

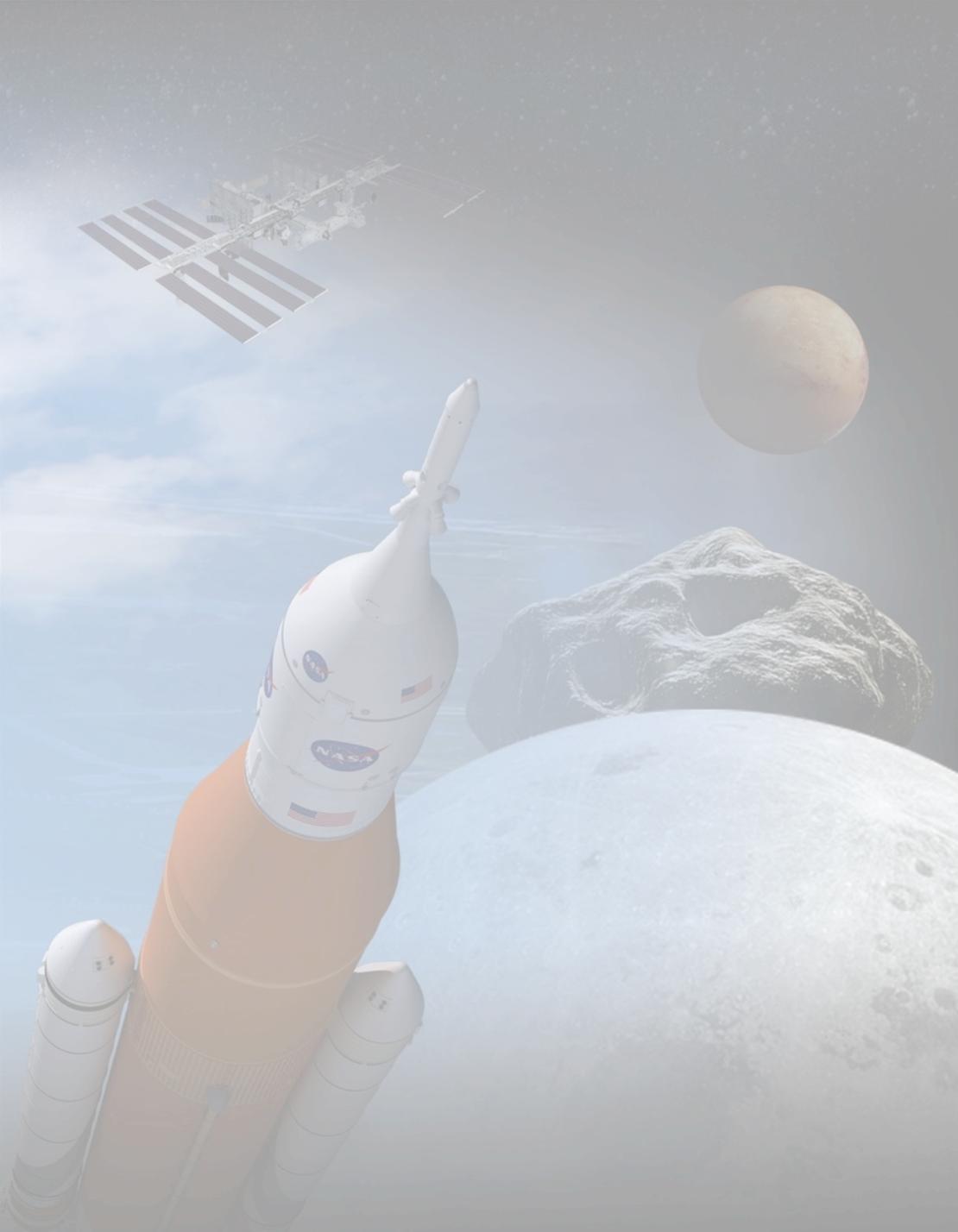


Marshall Space Flight Center

Technology Year in Review 2015

David Reynolds, Office of Center Chief Technologist
Mike Tinker, Deputy Center Chief Technologist

The 2015 Research & Technology Report is located at:
<http://www.sti.nasa.gov>



Marshall Space Flight Center

MSFC has a strong diverse portfolio of technology development projects, ranging from flight projects to very low Technology Readiness Level (TRL) laboratory projects. The 2015 Year in Review highlights the Center's technology projects and celebrates their accomplishments to raise awareness of technology development work that is integral to the success of future Agency flight programs.

The presentation is organized by funding sources:
Human Exploration and Operations Mission Directorate (HEOMD)

- Advanced Exploration Systems (AES)
- Exploration Systems Development (ESD)
- Space Launch System Academia Contracts/Grants (SLS Academia)

Science Mission Directorate (SMD)

Space Technology Mission Directorate (STMD)

- Technology Demonstration Missions (TDM)
- Centennial Challenges Program (CCP)
- Game Changing Development (GCD)
- Small Business Innovation Research (SBIR)
- Small Spacecraft Technology Program (SSTP)
- Center Innovation Fund (CIF)

MSFC Center Management and Operations (C&MO)

- Technology Investment Program (TIP)
- Center Strategic Development Steering Group (CSDSG)
- Dual-Use Technology Cooperative Agreement Notice (CAN)

Marshall supports three of the NASA Mission Areas:

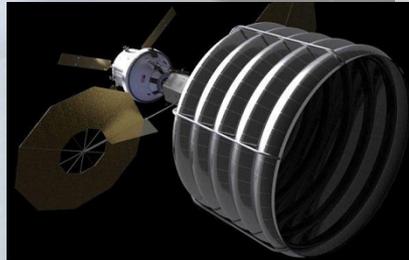
- **Human Exploration and Operations**



- **Science**



- **Space Technology**



- **Aeronautics Research**



Marshall Space Flight Center's Role in Agency Missions

Four Core Technology Themes

- **Space Transportation/Launch Vehicle Technology and Development**



- **Propulsion Systems Technology and Development**



- **Space Systems Technology, Development, and Integration**

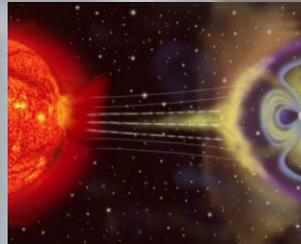
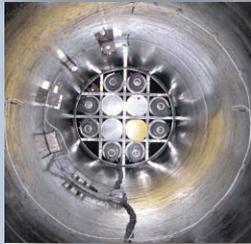
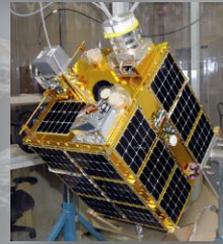
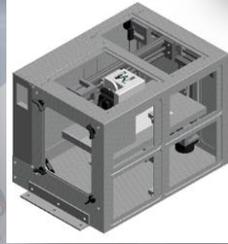
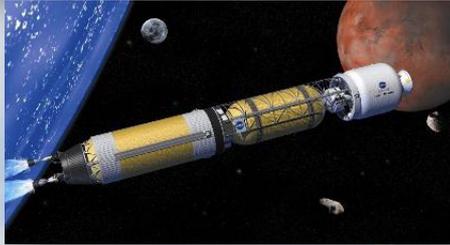
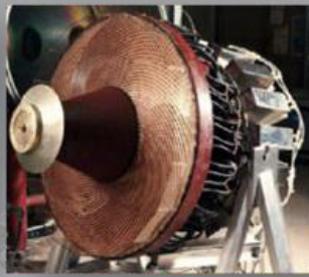
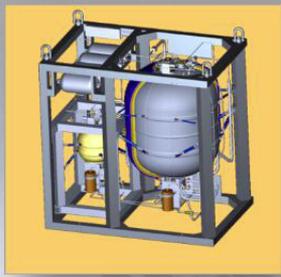


- **Scientific Research**



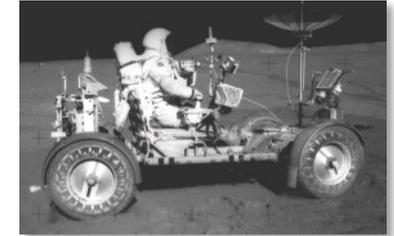
Marshall Space Flight Center Technology Emphasis Areas

- In-Space Propulsion with Emphasis on Cryogenics
- In-Space Propulsion (Green Propellants, Electric)
- Technologies for LEO Delivery of Small Payloads
- In-Space Propulsion (Nuclear)
- In-Space Propulsion (Solar Sails, Tethers)
- Propulsion Test beds and Demonstration Missions
- Technologies for BEO Exploration
- Technologies for LEO Delivery of Small Payloads
- Technologies Supporting Small, Affordable ISS Payloads
- Advanced Manufacturing with Emphasis on In-Situ Fabrication and Repair
- Human Habitation Elements and Life Support Systems
- X-ray Astrophysics; Scientific Instrument Dev.
- Space Environments and Space Weather, Research to Operations
- Small Spacecraft and Asset Mgmt. Technologies
- Rapid/Affordable Manufacturing with Emphasis on Propulsion Components



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Human Exploration and Operations Mission Directorate



The Human Exploration and Operations (HEO) Mission Directorate provides the Agency with leadership and management of NASA space operations related to human exploration in and beyond low-Earth orbit. HEO also oversees low-level requirements development, policy, and programmatic oversight.

MSFC Technology Year in Review 2015

Advanced Exploration Systems (AES)

- In-Space Manufacturing Project
- Nuclear Thermal Propulsion
- Autonomous Mission Operations EXPRESS
- Delay/Disruption Tolerant Network
- Lander Technologies
- Near-Earth Asteroid Scout
- Life Support Systems
- Exploration Augmentation Module
- Automated Propellant Loading
- Autonomous Fluid Transfer System

Space Launch System Advanced Development (SLS AD)

- Additively Manufactured Propellant Ducts and Manifold
- Advanced Manufacturing of Lightweight Carbon-Carbon Nozzle Extensions
- for Upper Stage Engines
- Computed Tomography Sensitivity Verification for Selective Laser Melting Space Launch System Engine Components
- Solid-State Ultracapacitor to Replace Batteries
- Lattice Boltzmann Method for Modeling Cryogenic Stage Zero-G Propellant Dynamics
- Hot-Fire Test of Liquid Oxygen/Hydrogen Selective Laser Melting Injector Applicable to the Exploration Upper Stage
- Testing of Selective Laser Melting Turbomachinery Applicable to the Exploration Upper Stage
- Additive Manufacturing Infrared Inspection
- Performance Improvement of Friction Stir Welds by Better Surface Finish
- Q2 Inconel 625 Material Properties Development
- Q4 Titanium 6-4 Material Properties Development
- Composite Dry Structure Cost Improvement Approach
- Pyroshock Characterization of Composite Materials
- Booster Interface Loads
- Advanced Booster High-Performance Solid Propellant and Composite Case/ Polybenzimidazole Nitrile Butadiene Rubber Insulation Development
- Advanced Booster Combustion Stability

Space Launch System Academia Contracts/Grants (SLS Academia)

- High Electrical Energy Density Devices for Aerospace Applications (Auburn University)
- Challenges Towards Improved Friction Stir Welds Using Online Sensing of Weld Quality (Louisiana State University)
- A New Modeling Approach for Rotating Cavitation Instabilities in Rocket Engine Turbopumps (Massachusetts Institute of Technology)
- Low Dissipation and High Order Unstructured Computational Fluid Dynamics Algorithms to Complement the Use of Hybrid Reynolds-Averaged Navier Stokes/Large Eddy Simulation Algorithms (Mississippi State University)
- Next Generation Simulation Infrastructure for Large-Scale Multicore Architectures (Mississippi State University)
- Development of Subcritical Atomization Models in the Loci Framework for Liquid Rocket Injectors (University of Florida)
- Determination of Heat Transfer Coefficients for Two-Phase Flows of Cryogenic Propellants During Line Chillover and Fluid Transport (University of Florida)
- Validation of Supersonic Film Cooling Numerical Simulations Using Detailed Measurement and Novel Diagnostics (University of Maryland)
- Advanced Large Eddy Simulation and Laser Diagnostics to Model Transient Combustion-Dynamical Processes in Rocket Engines: Prediction of Flame Stabilization and Combustion Instabilities (University of Michigan and Stanford University)
- Characterization of Aluminum/Alumina/Carbon Interactions Under Simulated Rocket Motor Conditions (Pennsylvania State University)
- Acoustic Emission-Based Health Monitoring of Space Launch System Vehicles (University of Utah)

MSFC Technology Year in Review 2015

In-Space Manufacturing Project

Project Manager(s)

Niki Werkheiser/ZP30 - (256) 544-8406

Project Description

In-Space Manufacturing (ISM) is a portfolio of project activities that will result in the technologies and capabilities required for sustainable, on-demand manufacturing and repair during exploration missions.

Notable Accomplishments

3D Printer Technical Demonstration on ISS produced all planned parts, and data analysis of the initial parts printed will determine if there are any significant effects due to printing in a microgravity environment. Recycler SBIR Awards – Include SBIR Phase I awards to recycle packaging materials (foam, bubble wrap, plastic bags) and a Phase II SBIR for on-orbit demonstration to recycle 3D printed parts back into feedstock.



Recycler for on-orbit demonstration as part of Phase II SBIR to recycle 3D-printed parts back into feedstock.

Nuclear Thermal Propulsion

Project Manager(s)

Sonny Mitchell, PM/ZP30 - (256) 544-7306

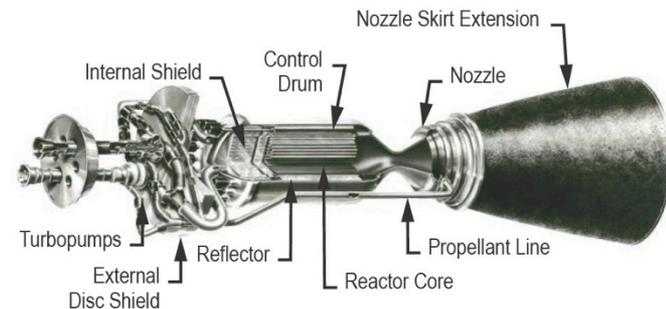
Michael G. Houts, PI/ZP30 - (256) 544 - 8136

Project Description

The Project focuses on demonstrating the affordability and viability of a fully integrated NTP system with emphasis on fuel fabrication and testing and an affordable development and qualification strategy. The goal is for NTP to be considered a mainstream option for supporting human Mars and other missions beyond earth orbit.

Notable Accomplishments

Dedicated fuel materials and processing laboratories at Oak Ridge National Laboratory and MSFC have fabricated fuel elements of various materials (some incorporating depleted uranium) for testing. Recent tests of a graphite surrogate (hafnium) fuel element were run in the NTREES test facility achieving a temperature of 2820K in a flowing hydrogen environment. Studies were completed examining various options for viable ground testing of an engine system. The use of low enriched uranium is being investigated to potentially reduce cost and schedule and increase programmatic flexibility.



NTP engine schematic.

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Autonomous Mission Operations EXPRESS

Project Manager(s)

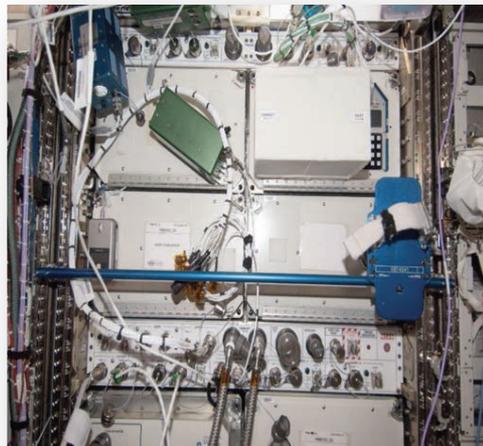
Jeremy Frank/Ames Research Center - (650) 604-2524
Angie Haddock/EO40 - (256) 544-6285

Project Description

Autonomous Systems and Operations (ASO) project conducted an autonomous command and control experiment on board the International Space Station (ISS) that demonstrated single-action intelligent procedures for crew command and control. The experiment enabled crew initialization of a facility-class rack with power and thermal interfaces involving core and payload command and telemetry processing without support from ground controllers.

Notable Accomplishments

The ASO team demonstrated software for autonomous operations on ISS to reduce the crew's dependence on ground-based mission control.



ISS EXPRESS rack 7

Delay/Disruption Tolerant Network

Project Manager(s)

Kelvin Nichols/EO50 - (256) 544-0759
Lee Pitts/COLSA - (256) 544-0666

Project Description

The Delay/Disruption Tolerant Network (DTN) is a combination of protocols that are being developed to extend the terrestrial internet into low-Earth orbit (LEO) and deep space to help form the solar system internet.

Notable Accomplishments

The operations had originally been scheduled to take place in three separate activities carried out over the course of two days. Everything ran smoothly during the first activity and ESA was able to execute the entire experiment in one session. ESA astronaut Andreas Mogensen was able to command the ESA Eurobot and walk it through a simulated lunar lander repair mission.

Astronaut controlling a Eurobot from ISS



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Lander Technologies

Project Manager(s)

Greg Chavers/FP30 - (256) 544-0494

Project Description

The Robotic Lunar Lander Development Activity was created to develop technologies that would enable and enhance robotic lunar surface missions at lower costs.

Notable Accomplishments

Notable accomplishments include the design of the low-cost robotic lunar lander with the prototype/engineering unit at the system level. Hot-fire test of the LOX/LCH regenerative cooled chamber, Autonomous Landing Hazard Avoidance Technology (ALHAT) closed-loop free flight on Morpheus, and development of subsystems and components for lunar landers with an application for science and exploration missions are also accomplishments.



