interested in concepts whose focus is on one of the following six areas: Cyber Space Mission Assurance Experiment; Space Trusted Autonomy; Resilient Cis-lunar Architectures; Quantum Sensing; Transformation AI to extract Information from Data; or In-space Additive Manufacturing. All proposals and supporting material must be received no later than 5:00 p.m. (PST), July 16.

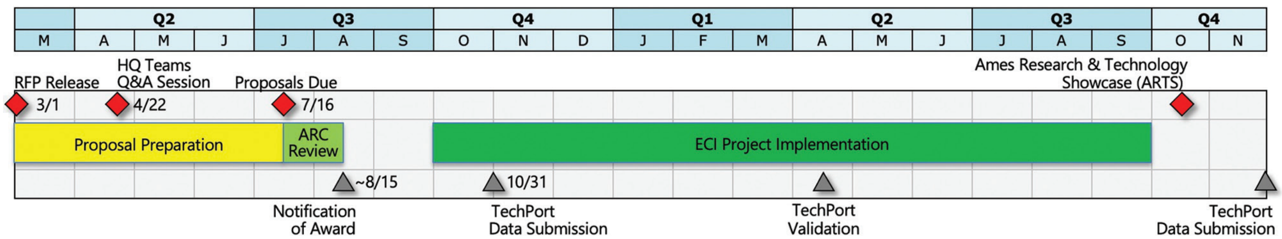
More information available at the Center Chief Technologist (CCT) website **https://www.nasa.gov/centers/ames/cct**

CONTACT Jill Bauman
jill.bauman@nasa.gov

Center Innovation Fund (CIF) and Early Career Initiative (ECI) Timeline

To help with proposal planning, the Office of the Center Chief Technologist has established the following rough CIF and ECI yearly cycles. Dates are approximate, and fluctuate slightly from year-to-year.





FY21 **Center Innovation Fund Winners**

Laser Analysis for Surface Preparation of Composite Bonded Joints
Lauren Abbott

Fluidic Telescope Experiment (FLUTE)
Edward Balaban

Enabling Neptune Aerocapture by Enhancing TPS Performance with Thermal Barrier Coatings
Brody Bessire

Rapid Prototyping of Active Microwave Metasurfaces by Inkjet Printing
Jessica Koehne

Big-data Efficiency and Automated Science Transfer (BEAST)
Megan MacDonald

Addressing Heat Flux Measurement Uncertainty for Current NASA Missions
Ruth Miller

Computationally Efficient Framework for 3D Flow-Coupled Radiative Calculations
Suman Muppidi

Machine Learning for Airspace Complexity Management
Nikunj Oza

Continuation of an Integrated Thermal Solution for Hypersonic Wing Leading Edge Applications
Keith Peterson

Enzymatic Life-Detection Sensor
Richard Quinn

PIAA-Vortex Coronagraph: Towards the Next Level of Performance for Exoplanet Imaging
Dan Sirbu

BioLEAD: BioLogical Exploration via Autonomous Detection
Marianne Sowa

MeDiCNE - Metabolomics-based Disease Characterization via Needle Trap Extraction
Kanch Sridhar

New NASA Challenge: TechLeap Prize

NASA's Flight Opportunities Program launches the TechLeap Prize aimed at providing development funding and access to suborbital flight testing for promising space technologies that meet a specific agency need. The first TechLeap Prize topic, developed in collaboration with NASA's Small Spacecraft Technology Program, is focused on discovering compact observation technologies for small spacecraft that can be tested on suborbital flights.

The Autonomous Observation Challenge No. 1 aims to identify integrated, compact precision pointing systems that could be used to autonomously detect, track, and collect data on transient events – both on Earth and beyond. NASA intends to award up to four winners with a maximum of $500,000 each and provide each winner access to a suborbital flight test on a vehicle provided by a NASA-contracted flight provider.

Q&A Webinar: June 30, 2021

Registration Deadline: July 28, 2021

Submission Deadline: Aug. 11, 2021

For more information visit:

https://www.nasa.gov/centers/armstrong/features/techleap-prize.html ■

NASA TechLeap PRIZE

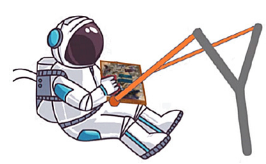
NASA@WORK Challenge: Lunar 911

This campaign is seeking technological, sociological, and operational insight related to the dissemination of crew and vehicle lunar surface distress data to fellow lunar surface, lunar orbiting, and Earth-based rescue coordinators. The NASA SAR Mission Office at the Goddard Spaceflight Center (GSFC) is developing the Lunar Search and Rescue (LunaSAR) architecture and hardware to support NASA-sponsored, international and commercial human exploration of the Moon under NASA's Artemis Program and future endeavors.

Deadline: July 9, 2021

For more information and to contribute visit:
https://www.nasa.gov/coeci/nasa-at-work ■

NASA@WORK Challenge: Launch Waste in Space!



This challenge seeks creative ideas for a new launcher that can jettison waste products (dry solid waste trash or wet trash) from the spacecraft. NASA is looking for new and creative ways of doing this. Things to consider are the characteristics of the waste products, how they exit the spacecraft, frequency and velocity of the jettisoned materials, and minimization of risk to the ship and crew. Submit your ideas today!

Deadline: July 30, 2021

For more information and to contribute visit:
https://www.nasa.gov/coeci/nasa-at-work ■

Challenge Owners: Michael Ewert (JSC) and Steven Sepka (ARC)