Lunar lander with solid rocket braking motor and rover

Near-Earth Asteroid Scout

Project Manager(s)

Leslie McNutt/FP30 - (256) 544-1611

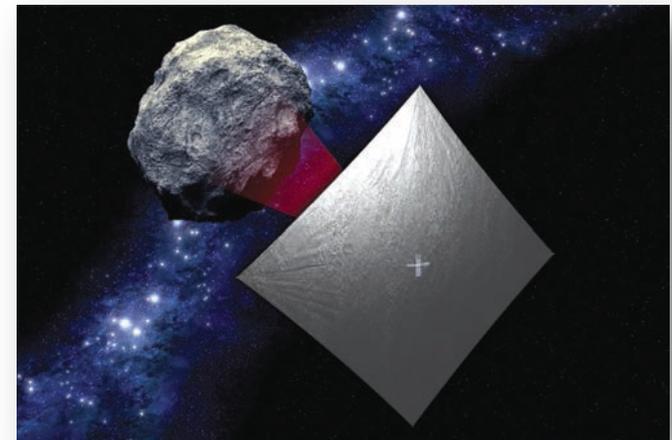
Les Johnson/ED04 - (256) 544-7824

Project Description

The Near-Earth Asteroid Scout (NEAS) mission will survey and image a near-Earth asteroid (NEA) for possible future human exploration using a small satellite propelled by an 86-m² solar sail.

Notable Accomplishments

The NEAS successfully completed its phase 0 and 1 Safety Reviews with the SLS Secondary Payload Safety Panel in January and September 2015, respectively. The phase 1 review was the final step in achieving preliminary design review maturity for the project. The solar sail Engineering Development Unit design is complete and is being built. A commercialization plan for the solar sail has been developed and a commercial partner was likely to be selected by early 2016.



Artist concept of the NEAS sailcraft surveying the target asteroid

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Life Support Systems

Project Manager(s)

Walter Schneider/FP10 - (256) 544-0557

Sarah Shull/Johnson Space Center - (281) 244-6441

Project Description

Development of reliable, energy-efficient, and low mass spacecraft systems to provide environmental control and life support is critical to enabling long-duration human missions beyond low-Earth orbit (LEO).

Notable Accomplishments

Method was accomplished to screen sorbents and desiccants used for carbon dioxide removal, and design reviews and testing of a cascade distillation system for urine processing were completed. Brine technologies to recover more water were developed to a level where the technologies can be compared for a final technology selection. Completed design reviews and preliminary testing for aerosol sampler flight demonstration to be flown on the ISS.



Integrated test chamber enables testing of LSS technologies in an environment that simulates human metabolic activity integrated with functional LSS hardware

Exploration Augmentation Module

Project Manager(s)

Lora Bailey/JSC Lead PM

Larry Gagliano/MSFC Support PM

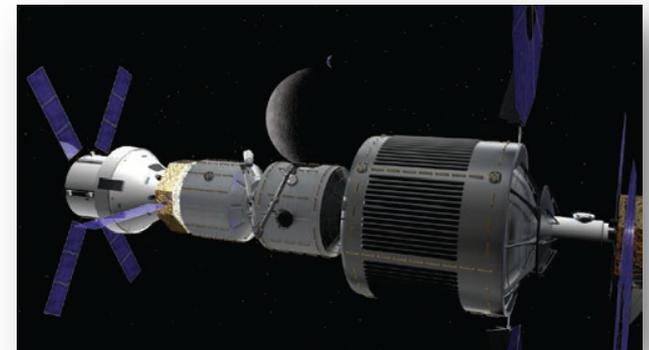
Project Description

This project will develop, integrate, and evaluate exploration system technologies needed to advance NASA's understanding of alternative Beyond Earth Orbit (BEO) vehicle architectures, requirements, and Earth independent operational concepts.

Notable Accomplishments

Accomplishments included completion of large scale habitat primary structure and baselined layout resulting in delivery of several physical volumetric and worksite assessments that led to design modifications and layout improvements. Several habitat design observations were delivered and are under review. The demonstrator provided a tangible platform for conveying large-scale habitat architecture approach and fostering collaborative efforts among key stakeholders and engineering disciplines.

Conceptual cis-lunar transit architecture



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Automated Propellant Loading

Project Manager(s)

Robert G. Johnson - (321) 867-7373

Curtis E. Banks/ES35 - (256) 544-4437

Project Description

Evaluate the performance of all composite pressure vessels at liquid nitrogen (LN2) temperatures while going to failure, and develop and apply structural health monitoring (SHM) sensors to quantify any structural damage or to maintain structural integrity prior to and while in use.

Notable Accomplishments

Each Center contributed manpower and expertise to evaluate composite tank performance at LN2 temperatures and a suite of SHM sensory technologies. The testing was performed at MSFC in the East Test Area. Each technology performed well at LN2 temperatures, but the fiber optics suffered from sensor application. The Acellent sensor? detected damage in the composite prior to failure. The finding was validated by the benchmark sensor and acoustic emission.



LN2 spewing out of the dome of an all-composite tank pressure vessel

Autonomous Fluid Transfer System

Project Manager(s)

Jeremy Frank/Ames Research Center - (650) 604-2524

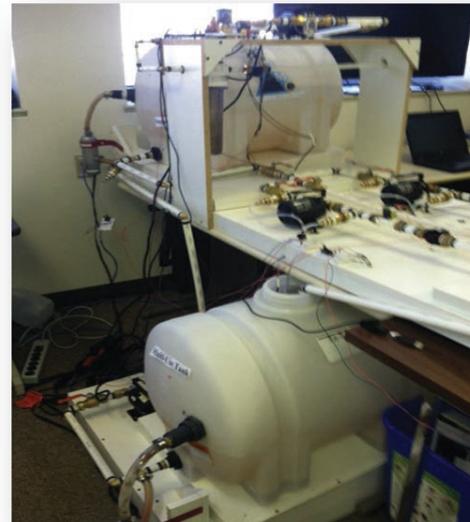
Angie Haddock/EO40 - (256) 544-6285

Project Description

The Autonomous Fluid Transfer System (AFTS) consists of two fluid tanks, one for a source of supply connected to one for multi-use. This system architecture allows a single fault tolerance as to transfer leg pump failures and flow meter failures. The manual transfer leg then adds an additional fault tolerance when both the primary and backup transfer legs have failed.

Notable Accomplishments

The first automated and autonomous procedure system that employs fault detection, isolation, and recovery was created.



Autonomous Fluid Transfer System

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Additively Manufactured Propellant Ducts and Manifold

Project Manager(s)

Elizabeth Robertson/ER21 - (256) 544-9692

Mindy Nettles/XP50 - (256) 544-1569

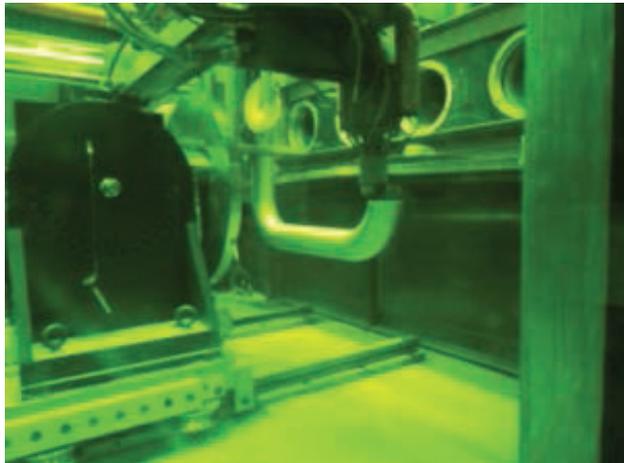
Project Description

The purpose of this effort was to design, fabricate, and test Inconel® 625 propellant ducts and manifolds. Tasks included using both the selective laser melting (SLM) and laser deposition technology (LDT) fabrication processes, as well as performing weld trials and material testing.

Notable Accomplishments

Completed fabrication and proof pressure tests of fuel and oxidizer turbine bowls. Fuel turbopump: Balanced rotor assembly. Passed torque checks. Component testing complete (15 tests). Methane chill test performed.

**LDT-built
propellant
ducts**



Advanced Manufacturing of Lightweight Carbon-Carbon Nozzle Extensions for Upper Stage Engines

Project Manager(s)

Pete Valentine/EM41 - (256) 544-2837

Mindy Nettles/XP50 - (256) 544-1569

Project Description

This task builds upon recent small NASA Marshall Space Flight Center (MSFC) efforts to develop a new type of carbon-carbon composite for upper stage engine nozzle extensions. This technology is also applicable to solid motors and first stages.

Notable Accomplishments

Completed nondestructive evaluations of nozzle extension tag-end rings via five methods. Completed analytical assessment of hoop tension ring specimen design and loading method for testing. Completed preparation of cutting plans for carbon-carbon tag-end rings. (Rings were fabricated by C-CAT.) Completed weaving of lyocell fabric at Highland Industries, Inc. Began fabrication of lyocell carbonization oil wringer at Buckeye Machine Fabricators, Inc. A new oil wringer is being fabricated through collaboration with the U.S. Navy and the Missile Defense Agency.

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Computed Tomography Sensitivity Verification for Selective Laser Melting Space Launch System Engine Components

Project Manager(s)

James Walker/EM20 - (256) 961-1784

Mindy Nettles/XP50 - (256) 544-1569

Project Description

This task focuses on understanding the detection sensitivity of the computed tomography (CT) system for finding critical defects and also for providing dimensional measurements in additive manufacturing (AM) Space Launch System (SLS) engine components. Selective laser melting (SLM) parts are being developed with a goal to provide a quantified assessment of CT nondestructive evaluation (NDE) for AM SLS engine components to help ensure their reliability and affordability.

Notable Accomplishments

The practical CT resolution appears to be at or near 0.010 inches. The modular reference standard concept works well and provides a lot of flexibility in assessing NDE performance. Some of the ideas from the gauge blocks and modular reference standard may work their way into the new ASTM guideline on AM NDE that NASA Marshall Space Flight Center is helping write. Many commercially available CT systems exist. The critical factors will be determining the range of part sizes that must be covered, which will drive the amount of x-ray energy required, and critical defect sizes, which will drive the focal spot size.

Solid-State Ultracapacitor to Replace Batteries

Project Manager(s)

Terry Rolin/ES43 - (256) 544-5579

Mindy Nettles/XP50 - (256) 544-1569

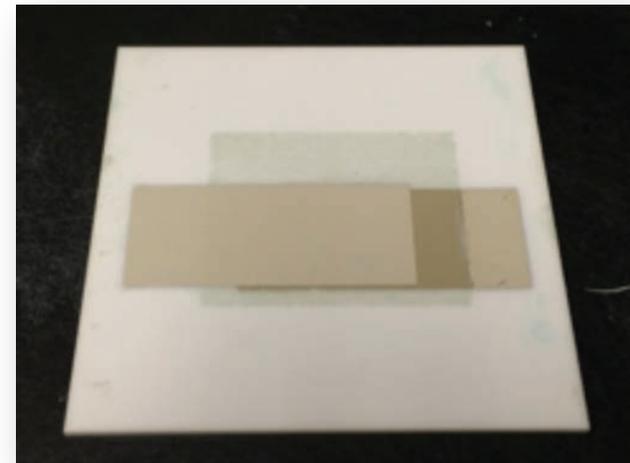
Project Description

This task was for research and development activities leading to a solid-state ultracapacitor to replace batteries. The work focused on internal barrier layer capacitor structures composed of barium titanate (BT) coated with various materials using atomic layer deposition (ALD) techniques.

Notable Accomplishments

Evaluation of the Spark Plasma Sintering task at ORNL was completed. A complete evaluation of zirconia as an alternate coating was conducted. A substantial amount of research in evaluating composite polyimide/BT dielectric materials was carried out. Evaluation of many variations of the single-layer ultracapacitor cell was completed with dielectric inks formulated from the various ALD-coated BT and doped perovskite ceramic materials.

Ultracapacitor device from doped BT materials



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Lattice Boltzmann Method for Modeling Cryogenic Stage Zero-G Propellant Dynamics

Project Manager(s)

Joseph Powers/EV41 - (256) 544-8513

Mindy Nettles/XP50 - (256) 544-1569

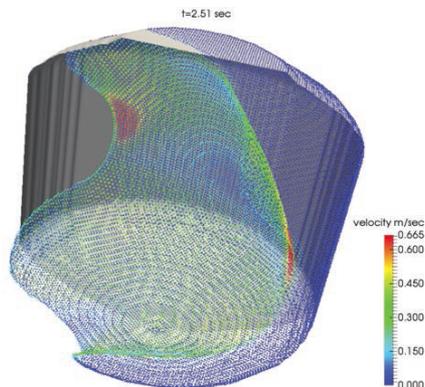
Project Description

Involved developing a new capability to predict liquid propellant sloshing/bulk motion effects on the spacecraft vehicle dynamics in low-g environments. Propellant dynamics are associated with flight conditions such as loiter, startup/shutdown transients, and maneuvering.

Notable Accomplishments

A single-component multiphase (SCMP) proof-of concept flow solver was developed and tested. Implemented the multiple relaxation time turbulence model using D3Q19 lattice and different equations of state to investigate stability properties. Investigated adaptive time stepping for better run-time. Successfully demonstrated stable 3D multiphase flow. Produced a solid foundation of research data that could facilitate transition of the flow solver capability to a production tool using advanced parallel processing hardware and software.

Zero-g fluid transient response in 0.5-m tank



Hot-Fire Test of Liquid Oxygen/Hydrogen Selective Laser Melting Injector Applicable to the Exploration Upper Stage

Project Manager(s)

Elizabeth Robertson/ER21 - (256) 544-9692

Mindy Nettles/XP50 - (256) 544-1569

Project Description

This task was to hot-fire an existing selective laser melting (SLM) injector that is applicable for all expander cycle engines being considered for the Exploration Upper Stage.

Notable Accomplishments

Accomplishments include selecting two of the injectors to use for hot-fire testing and completing the following tasks: Performed nondestructive evaluation on the original SLM injectors; Completed water flow testing; Fabricated the ablative chambers used to support testing; Completed test facility buildup; Wrote the test requirements document; and successfully completed the test readiness review. Completed six hot fire tests.

Water flow and hot-fire testing of two liquid oxygen/hydrogen SLM injectors



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Testing of Selective Laser Melting Turbomachinery Applicable to the Exploration Upper Stage

Project Manager(s)

Elizabeth Robertson/ER21 - (256) 544-9692

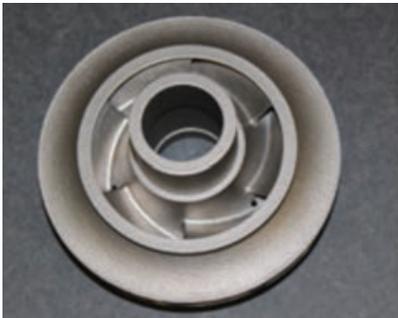
Mindy Nettles/XP50 - (256) 544-1569

Project Description

This task was to design, fabricate, and spin test to failure a Ti6-4 hydrogen turbopump impeller that was built using the selective laser melting (SLM) fabrication process. The impeller is sized around upper stage engine requirements. In addition to the spin burst test, material testing will be performed on coupons that were built with the impeller.

Notable Accomplishments

Accomplishments for this task include the design of the SLM impeller, impeller and material coupon fabrication, final machining, structured light scanning and inspection, spin burst testing, material strength data development, and data analysis. The spin test was successfully performed and operated up to 147,600 rpm, with the result that the impeller could not be failed with the equipment used.



SLM Ti6-4 manufactured turbopump impeller



Orion Delta 3D printer and manufactured part

Additive Manufacturing Infrared Inspection

Project Manager(s)

Darrell Gaddy/ER43 - (256) 544-0198

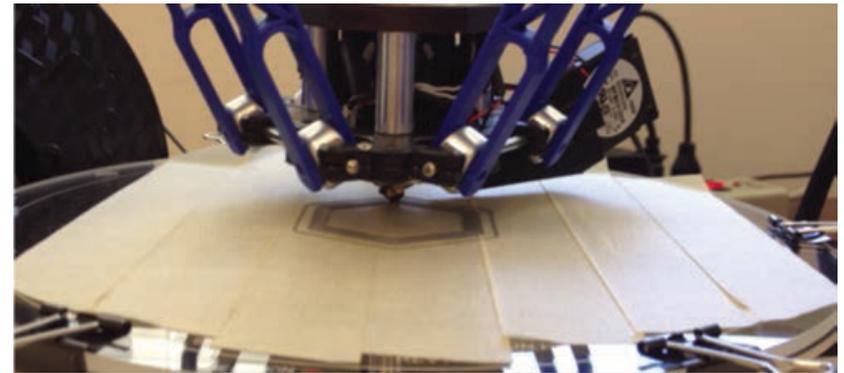
Mindy Nettles/XP50 - (256) 544-1569

Project Description

The Additive Manufacturing Infrared Inspection task started the development of a real-time dimensional inspection technique and digital quality record for the additive manufacturing process using infrared camera imaging and processing techniques. This will benefit additive manufacturing by providing real-time inspection of internal geometry that is not currently possible. It will also reduce the time and cost of additive manufactured parts with automated real-time dimensional inspections which deletes post-production inspections.

Notable Accomplishments

The task successfully proved the feasibility of infrared hardware for detecting additive manufacturing process. Custom software was developed to create 3D geometry files of the additively manufactured part.



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Performance Improvement of Friction Stir Welds by Better Surface Finish

Project Manager(s)

Sam Russell/EM20 - (256) 544-4411

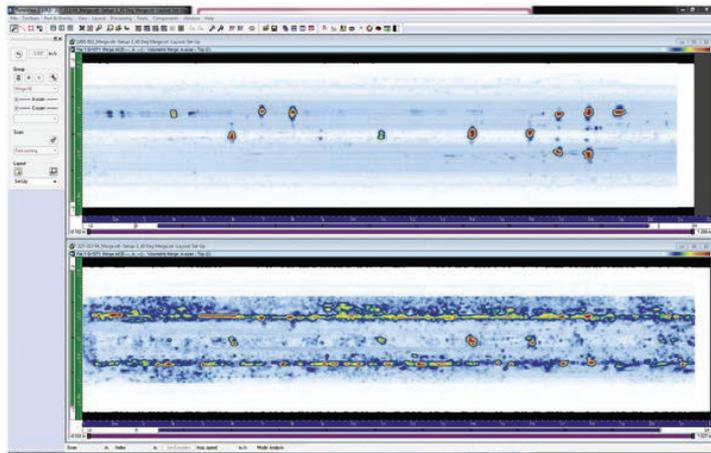
Mindy Nettles/XP50 - (256) 544-1569

Project Description

This study measures stress concentration effects and will develop an improved phased array ultrasonic testing (PAUT) technique for friction stir welding.

Notable Accomplishments

A report on SR-FSW was completed in FY 2015 and conventional friction stir welds (C-FSWs) were studied.



(a) PAUT scan of notched weld panel with welds smoothed and (b) PAUT notched weld panel with normal surface preparation. Both panels have the same electrical discharge machining notch pattern, seen as the colored spots.

Q2 Inconel 625 Material Properties Development Project Manager(s)

Kenneth Cooper/EM42 - (256) 544-8591

Mindy Nettles/XP50 - (256) 544-1569

Project Description

Involved the development and characterization of selective laser melting (SLM) parameters for additive manufacturing of nickel alloy 625 (a.k.a., Inconel® 625, or In625).

Notable Accomplishments

Design of experiments on 100 samples to determine the effects of changes in the global energy input on Rockwell hardness of produced coupons. Completed a study of annealing temperatures on mechanical properties and material microstructure. Established heat treatment parameters for future Inconel 625 processing. Planned a round robin test series in order to evaluate the state of the industry for SLM Inconel 625 production in terms of quality of material produced and amount of variability between vendors. Obtained commitments from three outside vendors to provide two test specimen builds each.

Completed samples ready for testing



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Q4 Titanium 6-4 Material Properties Development

Project Manager(s)

Kenneth Cooper/EM42 - (256) 544-8591

Mindy Nettles/XP50 - (256) 544-1569

Project Description

This task involved the development and characterization of selective laser melting (SLM) parameters for additive manufacturing of titanium-6%aluminum- 4%vanadium (a.k.a., Ti-6Al-4V, or Ti64).

Notable Accomplishments

Developed training and procedures for safe handling of reactive Ti64 powder. Developed initial SLM machine parameters to successfully build Ti64 parts. Corrected issues with baseplate materials. Evaluated state-of-the-industry for SLM Ti64 development. Provided recommendations for continued development efforts using alternative technologies.



SLM machine with glovebox required for Ti64

Composite Dry Structure Cost Improvement

Approach

Project Manager(s)

Alan Nettles/EM20 - (256) 544-6109

Mindy Nettles/XP50 - (256) 544-1569

Project Description

This effort demonstrates that by focusing only on properties of relevance, composite interstage and shroud structures can be placed on the Space Launch System vehicle that simultaneously reduce cost, improve reliability, and maximize performance. **This** effort provides a new methodology of how to utilize composites to reduce weight for composite structures on launch vehicles.

Notable Accomplishments

Testing of laminate is expensive and futile since no laminate failure criteria have been shown to be valid for practical use. Undamaged laminate testing is time consuming and costly. This is hard to justify, as these strength numbers will probably never be used since damage must be assumed to exist in the laminate. Undamaged laminate testing is more of a 'test of the test method' rather than a material property test. If a structure has a dominant loading case (such as compression for an interstage structure), then characterizing other strength (such as tension) is of no practical use. Costly fatigue testing is usually not necessary. The statistical significance (the obtaining of which is very costly) of the multitude of undamaged test specimens is lost many times over by the time a final design number for a given piece of hardware is agreed upon. Also, the final product will have an optimum layup based on undamaged properties that may not result in an optimum layup for damage tolerance considerations. This may contribute to design values that are either too high (poor reliability) or too low (compromised performance).

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Pyroshock Characterization of Composite Materials

Project Manager(s)

David Ordway/EV32 - (256) 544-8087

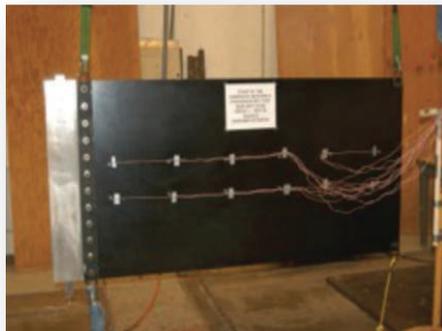
Steven Gentz/C105 - (256) 544-1642

Project Description

Composite materials are being considered for incorporation into the evolved Space Launch System (SLS) vehicle to improve performance and affordability. This task evaluates composite materials to ensure they can withstand the stresses induced into the vehicle during launch and stage separation.

Notable Accomplishments

Completed all 28 of the task assessment baseline composite pyroshock tests, which included 10 monolithic composite panel tests and 18 sandwich composite panel tests. Algorithms were developed to analyze the shock data, and statistical analysis was completed on the output from the algorithms for the monolithic composite panels. Analysis of the sandwich composite panel test data was completed. Testing of composite panels with and without melamine acoustic dampening foam was completed. The shock data from these tests were qualitatively compared to evaluate the effect the addition of acoustic foam has on shock transmissibility in the composite materials.



Pyroshock Test article

Booster Interface Loads

Project Manager(s)

Bill Wood/Langley Research Center - (757) 864-8355

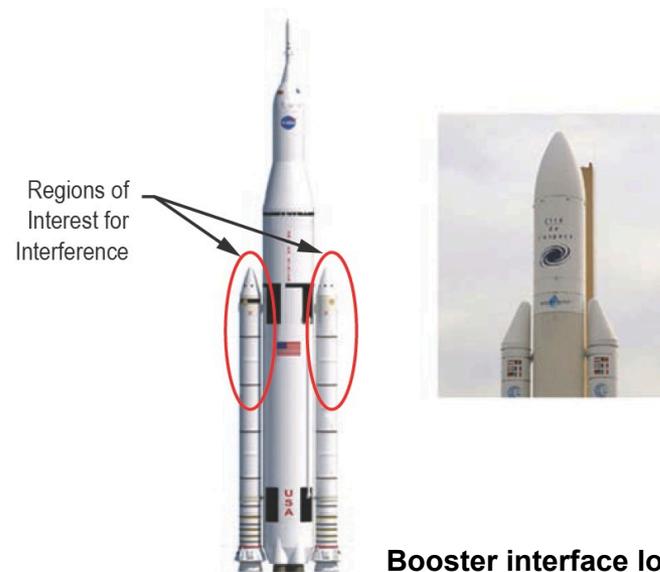
Steven Gentz/C105 - (256) 544-1642

Project Description

The interaction between shock waves and the wake shed from the forward booster/core attach hardware results in unsteady pressure fluctuations, which can lead to large buffeting loads on the vehicle. This task investigates whether computational tools can adequately predict these flows, and whether alternative booster nose shapes can reduce these loads.

Notable Accomplishments

The project has completed an initial set of computational fluid dynamics (CFD) cases covering six booster nose configurations for two Mach numbers and two angles of attack.



Booster interface loads

MSFC Technology Year in Review 2015

Advanced Booster High-Performance Solid Propellant and Composite Case/ Polybenzimidazole Nitrile Butadiene Rubber Insulation Development

Project Manager(s)

Jessica Chaffin/ER51 - (256) 544-5692

Steven Gentz/C105 - (256) 544-1642

Project Description

This assessment supported the evaluation of risk reduction for large booster component development/fabrication, NDE of low mass-to-strength ratio material structures, and solid booster propellant formulation. This work was requested in the Space Launch System (SLS) NASA Research Announcement for Advanced Booster Engineering Demonstration and/or Risk Reduction.

Notable Accomplishments

Evaluation of the HTPB formulation for improving mechanical properties at high solids loading (90%) has been completed. Additionally, scale-up of optimized HTPB formulation for propellant and bondline accelerated aging, and evaluation of burn rates through strands and subscale motors, was completed.



**Propellant
mixing at
AMRDEC**

Advanced Booster Combustion Stability Project Manager(s)

Kevin Tucker (retired)/ER42

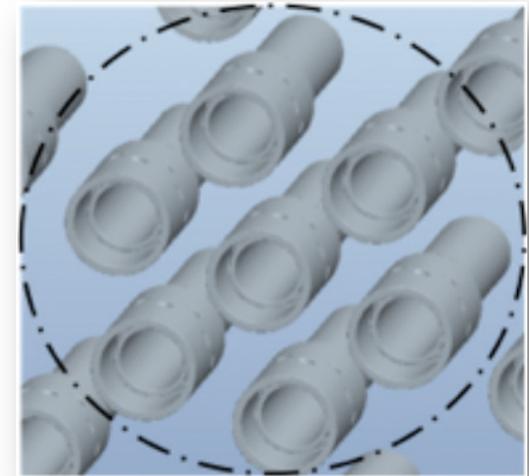
Steven Gentz/C105 - (256) 544-1642

Project Description

The objectives of this task were to (1) advance the predictive capability of state-of-the-practice combustion stability methodologies and tools used for the Space Launch System (SLS) injector combustion stability assessment, (2) facilitate more confident identification and characterization of combustion instabilities and efficient mitigation during SLS propulsion system development, and (3) minimize SLS development costs and improve hardware robustness.

Notable Accomplishments

Injector element design, scaling, testing, and computational fluid dynamics (CFD) simulation were completed. Demonstration of new capabilities on SLS Advanced Booster Engineering Design Risk Reduction (ABEDRR) injector was also accomplished.



**Seven elements
from an ABEDRR
injector**

MSFC Technology Year in Review 2015

High Electrical Energy Density Devices for Aerospace Applications *Auburn University*

Project Manager(s)

Z.Y. Cheng/Auburn University - (334) 844-3419

B.A. Chin/Auburn University - (334) 844-3322

Jeff Brewer/ES44 - (256) 544-3345

Terry Rolin/ES43 - (256) 544-5579

Project Description

This effort was to develop a database of the characteristics and specifications of commercially available electrical energy devices and experimentally determine the characteristics and specifications of these devices.

Notable Accomplishments

Using different electrical loads to simulate different applications in aerospace environments. Identifying the most promising candidates for use on space vehicles. Identifying emerging technologies in the energy storage device discipline and their potential applications.

Challenges Towards Improved Friction Stir Welds Using Online Sensing of Weld Quality *Louisiana State University*

Project Manager(s)

Muhammad Wahab/Louisiana State University - (225) 578-5823

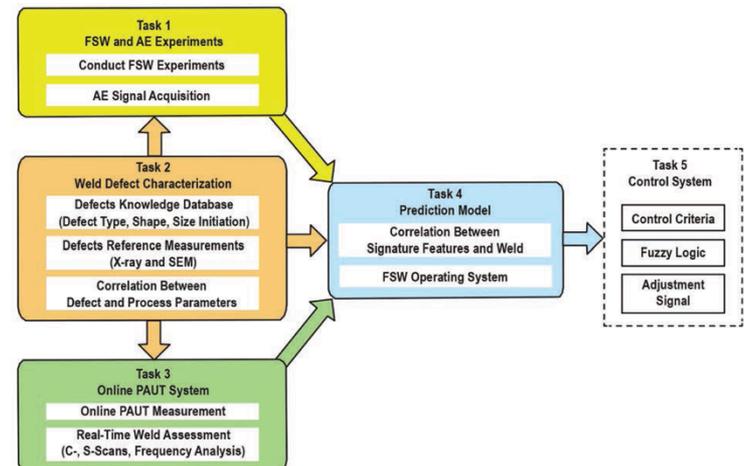
Arthur Nunes/EM32 - (256) 544-2699

Project Description

This task developed an online real-time system to determine weld quality for friction stir welds that may ultimately eliminate or reduce unforeseen or sudden failures in lightweight welded structures, increase cost effectiveness, and decrease risk.

Notable Accomplishments

Four issues have been analyzed, including defect regions, temperature during FSW, fracture surface and systems engineering management (SEM) analysis, and fracture origination detection methods.



Louisiana State University activity flow chart

MSFC Technology Year in Review 2015

A New Modeling Approach for Rotating Cavitation Instabilities in Rocket Engine Turbopumps

Massachusetts Institute of Technology

Project Manager(s)

Z. Spakovszky/Massachusetts Institute of Technology - (617) 253-2196

Andrew Mulder/ER42 - (256) 544-6750

Thomas Zoladz/ER40 - (256) 544-1552

Project Description

This project investigates the mechanism of formation and propagation of rotating cavitation in rocket engine turbopump inducers.

Notable Accomplishments

A new, open geometry, inducer platform for investigating cavitation dynamics was established and experimentally verified, fostering new research and broader dissemination of the results and insight. The hypothesized mechanism responsible for the onset of alternate blade cavitation and rotating cavitation has been identified in the calculations and will be verified with optical measurements.



Inducer rotating cavitation instabilities

Low Dissipation and High Order Unstructured Computational Fluid Dynamics Algorithms to Complement the Use of Hybrid Reynolds-Averaged Navier Stokes/Large Eddy Simulation Algorithms *Mississippi State University*

Project Manager(s)

Keith Walters/Mississippi State University - (662) 325-8231

Ed Luke/Mississippi State University - (662) 325-8424

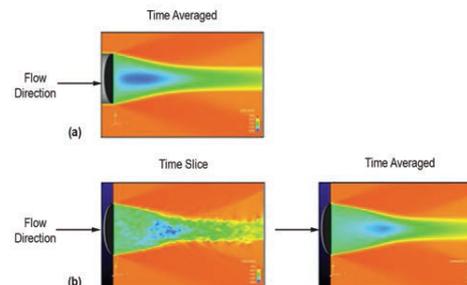
Chris Morris/EV33 - (256) 544-6728

Project Description

Developed a new methodology to predict loads (steady and unsteady) and heating for the Space Launch System (SLS) vehicle by using a hybrid Reynolds-averaged Navier Stokes (RANS)/large eddy simulation (LES) approach to directly capture turbulent fluid motion in parts of a simulation.

Notable Accomplishments

Initial implementations of two numerical methods in Loci/CHEM that result in improved capturing of unsteady and turbulent flow physics. Work in year two has resulted in stability improvements to these new methods, and development and testing of an improved dynamic hybrid RANS/LES turbulence model was also conducted.



Fluid motion: (a) Current capability versus (b) improved simulation techniques

MSFC Technology Year in Review 2015

Next Generation Simulation Infrastructure for Large-Scale Multicore Architectures *Mississippi State University*

Project Manager(s)

Ed Luke/Mississippi State University - (662) 325-8424

Jeff West/ER42 - (256) 544-6309

Project Description

The main goal of this project was to significantly advance the already high scalability of the Loci system to facilitate extreme scales that these advanced models will require.

Notable Accomplishments

The implementation of a prototype hybrid thread scheduler for Loci is complete and a comprehensive characterization of the thread parallelism inherent to the Line Symmetric Gauss-Seidel Linear System Solver (LSGS) used by many Loci codes has been performed. A robust vectorization strategy for the LSGS solver has been developed. Extension of the scale of entities managed by the Loci system has been increased from 2 billion to 4 billion entities, enabling a doubling of the scale of simulations that can be performed by Loci codes.

Development of Subcritical Atomization Models in the Loci Framework for Liquid Rocket Injectors *University of Florida*

Project Manager(s)

Siddharth Thakur/University of Florida - (352) 392-0817

Mrinal Kumar/University of Florida - (352) 392-0886

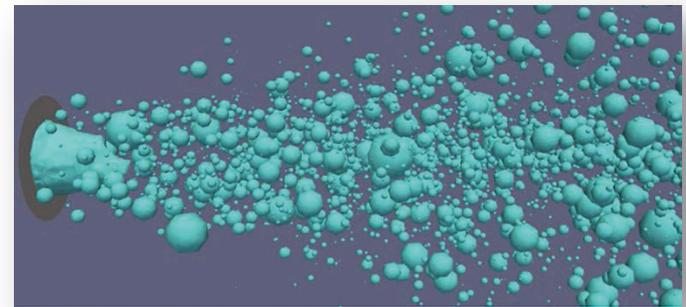
Jeff West/ER42 - (256) 544-6309

Project Description

The main objective of this project was to develop primary atomization modeling capability in the Loci-STREAM and Loci/CHEM codes using a computationally tractable phenomenological stochastic model. The accurate characterization of primary and secondary atomization in liquid rocket injectors operating under subcritical conditions was the desired goal.

Notable Accomplishments

Initial simulation results capturing the time-varying probabilistic distribution of the intact liquid core have been obtained. In addition, the developed unsteady models have been assimilated into the Loci-STREAM framework and coupled with the background flow solver.



Liquid jet break-up modeled by the stochastic primary atomization model

MSFC Technology Year in Review 2015

Determination of Heat Transfer Coefficients for Two-Phase Flows of Cryogenic Propellants During Line Chilldown and Fluid Transport *University of Florida*

Project Manager(s)

J.N. Chung/University of Florida - (352) 392-0886

Alok Majumdar/ER43 - (256) 544-8555

Project Description

The general scope of the project was to acquire detailed experimental data in both terrestrial and microgravity conditions for characterizing heat transfer coefficients in two-phase flows of cryogenic propellants (using liquid nitrogen as a simulant) with and without ingested helium gases.

Notable Accomplishments

An experimental database for all the cases without ingested helium has been successfully completed. An experimental system has been modified for the inclusion of helium ingestion effects, and some preliminary runs have been achieved.

Validation of Supersonic Film Cooling Numerical Simulations Using Detailed Measurement and Novel Diagnostics *University of Maryland*

Project Manager(s)

Chris Cadou/University of Maryland - (301) 405-0829

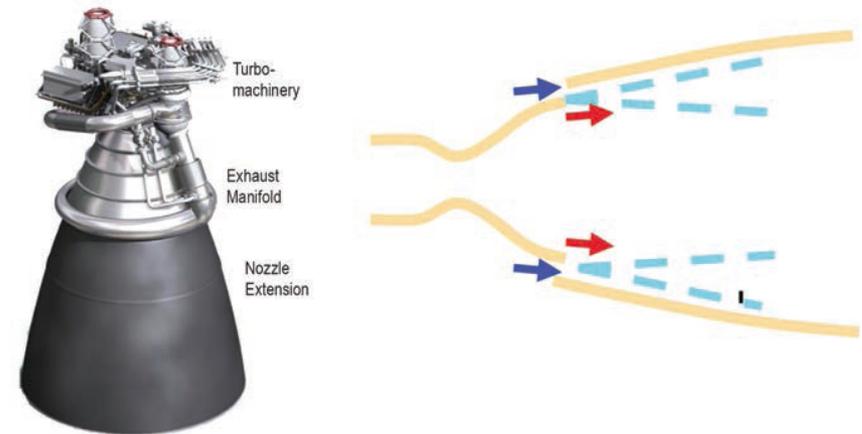
Joe Ruf/ER42 - (256) 544-4942

Project Description

This activity developed a numerical methodology and experimental data sets to enable validation of fluid dynamics simulations of supersonic film cooling (SSFC).

Notable Accomplishments

Detailed measurements of heat flux and pressures have been made for multiple film coolant flow rates. Work has begun to incorporate the lessons learned into fluid dynamic simulations implementing MSFC workhouse fluids code, Loci/CHEM.



J-2X film-cooled nozzle extension

MSFC Technology Year in Review 2015

Advanced Large Eddy Simulation and Laser Diagnostics to Model Transient Combustion-Dynamical Processes in Rocket Engines: Prediction of Flame Stabilization and Combustion Instabilities *University of Michigan and Stanford University*

Project Manager(s)

Jim Driscoll/University of Michigan - (734) 936-0101

Matthias Ihme/Stanford University - (650) 724-3730

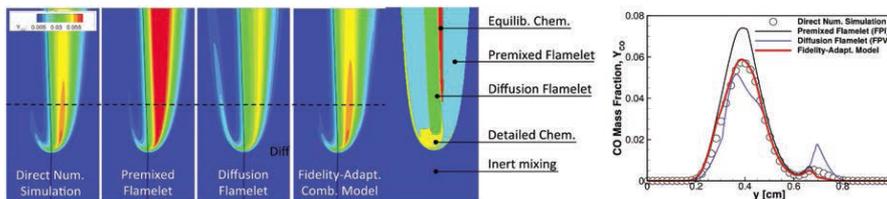
Jeff West/ER42 - (256) 544-6309

Project Description

The objective of this computational and experimental research effort is the development of a fully validated high-fidelity combustion modeling capability to enable the accurate prediction of unstable and combustion dynamical processes involving flame lift-off and flame stabilization in rocket engines.

Notable Accomplishments

This activity developed a methodology to enable advanced LES and laser diagnostics to model transient combustion dynamic processes in rocket engines. Experiments were conducted to investigate the combustion stability characteristics of shear coaxial injectors.



(a) Comparison of CO predictions from DNS, single-regime premixed flamelet and diffusion models, and newly developed FAM model; (b) combustion subzone identification to achieve optimal combustion submodel assignment; and (c) quantitative comparison of CO predictions from DNS, single-regime flamelet models, and FAM

Characterization of Aluminum/Alumina/Carbon Interactions Under Simulated Rocket Motor Conditions *Pennsylvania State University* Project Manager(s)

Kenneth Kuo/Pennsylvania State University - (814) 863-6270

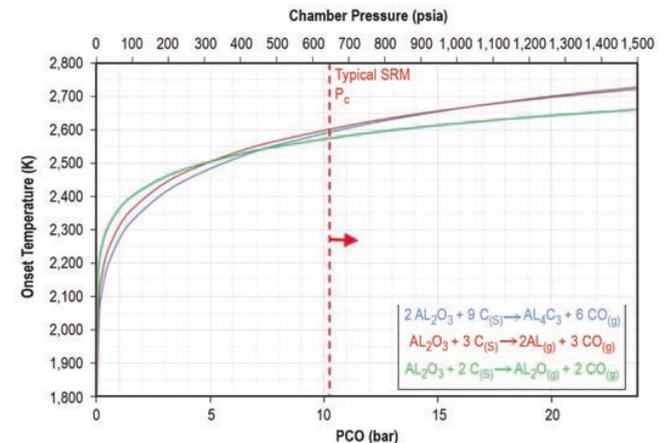
Matthew Cross/ER43 - (256) 544-1724

Project Description

The primary goal is evaluation of the chemical reaction mechanism and approximate reaction rates between Al₂O₃ and carbon.

Notable Accomplishments

55 laser-heating experiments were conducted. Of those, 29 tests were considered in the nominal configuration with 100% Al₂O₃ in graphite crucible, 23 were conducted with Ar, and six with CO atmospheres. In addition, eight were conducted with various Al₂O₃/Al mixtures. Development of a unique high-pressure, high-temperature induction furnace (1,000 psia and 2,700 K) was completed.



Onset temperature of several Al₂O₃/carbon reactions as functions of CO partial pressure and corresponding SRM chamber pressure

MSFC Technology Year in Review 2015

Acoustic Emission-Based Health Monitoring of Space Launch System Vehicles *University of Utah* Project Manager(s)

V. John Mathews/University of Utah - (814) 863-6270

Daniel Adams/University of Utah - (801) 585-9807

Alan Nettles/EM20 - (256) 544-6109

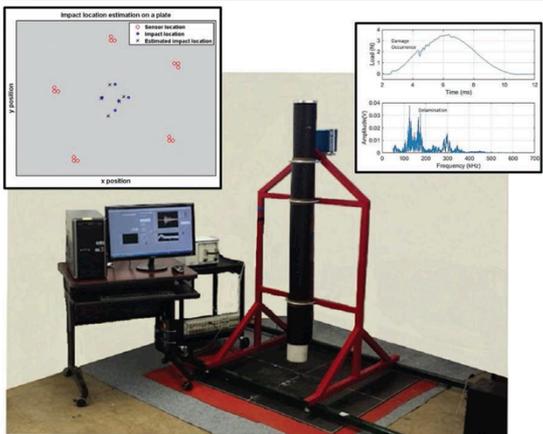
Project Description

An acoustic, emission-based structural health monitoring system is being developed for Space Launch System (SLS) vehicles using a sparse distribution of sensors. The system will estimate the location of impact events on metallic and composite structures and determine whether the impact has produced damage in a composite structure and indicate the type of composite damage produced.

Notable Accomplishments

Developed an automated method for time-of-arrival estimation required for impact location estimation in composite structures.

Developed a modified impact location estimation algorithm for use on composite sandwich structures.



Instrumented impact of composite panel with acoustic emission sensor network. Performance analyses have shown that the method works well for composite laminates and sandwich structures without prior knowledge of the anisotropic properties of the structure.

MSFC Technology Year in Review 2015

Science Mission Directorate



NASA's Science Mission Directorate (SMD) conducts scientific exploration enabled by the use of space observatories and space probes that view the Earth from space, observe and visit other bodies in the solar system, and peer out into our Galaxy and beyond.

- Mars Ascent Vehicle
- Advanced Ultraviolet, Optical, and Infrared (UVOIR) Mirror Technology Development for Very Large Space Telescopes

MSFC Technology Year in Review 2015

Mars Ascent Vehicle

Project Manager(s)

John Dankanich/ZP30 - (256) 544-3441

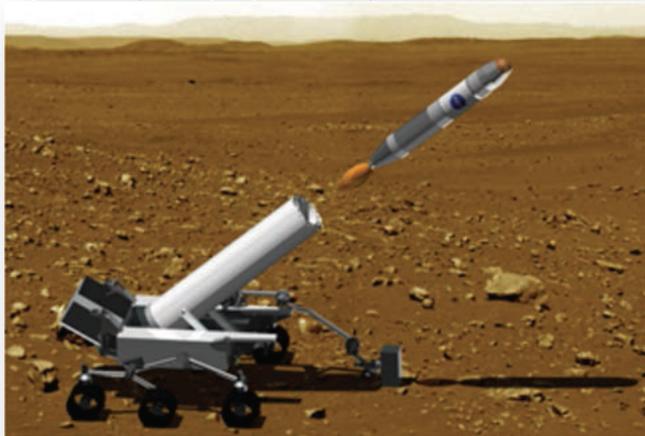
Robert Shotwell/Jet Propulsion Laboratory - (256) 544-6562

Project Description

The scope of these tasks included completion of a third design and analysis cycle (DAC) of a first stage solid motor with industry partner ATK; a fourth DAC in-house led by MSFC; completion of a new propellant formulation project, thrust vector control assessment, concept development, and fuel environmental testing for a hybrid MAV; and assessment of a liquid MAV with potential to freeze and thaw propellants.

Notable Accomplishments

The first stage solid motor DAC-4 was completed, meeting nearly all metrics for the two-stage solid MAV; the propellant formulation completed development with superior performance to alternative formulation for the MAV environment, and concepts were developed for reduced mass and resources (heating) required using either liquid or hybrid propulsion systems.



**MAV
launched
from the
mobile MAV
platform**

Advanced UVOIR Mirror Technology Development for Very Large Space Telescopes

Project Manager(s)

H. Philip Stahl/ZP10 - (256) 544-0445

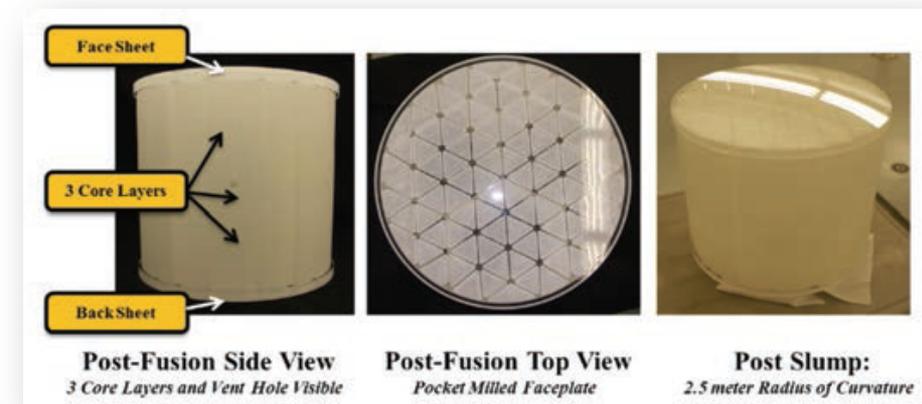
Michael Effinger/ZP21 - (256) 961-7485

Project Description

The Advanced Mirror Technology Development (AMTD) project is in phase 2 of a multiyear effort, initiated in FY 2012, to mature the Technology Readiness Level (TRL) to TRL-6 by 2018 for critical technologies. These technologies are required to enable 4-m-or-larger ultraviolet, optical, and infrared (UVOIR) space telescope primary mirror assemblies for general astrophysics and ultrahigh contrast observations of exoplanets.

Notable Accomplishments

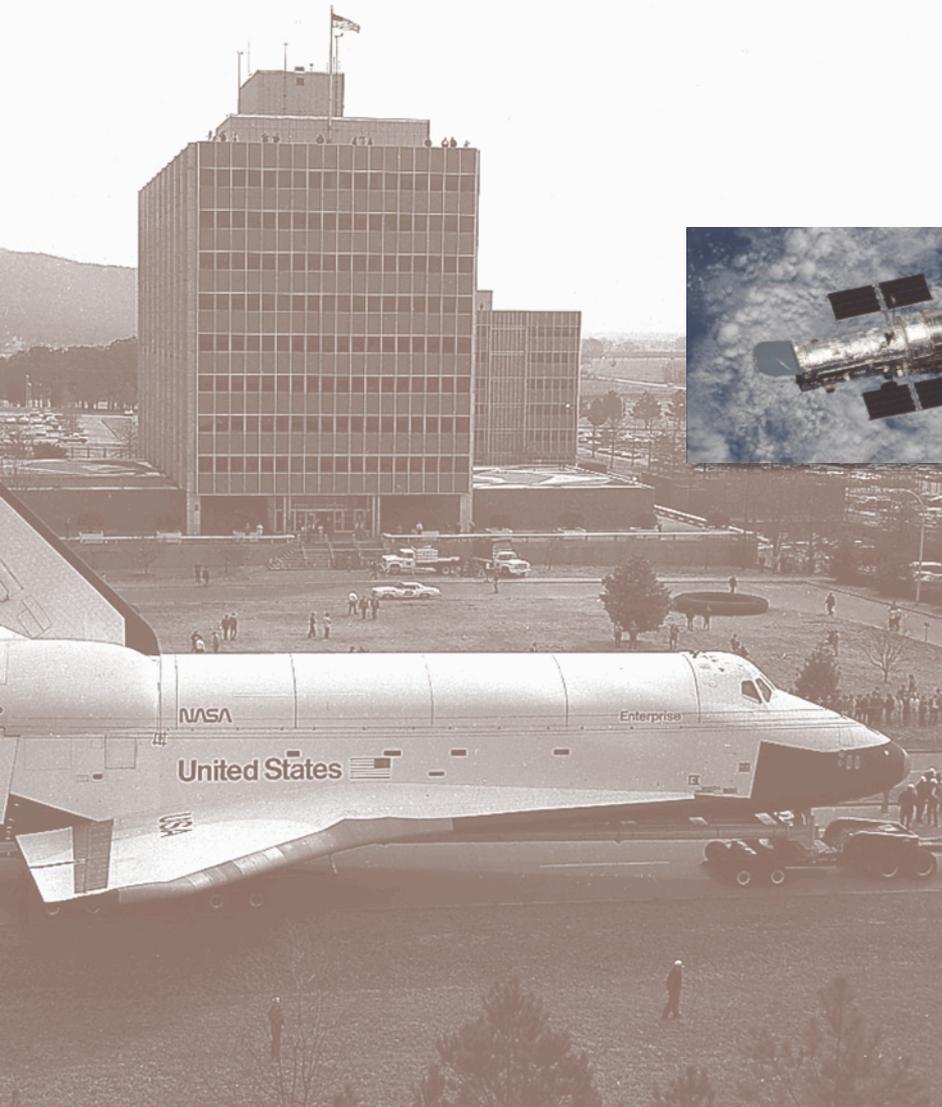
The advancements of AMTD phase 1 were successfully reviewed by the Cosmic Origins Program Office TRL Review Board, and phase 2 technology areas are progressing.



Deep core mirror at different processing stages

MSFC Technology Year in Review 2015

Space Technology Mission Directorate



The Space Technology Mission Directorate (STMD) is responsible for developing the crosscutting, pioneering, new technologies and capabilities needed by the agency to achieve its current and future missions. STMD rapidly develops, demonstrates, and infuses revolutionary, high-payoff technologies through transparent, collaborative partnerships, expanding the boundaries of the aerospace enterprise. STMD employs a merit-based competition model with a portfolio approach, spanning a range of discipline areas and technology readiness levels. By investing in bold, broadly applicable, disruptive technology that industry cannot tackle today, STMD seeks to mature the technology required for NASA's future missions in science and exploration while proving the capabilities and lowering the cost for other government agencies and commercial space activities.

MSFC Technology Year in Review 2015

Technology Demonstration Missions (TDM)

- Technology Demonstration Missions Summary
- Evolvable Cryogenic Project Portfolio
- Composites for Exploration Upper Stage

Centennial Challenges Program (CCP)

- Centennial Challenges Summary

Game Changing Development (GCD)

- Fast Light Optical Gyroscopes
- Adjustable Grazing-Incidence X-ray Optics
- Multi-spacecraft Autonomous Positioning System
- NanoLaunch
- Magnetogram Forecast: An All-Clear Space-Weather Forecasting System
- Programmable Ultra-Lightweight System Adaptable Radio
- Propulsion Descent Technologies
- Materials Genome Initiative
- Low Cost, Upper Stage-Class Propulsion
- Additive Construction With Mobile Emplacement
- Microelectrospray Thrusters

Small Business Innovation Research (SBIR)

- Small Business Innovation Research and Small Business Technology Transfer Programs

Small Spacecraft Technology Program (SSTP)

- Iodine Satellite

Center Innovation Fund (CIF)

- Flexible Hybrid Battery/Pseudocapacitor Using Carbon Nanotube Electrodes
- High-Fidelity Design Tools and a New Hydrogen Containment Process for Nuclear Thermal Engine Ground Testing
- Novel Aerogel-Based Catalysts for Spacecraft Life Support Application
- Deployable Nozzle Extension
- Novel Metrology Concept for High-Resolution Grazing Incidence Optics
- Correlated Electromagnetic Levitation Actuator
- Flexible Electrostatic Tools for Capture and Handling
- Superior Epoxies for Cryogenic Composite Tank Fabrication
- Radar Hazard Identification for Planetary Landers
- Linear Transformer Driver Development
- Second Generation QUATARA Flight Computer

MSFC Technology Year in Review 2015

Technology Demonstration Missions Summary

Project Manager(s)

Larry Gagliano/FP50 - (256) 544-7175

Danny Harris/FP50 - (256) 961-7353

Raymond French/FP50 - (256) 961-7642

Project Description

The Technology Demonstration Missions (TDM) program is completing four years of funding and managing state-of-the-art missions, which align with the strategic goals of NASA and the Space Technology Mission Directorate. During the 2014-2015 year, NASA Marshall Space Flight Center (MSFC) has managed seven projects as part of the TDM program:

- Low Density Supersonic Decelerator (LDSD)
- Green Propellant Infusion Mission (GPIM)
- Deep Space Atomic Clock (DSAC)
- Evolvable Cryogenics (eCryo)
- Laser Communications Relay Demonstration (LCRD)
- Composites for Exploration Upper Stage (CEUS)
- Solar Electric Propulsion (SEP)

Notable Accomplishments

LDSD: A successful subsonic inflation load test of two 30-meter supersonic ring sail parachutes was completed, as well as the integration activities for Test Vehicles 2 and 3. A Supersonic Flight Dynamics Test was conducted and yielded profitable data.

GPIM: Five thrusters were integrated onto the Green Propellant Propulsion Subsystem (GPPS) and the GPPS onto the BCP-100 spacecraft.

DSAC: Flight software and the clock hardware were completed, integrated, and tested and began flight payload testing and integration.

eCryo: Successfully completed formulation review and Key Decision Point-C (KDP-C). Shared lessons learned from the EDU tank build and test. Radio Frequency Mass Gauge avionics simulator was designed, built, and delivered to Goddard Space Flight Center for a flight demonstration, and Phase A testing of a study for an Integrated Vehicle Fluids systems was completed.

LCRD: The space switching unit, the controller electronics box, and the optical gimbal assembly were delivered for integration and testing. A successful demonstration of bi-directional communication between the MIT-LL and the LCRD hardware was completed.

CEUS: Successfully completed a System Requirements Review (SRR) and Key Decision Point-B (KDP-B) and established an Automated Fiber Placement robotic fabrication capability at Langley Research Center and MSFC.

SEP: Completed fabrication and testing of 300V and 120V power processing units as well as a HERMeS thruster operating in a vacuum chamber at Glenn Research Center. Subsequently, integration tests were performed demonstrating the HERMeS thruster operation with the 300V and the 120V power processing units. An Asteroid Retrieval Vehicle reference configuration was developed for future missions.

MSFC Technology Year in Review 2015

Evolvable Cryogenic Project Portfolio

Project Manager(s)

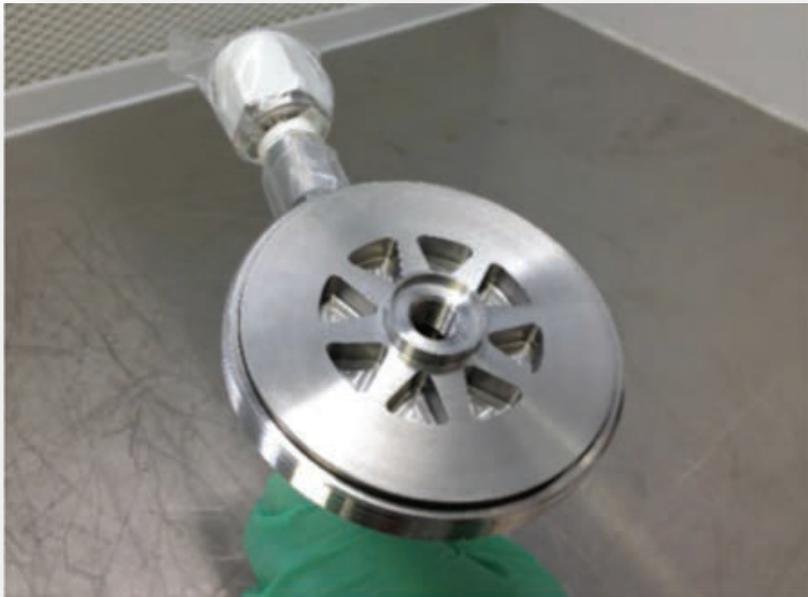
Arthur Werkheiser/ZP30 - (256) 544-1269

Project Description

The main objective of this task is to enhance the knowledge and technology related to handling cryogenic propellants; specifically liquid hydrogen. The VSLT was an effort to find a better cryogenic valve seat material that could reduce leakage of cryogenic liquids by at least two magnitudes.

Notable Accomplishments

MSFC is applying for a patent on the newly developed cryogenic valve design.



Valve seat leak test element

Composites for Exploration Upper Stage

Project Manager(s)

John Vickers (EM01) - (256) 544-3581

John Fikes (ZP30) - (256) 544-5570

Project Description

The purpose of this project is to design, build, and test composite Universal Stage Adapter (USA) structures on the same scale needed for the EUS to validate manufacturability, structural margins, and weight savings. The project is also advancing the certification pathway for inclusion of composites on future large human rated launch vehicles, and providing designers a validated alternative structural material candidate in future trade studies for SLS as well as other large booster and space science platform structures.

Notable Accomplishments

A composite tool was designed and built to allow for 1/8th arc segments of a 12-foot tall cylindrical panel to be manufactured at the MSFC Composites Technology Center and delivered to MSFC.



MSFC composites AFP capability

MSFC Technology Year in Review 2015

Centennial Challenges Summary

Project Manager(s)

Monsi Roman / NASA / Program Manager - (256) 544-4071

Eric Eberly / NASA / Dep. Program Manager - (256) 544-2092

Project Description

The Centennial Challenges program offers prizes to independent inventors including small businesses, student groups and individuals. These independent inventors are sought to generate innovative solutions for technical problems of interest to NASA and the nation, and to stimulate opportunities for creating new industries and new business ventures.

Notable Accomplishments

The fourth year of the **Sample Return Robot (SRR)** Challenge to demonstrate robots that can locate and retrieve geologic samples from a wide and varied terrain without human control or use of terrestrial navigation aids. No team met the Level 1 competition requirements this year. West Virginia University met two of Level 2 requirements and received a \$100,000 award. The second year of the **Mars Ascent Vehicle (MAV)** Challenge to develop an autonomous robotic system that can load a sample into a rocket, launch to a predetermined altitude of 5,280 feet and safely return the sample container to the earth surface. Fifteen teams participating in the inaugural event: North Carolina State Univ. (1st Place, \$25,000) and Tarleton State Univ. (2nd Place, \$15,000).



The West Virginia University Mountaineers took home a Level 2 prize for \$100,000 at the 2015 Sample Return Robot Challenge, which offers a total \$1.5 million prize purse

The first year of the **Cube Quest Challenge** is to design, build, and launch flight-qualified, small satellites capable of advanced operations near and beyond the moon, to demonstrate communications and propulsion technologies. Thirteen teams participated in Ground Tournament-1 (GT-1); five teams met GT-1 requirements and won \$20,000 each. The top three teams that win GT-4 will have the opportunity to become secondary payloads on the first integrated flight of NASA's Orion spacecraft and SLS rocket. The design challenge of the **3-D Printed Habitat Challenge** is to advance the additive construction technology to create sustainable housing on Earth and beyond. Of the 165 entries received for the Design Competition, 94 met the minimum requirements, with the top 30 competing for the top three places at the Maker Faire in New York. The first-place winner, Team Space Exploration Architecture and Clouds Architecture Office, was awarded \$25,000. The second-place winner, Team Gamma (Foster + Partners), was awarded \$15,000. The third-place winner, EAS European Astronaut Centre, was not eligible to receive prize money because the team was not from the United States.

The Cube Quest Challenge offers a \$5.5 million prize purse



MSFC Technology Year in Review 2015

Fast Light Optical Gyroscopes

Project Manager(s)

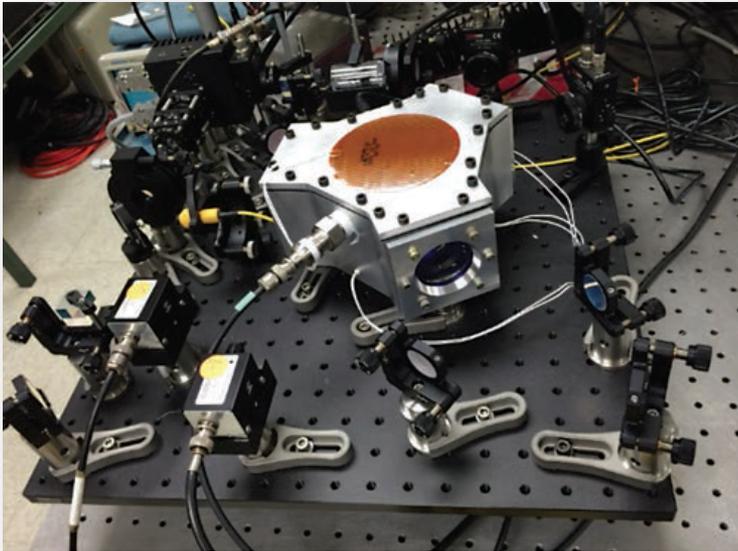
David D. Smith/ES34 - (256) 544-7778

Project Description

MSFC and AMRDEC are working on the development of a passive FLOG (PFLOG), while Northwestern is developing an active FLOG. The project has demonstrated new benchmarks in the state of the art for scale factor sensitivity enhancement.

Notable Accomplishments

Achieved largest cavity scale factor enhancement measured in any system (>300) by temperature tuning an atomic vapor in a unidirectional passive cavity, demonstrating possibility for reduction in quantum noise-limited sensitivity.



Monolithic, vacuum-enclosed, temperature-stabilized atomic vapor PFLOG cavity on a rotation stage

Adjustable Grazing-Incidence X-ray Optics

Project Manager(s)

Stephen L. O'Dell/ZP12 - (256) 961-7776

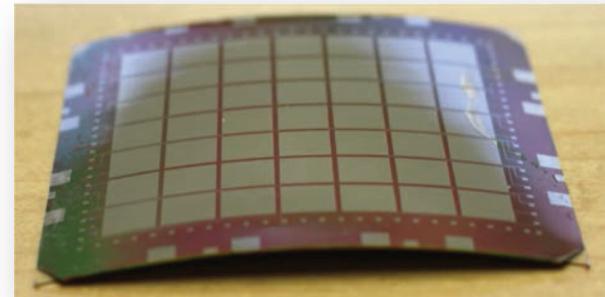
Paul B. Reid/Smithsonian Astrophysical Observatory - (617) 495-7233

Project Description

The goal of this technology research is to enable the cost-effective fabrication of large-area, lightweight grazing-incidence x-ray optics with subarcsecond resolution.

Notable Accomplishments

Made significant progress in developing thin film pixelated piezoelectric devices—over 90% yield in active pixels, on-device thin-film transistors (for row-column addressing) and strain gauges (to monitor deformations), and use of anisotropic conductive films (to simplify electrical connections). MSFC has developed an in-situ stress monitor to help accurately control coating stress during deposition and is preparing with SAO for x-ray testing in late 2016.



Grazing-incidence conical mirror segment with a backside piezoelectric array for active figure correction through voltage-controlled bimorph deformation. The photo displays a fabricated active mirror segment, with a 7 x 7 array of 1-cm square electrodes.

MSFC Technology Year in Review 2015

Multi-spacecraft Autonomous Positioning System

Project Manager(s)

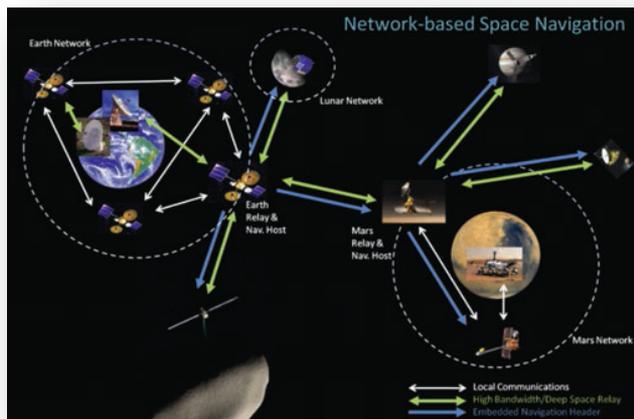
Dr. Evan Anzalone - (256) 544-5492

Project Description

MAPS takes advantage of the growing inter-spacecraft communication network and infrastructure to allow for Earth-autonomous state measurements to enable network-based space navigation. To support initial flight validation, a Low Earth Orbit demonstration mission concept is being developed to capture in-flight accuracy of the spacecraft clocks as well as in-flight packet transmission, and state estimation among a limited number of assets.

Notable Accomplishments

Demonstrated HIL architecture using multiple flatsats communicating via commercial radios simulating LEO Mission. Implementation of MAPS navigation algorithms into flatsat flight software stack using libSprite. Integration and demonstration of MAPS packet definitions with standard CCSDS protocols.



MAPS concept of operations

NanoLaunch

Project Manager(s)

Jonathan Jones/ER50 - (256) 544-1043

Lawanna Harris/EV32 (detailed to ZP30) - (256) 544-9592

Project Description

NASA's NanoLaunch effort seeks to mature both Earth-to-orbit and on-orbit propulsion and avionics technologies, leading to affordable, dedicated access to low-Earth orbit for CubeSat-class payloads.

Notable Accomplishments

NanoLaunch project was able to design, build, test, and successfully launch a high-powered rocket and avionics suite four times.



NL2A single-stage vehicle configuration

MSFC Technology Year in Review 2015

Magnetogram Forecast: An All-Clear Space-Weather Forecasting System

Project Manager(s)

Nasser Barghouty/ - (256)-961-7600

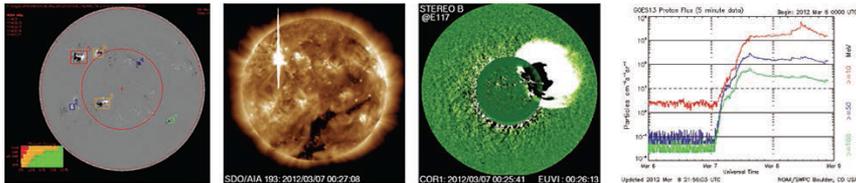
David Falconer / University of Alabama/Huntsville/CSPAR - (256) 961-7616

Project Description

MAG4 system automatically downloads near-real-time line-of-sight (LOS) and Vector Helioseismic and Magnetic Imager (HMI) magnetograms on the Solar Dynamics Observatory (SDO) satellite. MAG4 also identifies active regions on the solar disk, measures a free energy proxy, and then applies forecasting curves to convert the free-energy proxy into predicted event rates. This is done for X-class flares, M- and X- class flares, CMEs, fast CMEs, and Solar Energetic Particle Events (SPEs).

Notable Accomplishments

During FY2015, MAG4 was enabled to use vector magnetograms. A pilot study was conducted that suggests the possibility of forecasting event rates from far-side coronal imagers by estimating the total magnetic flux of far-side active regions using their coronal luminosity, thus, potentially, being able to predict event rates of active regions before they rotate onto the disk.



On the left is seen a graphical display of MAG4 forecast for March 6, 2012, followed by the flare and CME as observed by SDO and STEREO B, respectively. On the right, the SPE event as measured by GOES13.

Programmable Ultra-Lightweight System Adaptable Radio

Project Manager(s)

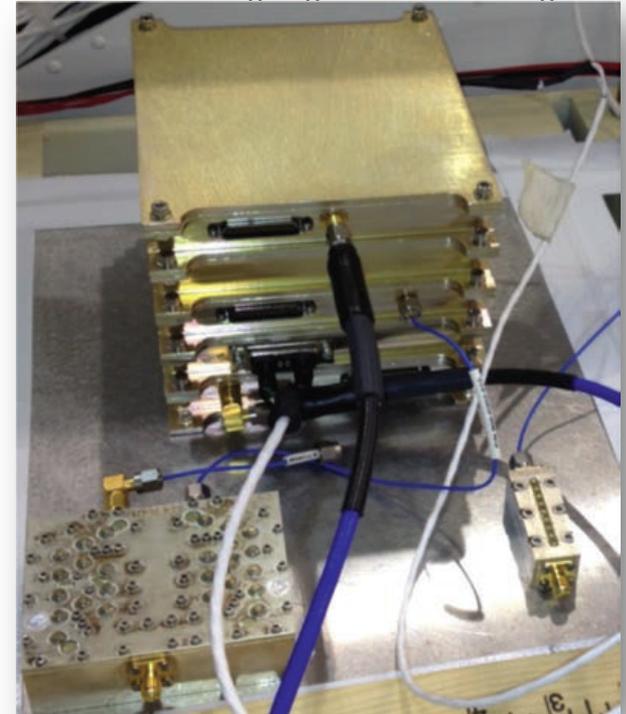
Arthur Werkheiser/ZP30 - (256) 544 - 1269

Project Description

The MSFC Transceiver is designed for the CubeSat market, but has the potential for other markets. PULSAR project aims to reduce size, weight, and power (SWaP) while increasing telemetry data rate.

Notable Accomplishments

PULSAR has been demonstrated during engine hot-fire testing as part of HiDaq.



PULSAR unit

MSFC Technology Year in Review 2015

Propulsion Descent Technologies

Project Manager(s)

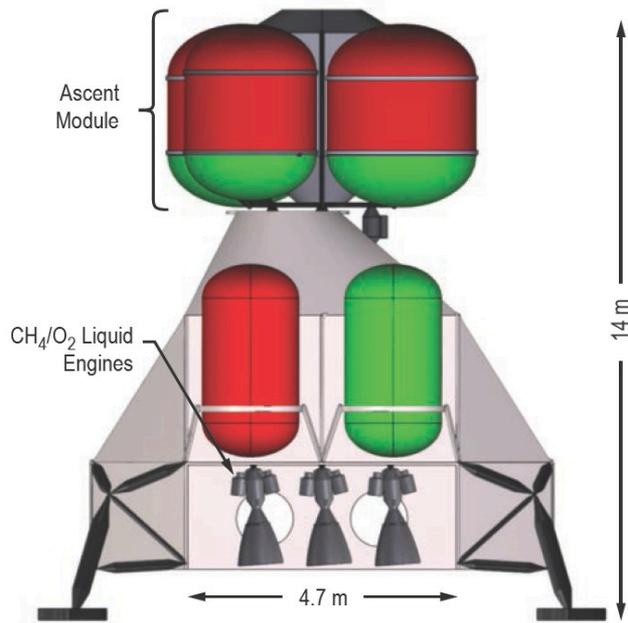
Francisco Canabal / - (256) 544-3053

Project Description

In this project propulsion descent technology aerothermodynamic challenges are investigated. A study is carried out with the human architecture concept for a Mars lander V1 operating in retro-propulsion mode during its descent into Mars atmosphere.

Notable Accomplishments

The main accomplishment of this task is the prediction of the aerothermodynamics environment of a 12 engine Mars lander concept operating in SRP mode.



Mars lander concept V1

Materials Genome Initiative

Project Manager(s)

John Vickers/ EM01 - (256) 544-3581

John Fikes (ZP30) - (256) 544-5570

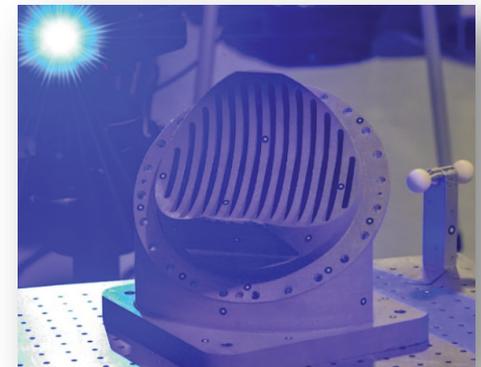
Project Description

The MGI Project Element is a cross-center effort focused on the integration of computational tools to simulate manufacturing processes and materials behavior. These computational simulations will be utilized to gain understanding of processes and materials behavior to accelerate process development and certification. This work will help to more efficiently integrate new materials in existing NASA projects and lead to the design of new materials for improved performance.

Notable Accomplishments

A near-IR camera system has been developed and calibrated to monitor the melt pool for metallic additive manufacturing systems. Thermal maps of the melt pool and semi-solidus areas have been analyzed to develop algorithms to track and quantify the melt pool area. Thermal models of the the melt pool for two SLM systems being used by the SLS program have been developed to modify processing parameters to improve reproducibility of the SLM process.

Pogo Z-baffle additively manufactured for use in SLS



MSFC Technology Year in Review 2015

Low Cost, Upper Stage-Class Propulsion

Project Manager(s)

John Vickers/ EM01 - (256) 544-3581

John Fikes (ZP30) - (256) 544-5570

Tony Kim (ZP30) - (256) 544-6217

Project Description

The Low Cost Upper Stage-Class Propulsion (LCUSP) project element will (1) develop materials properties and characterization for SLM manufactured GRCop, (2) develop and optimize SLM manufacturing process for a full component GRCop chamber and nozzle, (3) develop and optimize the Electron Beam Freeform Fabrication (EBF3) manufacturing process to direct deposit a nickel alloy structural jacket and manifolds onto an SLM manufactured GRCop chamber, and (4) demonstrate the process for integrating the engine combustion chamber system by performing a hot fire, resistance test.

Notable Accomplishments

A solid monolithic part with relevant feature sizes has been demonstrated. A process to join two parts that exceeds the dimensions of the SLM machine build box has been successfully demonstrated through electron beam welding. Microscopy of SLM trials has shown a process set that produces highly dense parts that can be nearly completely densified in the standard post SLM build Hot Iso-static Press (HIP) cycle.



Example of a previous engine component testing at MSFC's Test Stand 116

Additive Construction With Mobile Placement

Project Manager(s)

Niki Werkheiser Project Element Co-Lead - (256) 544 - 8406

Robert Mueller Project Element Co-Lead Kennedy Space Center - (321) 867 - 2557

Project Description

The Additive Construction with Mobile Placement (ACME) project is developing technology to build structures on planetary surfaces using in-situ resources. The project focuses on the construction of both 2D (landing pads, roads, and structure foundations) and 3D (habitats, garages, radiation shelters, and other structures) infrastructure needs for planetary surface missions.

Notable Accomplishments

Performed a hypervelocity impact test of martian simulant concrete at White Sands and completed construction of straight and curved wall segments from martian simulant concrete at MSFC.

Demonstrated a regolith feedstock delivery/size sorting system at KSC.



Concept of potential emplacement devices

MSFC Technology Year in Review 2015

Microelectrospray Thrusters

Project Manager(s)

John Dankanich/ZP30 - (256) 544-3441

Nate Demmons/Busek Co., Inc. - (508) 655-5565

Colleen Marrese-Reading/JPL - (818) 354-8179

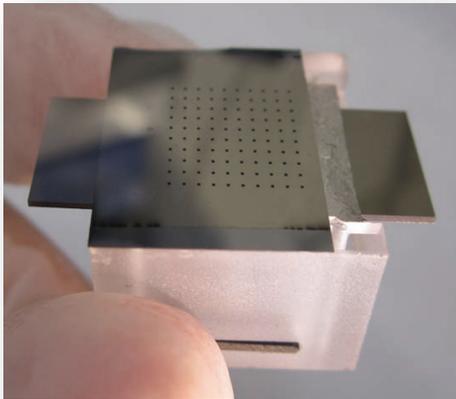
Paulo Lozano/MIT- (617) 258-0741

Project Description

NASA is investing in technologies to enable high-value missions with very small spacecraft; however, these nanosatellites currently lack any appreciable propulsion capability. Electric propulsion is an approach to accelerate propellant to very high exhaust velocities through the use of electrical power.

Notable Accomplishments

The project included the delivery and long-duration testing of systems from both Busek and MIT, though neither set met the full life or performance requirements within the contracted efforts. Busek was selected for a flight demonstration and transitioned to the Small Spacecraft Technology Program, and MIT has received follow-on efforts, completed additional long-duration testing, and also performed a flight demonstration.



JPL indium thruster

MSFC Technology Year in Review 2015

Small Business Innovation Research and Small Business Technology Transfer Programs

Project Manager(s)

Lynn Garrison/ZP30 - (256) 544-6719

Gwen Jasper/ZP30 - (256) 544-1666

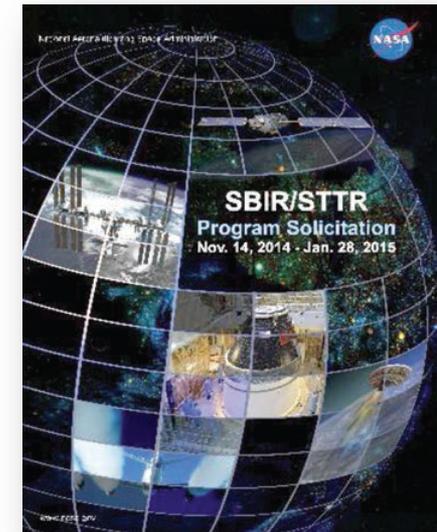
Project Description

The Small Business Innovation Research (SBIR)/ Small Business Technology Transfer (STTR) programs fund the research, development, and demonstration of innovative technologies that fulfill NASA's needs as described in the annual Solicitations and have significant potential for successful commercialization.

Notable Accomplishments

The PY 2015 SBIR/STTR Phase I feasibility studies were completed. For Human Exploration and Operations Mission Directorate subtopics, NASA Marshall Space Flight Center (MSFC) was lead Center on four subtopics: Nuclear Thermal Propulsion, Extreme Temperature Structures, Spacecraft Cabin Atmosphere Quality and Thermal Management, Recycling Reclamation of 3D Printer Plastic, and participating Center in eight subtopics. For the Space Technology Mission Directorate (STMD), MSFC was lead Center for two subtopics: Large-Scale Polymer Matrix Composite Structures, Materials and Manufacturing Processes; and Advanced Metallic Materials and Processes Innovation, and participating Center on one subtopic. For the SBIR SELECT Solicitation: MSFC was lead Center for one SMD subtopic: Advanced Technology Telescope for Balloon and Sub-Orbital Missions, and participating Center in 17 subtopics. For STTR solicitation, MSFC was lead Center for two subtopics: Affordable Nano/Micro Launch Propulsion Stages and Experimental and Analytical Technologies for Additive Manufacturing, and participating Center on one subtopic.

MSFC received 44 PY 2015 phase I awards and 18 phase II awards. ZP30 developed briefing charts for SBIR/STTR technical monitor's (TM's) and contracting officer's (COR's) technical reps and conducted these briefings on April 1 and 23, 2015. The MSFC SBIR Office along with the Center New Technology Representative and NASA Shared Services Center provided valuable information to assist the TMs and CORs in the successful execution of phase I and II contracts. MSFC SBIR phase III contracts will continue the development of the SBIR/STTR innovation with funding from NASA programs/projects and/or external funding sources. The SBIR program has funded In-Space Manufacturing Project activities that will result in the technologies and capabilities required for sustainable, on-demand manufacturing and repair during Exploration missions. Several SBIRs have been awarded with the purpose of demonstrating the ability to recycle obsolete or damaged 3D-printed parts into feedstock for the on-orbit 3D printing of new items.



MSFC Technology Year in Review 2015

Iodine Satellite

Project Manager(s)

John Dankanich/ZP30 - (256) 544-3441

Hani Kamhawi/Glenn Research Center - (216) 977-7435

James Szabo/Busek Co., Inc. - (508) 655-5565

Project Description

This project is a collaborative effort to mature an iodine propulsion system while reducing risk and increasing fidelity of a technology demonstration mission concept.

Notable Accomplishments

The spacecraft design has evolved significantly throughout FY 2015, from phase A to the preliminary design review (PDR) and through the DAC-2 and 3. This iSat project went through another Space Technology Mission Directorate program management council and was approved through phase F, including all required operations costs. The launch costs are assumed to be contributed from a Department of Defense partner.



Interim concept design as of October 2015

MSFC Technology Year in Review 2015

Flexible Hybrid Battery/Pseudocapacitor Using Carbon Nanotube Electrodes

Project Manager(s)

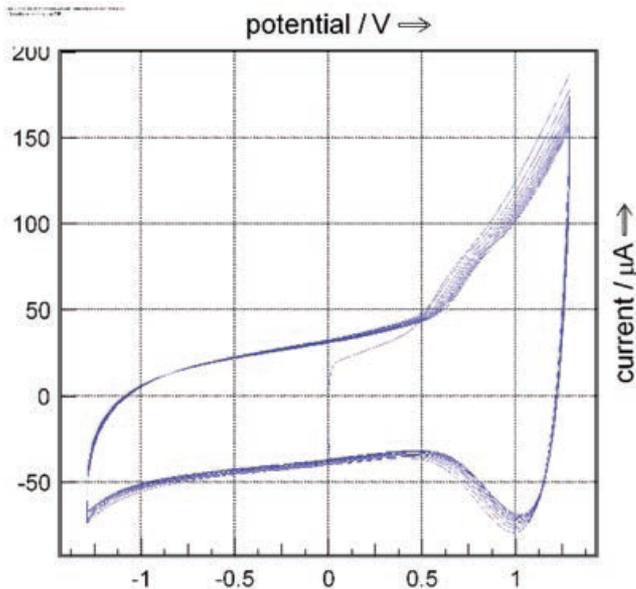
Dr. Dennis S. Tucker/EM32 - (256) 544-7022

Project Description

The purpose of this project was to develop a flexible hybrid battery/pseudocapacitor in one unit. The approach was to coat carbon nanotube sheets with titanium dioxide to act as a capacitor electrode.

Notable Accomplishments

Demonstrated a pure capacitor effect using titanium oxide-coated carbon nanotube sheets as the capacitor electrodes and a pure battery effect using silicon-coated carbon nanotube sheets as battery electrodes.



Cyclic voltammetry curve showing hybrid effect

High-Fidelity Design Tools and a New Hydrogen Containment Process for Nuclear Thermal Engine Ground Testing

Project Manager(s)

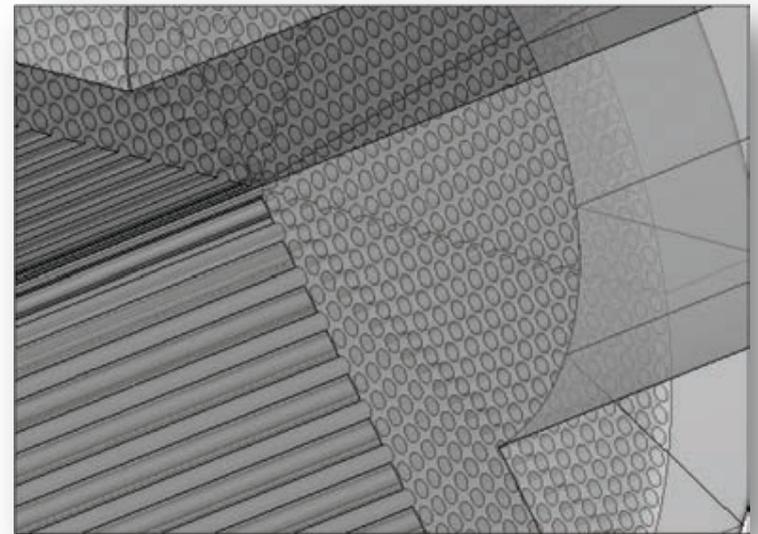
Ten-See Wang/EV33 - (256) 544-0503

Project Description

This project developed a total hydrogen containment process to enable the testing required for nuclear thermal propulsion (NTP) engine development.

Notable Accomplishments

A new hydrogen containment process was developed for ground testing of an NTP engine with a high fidelity, multidimensional, pressure-based, multiphase CFD methodology.



A 240° view of the cooling tubes layout

MSFC Technology Year in Review 2015

Novel Aerogel-Based Catalysts for Spacecraft Life Support Application

Project Manager(s)

Matt Mansell/ES62 - (256) 544-8297

Walter Schneider/FP10 - (256) 544-0557

Project Description

The objective of this project was to demonstrate the feasibility of using aerogel-supported metals as catalysts for CO₂ reduction or any other life support processes identified as likely to benefit from this technology.

Notable Accomplishments

Demonstrated significant carbon deposition on external and internal surfaces of two iron-containing gel materials. Conducted materials characterization (scanning electron microscopy with image analysis techniques), providing evidence for dispersion of catalytic centers, solid product morphology, and pore size distribution.



Carbon formed from the reduction of CO by hydrogen on (and within) an iron-impregnated silica gel particle. Particle mean diameter is approximately 8 mm.

Deployable Nozzle Extension

Project Manager(s)

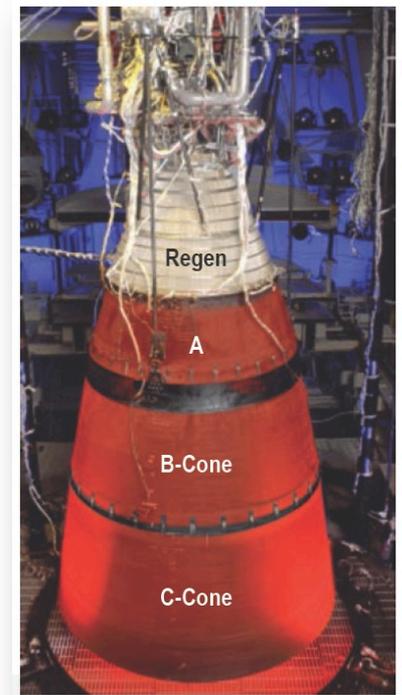
Joseph Ruf/ER42 - (256) 544-4942

Project Description

This task's objective was to obtain sufficient technical understanding of the DNE's capabilities such that an investment of significant funds for further development could be made with a high level of confidence.

Notable Accomplishments

The team has concluded that the DNE concept should work on an RL10, and the concept is worth investing in to further its development.



RL10 with B- and C-cones in flight position (Photo: Pratt & Whitney)

MSFC Technology Year in Review 2015

Novel Metrology Concept for High-Resolution Grazing Incidence Optics

Project Manager(s)

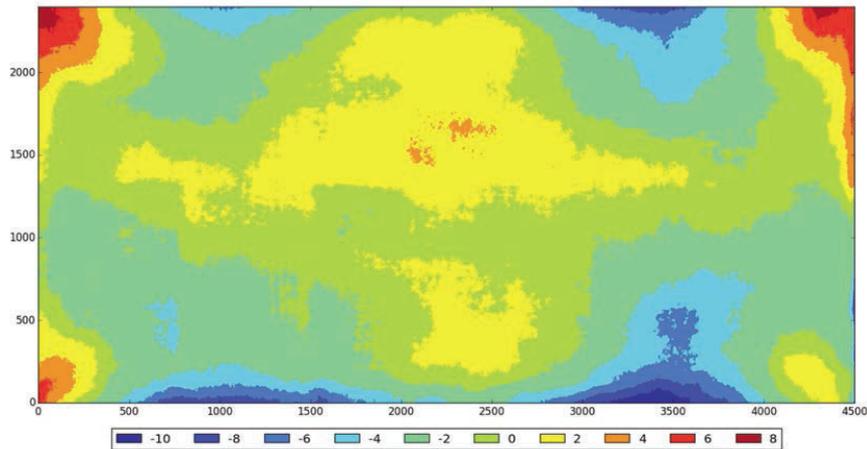
Mikhail Gubarev/ZP12 - (256) 544-7816

Project Description

Given the recent introduction of optical surface error correction methods, such as differential deposition and smart optics, the availability of in situ surface figure metrology methods becomes crucial for development of the high-resolution, high-effective-area x-ray optics needed for future NASA astrophysics missions.

Notable Accomplishments

Software code for grayscale offset calibration (monitor calibration) was developed. The figure below shows the map of the grayscale offset measured for the ultra-high-definition monitor used for the deflectometer breadboard.



The measured map of the grayscale offset at the monitor. The map was used for the monitor calibration.

Correlated Electromagnetic Levitation Actuator

Project Manager(s)

Sarah Triana/EV42 - (256) 544-6042

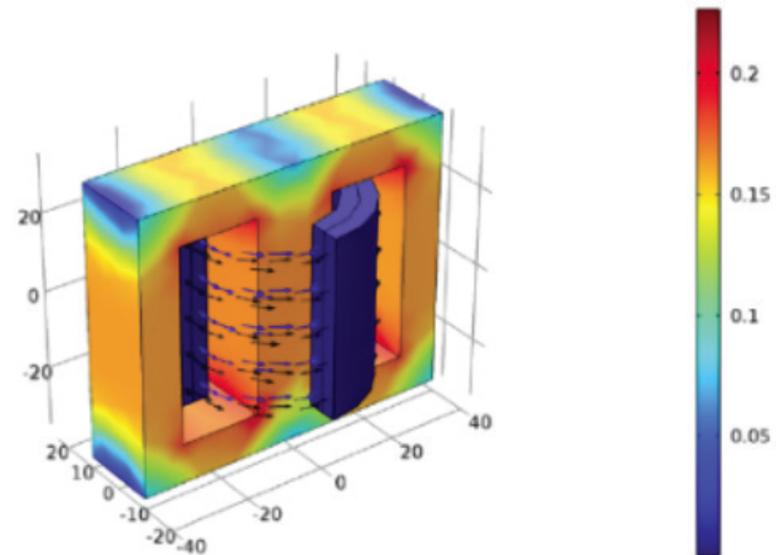
Paul Britton/QD33 - (256) 544-8301

Project Description

Seek to prove we can create an efficient frictionless reaction wheel using correlated electromagnets by levitating and rotating one above the other and changing the levitation height and rotation by actuation.

Notable Accomplishments

A controller was designed to control each individual e-maxel's polarity and intensity. Modeling was done to show that we can match the test data. If the model matches the test data, then we can use the model to predict future characteristics and behavior.



Magnetic field model

MSFC Technology Year in Review 2015

Flexible Electrostatic Tools for Capture and Handling

Project Manager(s)

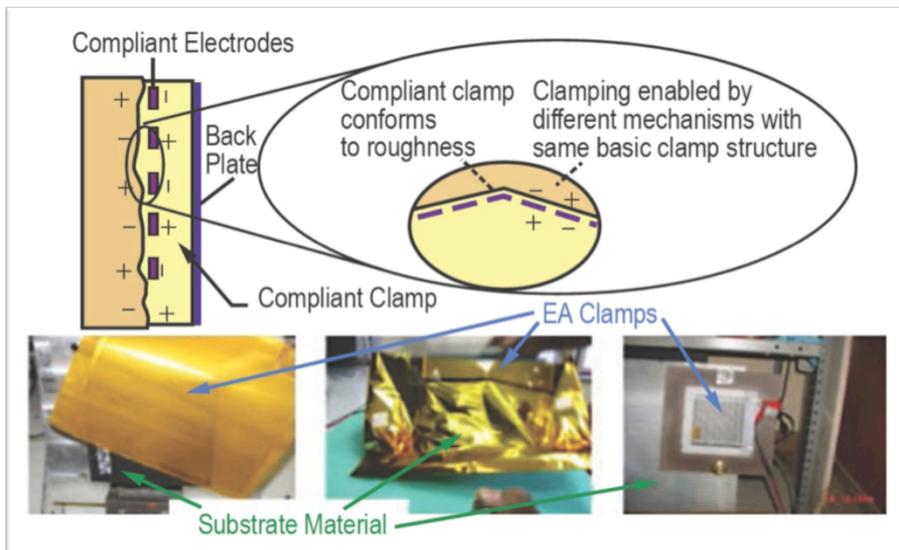
Tom Bryan/ES35 - (256) 653-5990

Project Description

Flexible electrostatic (ES) gripper tools have the capabilities for capturing spacecraft and to grip and release various materials on command. The tools conform to different surfaces due to flexibility, are designed with fewer moving parts, and have potential to be more reliable than other concepts.

Notable Accomplishments

Assembled a reactive 5-axis spacecraft air-bearing reconfigurable simulator (air-jet spun). Fabricated a 4-jointed retractable capture boom with spin table and compliant ES gripper mount.



Superior Epoxies for Cryogenic Composite Tank Fabrication

Project Manager(s)

Richard Grugel/EM31 - (256) 544-9165

Project Description

The intent of the work is to ascertain the viability of ionic liquid (IL) epoxy based carbon fiber composites for use as storage tanks at cryogenic temperatures

Notable Accomplishments

Sample sections from a fabricated, liner-less composite cylinder were subjected to direct quenching into liquid oxygen (LOX) and liquid hydrogen (LH2). No cracking of the matrix or debonding from the fibers were seen.



COPV fabricated using the IL-based epoxy

MSFC Technology Year in Review 2015

Radar Hazard Identification for Planetary Landers

Project Manager(s)

Paul Meyer/ZP11 - (256) 961-7892

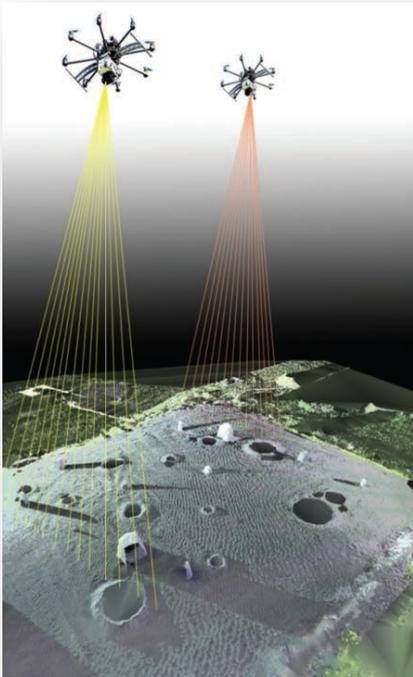
Mike Hannan/EV41 - (256) 544-1403

Project Description

This project endeavors to see if low-cost automotive sensors being developed for autonomous cars can be used on NASA landers.

Notable Accomplishments

Assembled the radar, power interface, data acquisition, GPS, and IMU into a flight system. Flight-tested a low-cost auto radar for use as a hazard identification sensor.



Visualization of radar scanning the surface or Octocopter flying over the terrain field carrying the radar

Linear Transformer Driver Development

Project Manager(s)

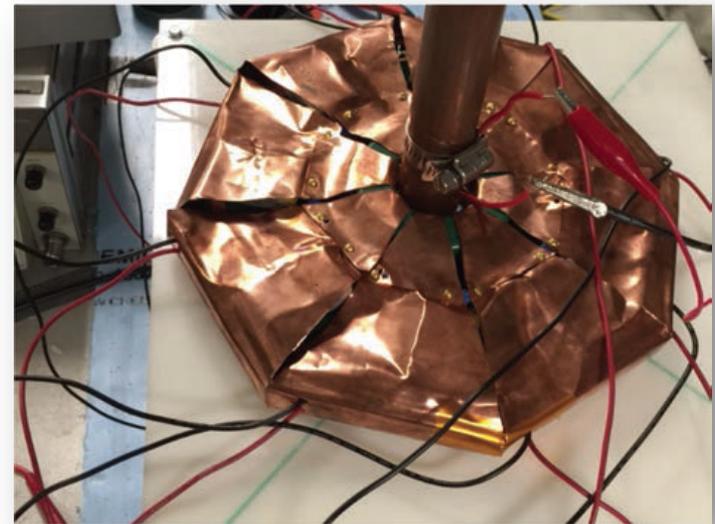
Robert Adams/ER24 - (256) 544-3464

Project Description

The objective of this project is to construct a first and second generation LTD capable of producing a 100-ns signal at roughly hundreds of joules per pulse. This energy level would demonstrate the building blocks for a much larger system capable of pulsing several electric propulsion systems, or could be applied to a rail gun/launch assist application.

Notable Accomplishments

Test results show cyclic behavior known as ringing with each cycle having lower amplitude (voltage and current) than the previous one. Most of the inefficiency is due to impedance mismatch; the actual core and inductive losses appear to be very small.



LTD cavity latest version

MSFC Technology Year in Review 2015

Second Generation QUATARA Flight Computer

Project Manager(s)

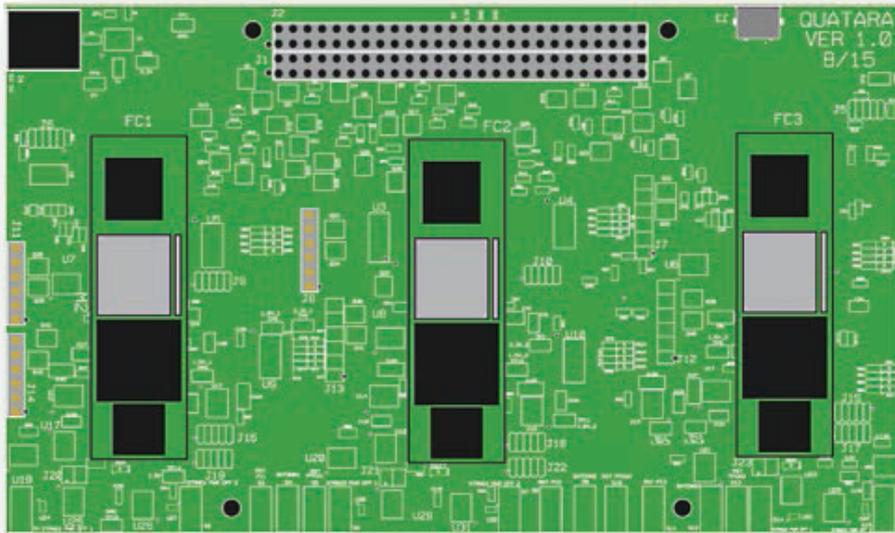
Jose Carlos Molina Fraticelli/ES53 - (256) 544-0328

Project Description

The QUATARA computer enables a CubeSat to manage more data, process more sensors, and control multiple actuators without compromising the computational capabilities of any single microprocessor.

Notable Accomplishments

A custom FPGA communication interface has been developed to pass data between the flight computer nodes at high speeds. Custom software was developed and installed on the nodes to test the interface. A prototype printed circuit board was designed and manufactured.



QUATARA prototype printed circuit board

MSFC Technology Year in Review 2015

MSFC Center Management And Operations



MSFC Technology Year in Review 2015

Technology Investment Program (TIP)

- Common Data System Architecture for Earth and Space Science Instruments
- Lightweight Integrated Solar Array and Transceivers
- High Thermal Conductivity NARloy-Z-Diamond Composite Combustion Chamber Liner for Advanced Rocket Engines
- Oxygen-Rich Material Testing
- Radio Frequency Identification for Automated Inventory Management
- Formation Flying for Satellites and Unmanned Aerial Vehicles
- Solar Sail Attitude Control Capability
- CubeSat Demonstration Mission

Center Strategic Development Steering Group (CSDSG)

- Chromospheric Lyman-Alpha Spectropolarimeter
- International Space Station Agricultural Camera Reutilization for Earth Observation
- Direct Fabrication of Grazing Incidence Optics
- Regenerable Catalyst From In Situ Resources for Life Support Using Ionic Liquids
- X-ray Surveyor Strawman Payload Definition
- GreenSat
- Oxygen-Rich Assessment of Mondaloy Alloy
- Marshall Grazing Incidence X-ray Spectrometer
- Methane Pump Test

Dual-Use Technology Cooperative Agreement Notice (CAN)

- Optimization of Ultracapacitors
- Low-Cost Plasma Micropropulsion Using 3D Printing and Off-the-Shelf Components
- Liquid Oxygen Expansion Cycle — A Dual-Cooled Expander Cycle Engine Using Hydrogen and Oxygen
- Enabling Fast-Responding Pressure-Sensitive Paint Systems in Blowdown Wind Tunnels
- Multi-Mode Micropropulsion for Small Spacecraft
- Topic Mapping
- Printing Outside the Box: Additive Manufacturing Processes for Fabrication of Large Aerospace Structures
- Improving the Interlaminar Shear Strength of Out-of-Autocave Composites

MSFC Technology Year in Review 2015

Common Data System Architecture for Earth and Space Science Instruments

Project Manager(s)

Timothy Lang/ZP11 - (256) 961-7861

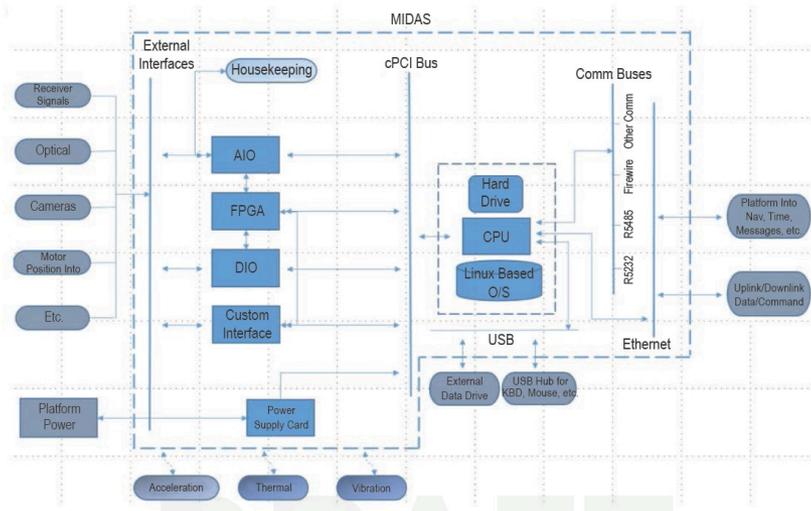
Anthony Guillory/ZP21 - (256) 961-7441

Project Description

The objective of this project was to develop and test a compact common data system architecture for use in Earth and space science instruments.

Notable Accomplishments

Trade study of existing data system architectures to identify common characteristics. MIDAS design and technical documentation reviewed and completed. MIDAS-AMPR designed and under construction. Schedule for remaining work developed.



Functional block diagram for MIDAS

Lightweight Integrated Solar Array and Transceivers

Project Manager(s)

Les Johnson/ED04 - (256) 544-7824

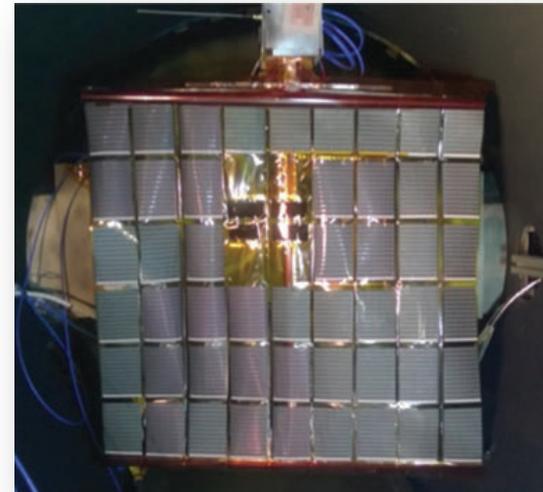
John Carr/ES44 - (256) 544-7114

Project Description

The Lightweight Integrated Solar Array and Transceiver (LISA-T) builds upon NASA Marshall Space Flight Center's (MSFC's) experience in space-deployed structures such as NanoSail-D. LISA-T enables higher power generation in small-scale satellites at low weights and high stowage efficiency without the need for solar tracking.

Notable Accomplishments

A pathfinder flat-panel LISA-T array was successfully deployed and illuminated in the MSFC High Intensity Solar Environment Test (HISSET) test chamber, taking the system to Technology Readiness Level-5.



Pathfinder flat-panel LISA-T array. 1U CubeSat with antennas shown at the top.

MSFC Technology Year in Review 2015

High Thermal Conductivity NARloy-Z-Diamond Composite Combustion Chamber Liner for Advanced Rocket Engines

Project Manager(s)

Biliyar Bhat/EM31 - (256) 544-2596

Sandra Greene/ER32 - (256) 544-8902

Project Description

The performance of future liquid propulsion systems can be improved significantly by increasing the heat transfer through the combustion chamber liner. Prior work performed has shown that the thermal conductivity of NARloy-Z alloy can be improved significantly by embedding high thermal conductivity diamond particles in the alloy matrix to form NARloy-Z-diamond composite.

Notable Accomplishments

NARloy-Z-28vol%Cu-D cylinders have been successfully sintered using the FAST process. Thermal conductivity and tensile properties are excellent.



Combustion chamber liner ring (2.5 in inner diameter, 2.75 in outer diameter, 1 ft long) made from NARloy-Z-Cu-D composite

Oxygen-Rich Material Testing

Project Manager(s)

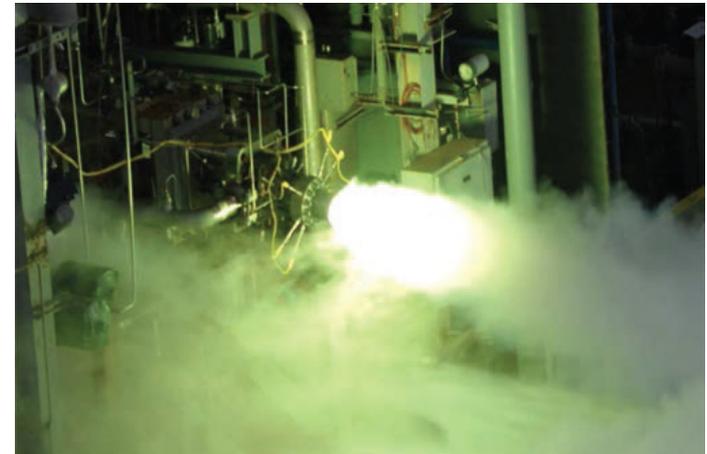
William Greene/XP20 - (256) 544-1038

Project Description

In support of the United States (U.S.) Air Force, NASA Marshall Space Flight Center (MSFC) is helping to develop and demonstrate technology that may be required for a future high-pressure, oxygen-rich, RP-1-fueled engine. Demonstrating potential oxygen-rich materials in appropriate high-pressure environments is critical to optimizing such an engine design.

Notable Accomplishments

Completed tests with the oxygen-rich preburner hardware in 2015. Figure below shows an image of the current assembly. A new spool section will be used to hold the material samples, and will be assembled in the preburner hardware. The spool section accommodates two material samples at a time.



Oxygen-rich/RP-1 preburner testing at MSFC

MSFC Technology Year in Review 2015

Radio Frequency Identification for Automated Inventory Management

Project Manager(s)

Carole Wagner/EO40 - (256) 544-2719

Shawn Hicks/Teledyne Brown Engineering - (256) 544-1628

Project Description

This effort has utilized radio frequency identification (RFID) technologies to help reduce the real-time errors that occur as a result of improper location callout for equipment/items.

Notable Accomplishments

Testing of both the RFID-enabled CTB and ISIS drawer showed that the technology is feasible for both ISS and deep space habitat system applications. This RFID technology provides for an autonomously operating spacecraft, resulting in a reduction of required ISS and ground crew maintenance and servicing while optimizing resource utilization.



RFID-enabled CTB

Formation Flying for Satellites and Unmanned Aerial Vehicles

Project Manager(s)

Garrick Merrill/ES36 - (256) 544-4409

Project Description

The goal of this project is to develop a scalable mesh network between vehicles to share real-time position data and maintain formations autonomously. The second generation design employs a hardware independent design and implementation of a software-based Time Division Multiplex Architecture mesh network with low latency and multihop capability. Small UAVs and simulated satellites were used to demonstrate the system in flight conditions. UAVs built by the Aero-M team will be used to demonstrate the formation flying in the West Test Area of NASA Marshall Space Flight Center.

Notable Accomplishments

UAV flight tests included up to five UAVs with formation nodes, and demonstrated autonomous formation flying and the various operating modes. Satellite orbital simulations with up to four nodes configured as satellites and durations up to three days were completed. The code that was developed for the formation nodes, controls the mesh network, and enables formation maneuvers was made available to U.S. citizens through the NASA software catalog.



Quadcopter UAVs in formation

MSFC Technology Year in Review 2015

Solar Sail Attitude Control Capability

Project Manager(s)

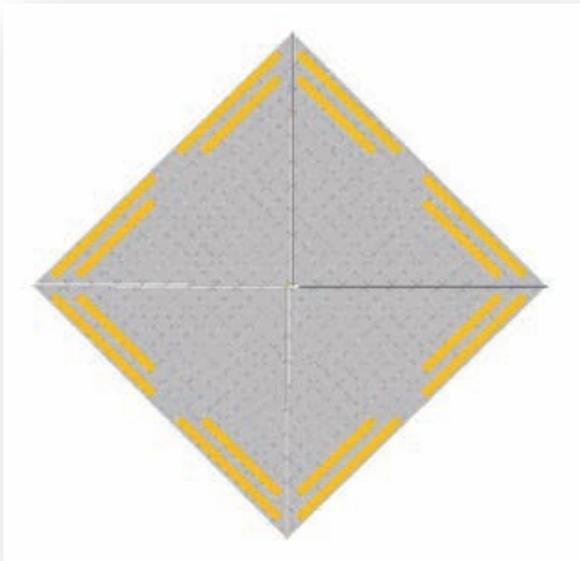
Tiffany Russell Lockett/ED04 -(256) 961-1304
Dr. Jeremy Munday/University of Maryland - (301) 405-4960

Project Description

The purpose of this project is to investigate attitude control capabilities for solar sailing and endorse the best concept for future solar sail missions without the reliance on propellant-based systems.

Notable Accomplishments

The translation table concept is currently incorporated into the flight design of the Near Earth Asteroid Scout mission for additional attitude control support for the spacecraft. The translation table will help align the center of mass and center of pressure to minimize the disturbance torques produced by the sail.



Conceptual
render of
reflective
control devices
along the edge
of a solar sail
(Source: NASA)

CubeSat Demonstration Mission

Project Manager(s)

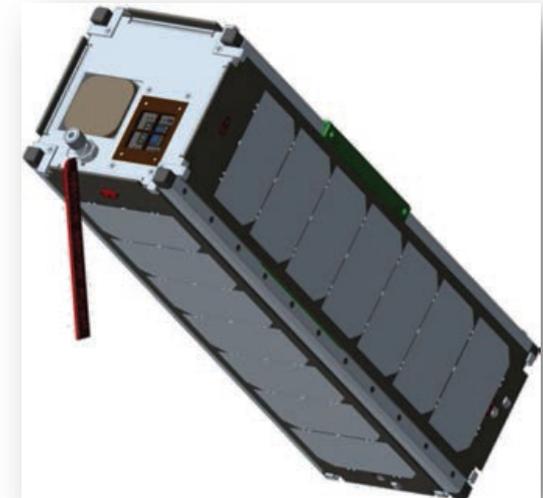
Jeremy Rousseau PE/ER52 - (256) 544-7331

Project Description

The primary technical objectives were to provide a low cost CubeSat for a demonstration mission that demonstrates 3-axis fine attitude control using Electrically Controllable Solid Propellant Thrusters while increasing the TRL of two other MSFC developed technologies: CubeSat Attitude Determination System & Magnetic Torquers.

Notable Accomplishments

Developed and tested low cost alternative propulsion system prototypes and vehicle chassis with an estimated vehicle cost savings of 80% and 95% respectively. Provided a flight ready revision for the Modular Attitude Determination System (MADS 2.0) Provided a system design with hardware cost within the allocated project budget.



Assembled satellite

MSFC Technology Year in Review 2015

Chromospheric Lyman-Alpha Spectropolarimeter

Project Manager(s)

Dr. Amy Winebarger/ZP13 - (256) 961-7509

Todd Holloway/ZP21 - (256) 961-7581

Ryouhei Kano/National Astronomical Observatory of Japan

Javier Trujillo Bueno/Instituto de Astrofísica de Canarias

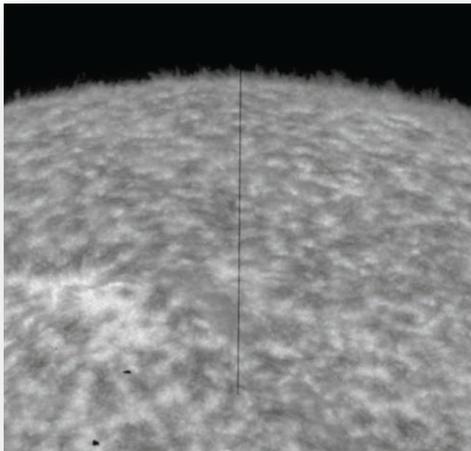
Frédéric Auchère/Institut d'Astrophysique Spatiale

Project Description

The aim of the Chromospheric Lyman-Alpha Spectropolarimeter (CLASP) is to achieve the first measurement of magnetic field in the upper chromosphere and transition region of the Sun through the detection and measurement of Hanle effect polarization of the Lyman-alpha line.

Notable Accomplishments

CLASP was launched from White Sands Missile Range on September 3, 2015. The initial data indicate that CLASP detected scattering polarization in Lyman-alpha. Additional analysis is underway to infer the chromospheric magnetic field from the CLASP data.



The quiet sun region observed by CLASP.

This image is taken with the slitjaw camera with a broadband filter centered on the Lyman-alpha spectral line. The black line in the image is the slit.

International Space Station Agricultural Camera Reutilization for Earth Observation

Project Manager(s)

PI Burgess Howell / USRA - (256) 961-7908

PM Jeff McCracken / ZP21 - (256) 961-7457

Project Description

Reutilize the International Space Station Agricultural Camera (ISSAC) by adapting it to external use on the Multiple User System for Earth Sensing (MUSES). This reutilization will provide a low-cost mechanism for the collection of data and information to serve a variety of scientific, humanitarian, and technical purposes, and provide both tangible and intangible benefits in varying degrees to several entities and groups.

Notable Accomplishments

A study to investigate the possible use of ISSAC as an external ISS payload on the MUSES Platform was completed in 2015. The study concluded that the ISSAC hardware would survive outside the ISS, but with operational caveats, and raised the project technology readiness level from 2 to 3.



ISSAC camera recently returned from ISS on SpaceX-5

MSFC Technology Year in Review 2015

Direct Fabrication of Grazing Incidence Optics

Project Manager(s)

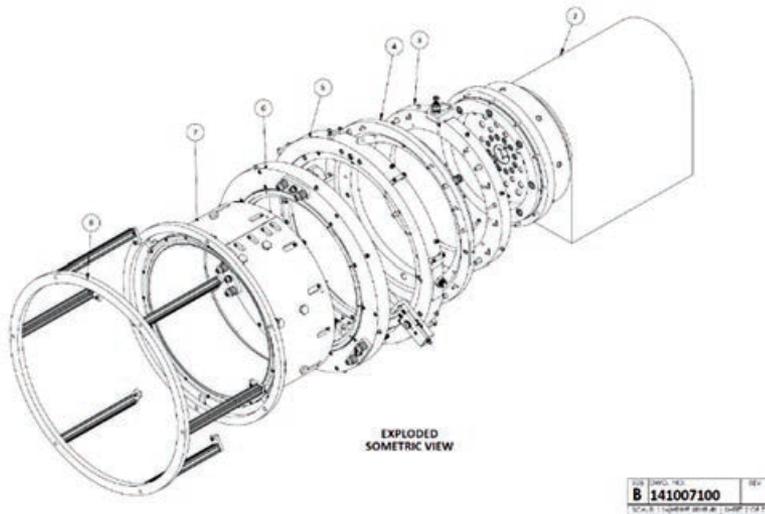
Mikhail Gubarev/ZP12 - (256) 544-7816

Project Description

The challenge is to develop the optical fabrication technology capable of producing Chandra-like full-shell optics but with an order of magnitude lighter mirror shells and at an affordable price.

Notable Accomplishments

Inner and outer diameter diamond turning mounts and polishing fixture have been developed and fabricated. Metrology mounts for the direct fabrication of high resolution x-ray optics designed to minimize the shell distortions have also been completed.



Inner diameter diamond turning mount developed for the project

Regenerable Catalyst From In Situ Resources for Life Support Using Ionic Liquids

Project Manager(s)

Morgan Abney / ES62 - (256) 961 - 4758

Laurel Karr / EM10 - (256) 544 - 7817

Project Description

This project aims to demonstrate the use of ionic liquids to recover catalyst metal from carbon waste products in a life support architecture, to deposit the extracted metal onto a substrate, and to demonstrate the catalytic activity of the resulting substrate/catalyst material.

Notable Accomplishments

Four tasks were accomplished during the project. First, the catalytic activity of iron on a copper support was demonstrated using traditional electro-plating methods (no ionic liquids used). The second task was to demonstrate extraction of iron from iron catalyst that had produced a large quantity of carbon using an ionic liquid. The third task was to demonstrate plating of iron on a copper support using an ionic liquid. The fourth accomplished task was to demonstrate catalytic activity of the iron plated from the ionic liquid. This project has demonstrated four key aspects to an ionic-liquids-based regenerative catalyst system for achieving 100% oxygen recovery for long-duration manned space flight.



Carbon remaining after ionic liquid extraction (left) and ionic liquid containing iron (right)

MSFC Technology Year in Review 2015

X-ray Surveyor Strawman Payload Definition

Project Manager(s)

M.C. Weisskopf / ZP12 - (256) 961 - 7798

J. Gaskin / ZP12 - (256) 961 - 7818

A. Vikhlinin / SAO

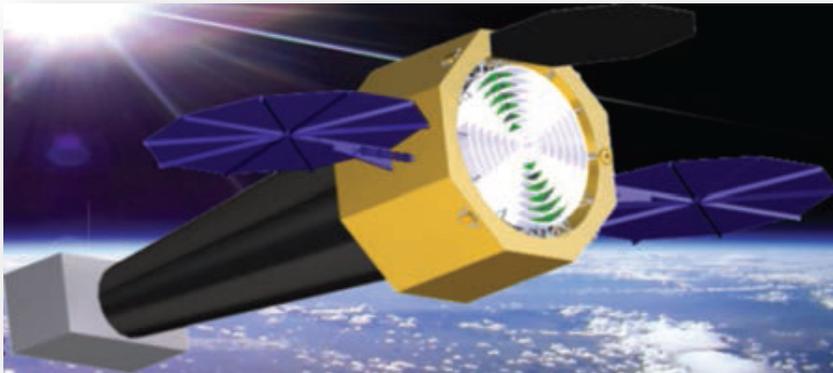
H. Tananbaum / SAO

Project Description

The goals for the observatory are: excellent (at least Chandra-like) angular resolution, while providing a factor of 30-100 higher throughput and a suite of next-generation science instruments. These instruments include a microcalorimeter, a High Definition Imager and high-efficiency gratings for spectroscopy in the soft X-ray band to detect and characterize extremely faint objects and study physical processes in a wide range of astrophysical settings. The strawman X-ray Surveyor Mission concept was developed in response to the "Planning for the 2020 Decadal Survey.

Notable Accomplishments

All crucial technologies for the telescope and focal plane instrumentation are actively being developed. Designing the focal length to be approximately that of *Chandra* and utilizing *Chandra* heritage systems for the spacecraft, results in a *Chandra*-like cost.



X-ray Surveyor strawman concept

GreenSat

Project Manager(s)

Joel Robinson / CS10 - (256) 544 - 3513

Project Description

MSFC conducted a 45-day trade study looking at the combination of the 50N system with this small spacecraft. FY15 resources were used to have continued discussions with ORS about integrating the propulsion system to enhance spacecraft capabilities.

Notable Accomplishments

Participated in DoD SERB – Jan 6, 2015

Approval from Export Control – Jan 25, 2015

Partnership Working Group approval – Feb 12, 2015



ORS modular space vehicle

MSFC Technology Year in Review 2015

Oxygen-Rich Assessment of Mondaloy Alloy

Project Manager(s)

William Greene / XP20 - (256) 544-1038

Project Description

In support of the U.S. Air Force, MSFC is helping to develop and demonstrate technology that will be required for a high pressure, oxygen rich, RP-1 fueled engine. Demonstrating Mondaloy in a high pressure, oxygen rich environment will help confirm its application in this new engine development program.

Notable Accomplishments

When the preburner testing at MSFC is completed, the results will provide an assessment of the Mondaloy alloy in a high pressure, oxygen rich environment. The samples and required spool section will then be removed and the original preburner assembly will be used to support MSFC's testing of new subscale staged combustion hardware. MSFC also prepared the drawing of the material sample required to mate with the spool section.



MSFC's oxygen-rich/RP-1 preburner assembly

Marshall Grazing Incidence X-ray Spectrometer

Project Manager(s)

Dr. Amy Winebarger/ZP13 - (256) 961-7509

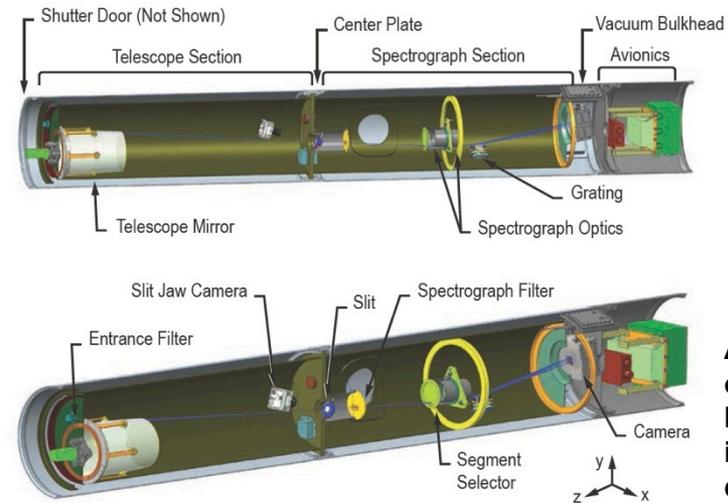
Jeff McCracken/ZP21 - (256) 961-7457

Project Description

The culmination of technological advances in grating lithography, mirror fabrication techniques, and camera efficiencies can now be leveraged to build imaging spectrometers similar to world-class x-ray observatories such as the Chandra X-ray Observatory, but at a far more reasonable cost. Using a novel implementation of corrective optics, the Marshall Grazing Incidence X-ray Spectrometer (MaGIXS) will measure, for the first time, the solar spectrum from 0.6 to 2.4 nm with a 6-arcsec resolution over an 8-arcmin slit.

Notable Accomplishments

MaGIXS was selected in 2014 and will launch on a sounding rocket from White Sands Missile Range in the summer of 2018 or 2019.



A schematic of the MaGIXS instrument concept

MSFC Technology Year in Review 2015

Methane Pump Test

Project Manager(s)

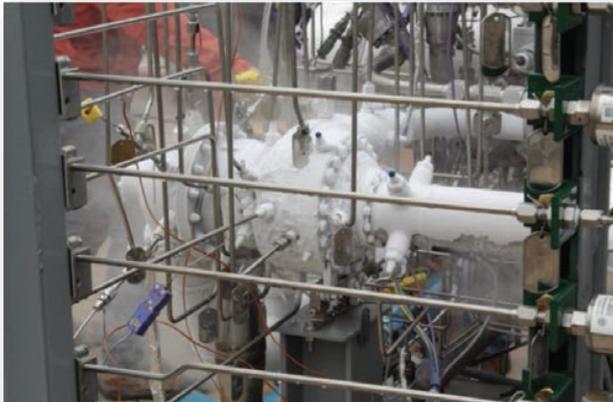
T. Derek O'Neal/ER31 - (256) 544-2543

Project Description

The technical goal was to obtain early turbopump test data with LCH₄ to support the development of propulsion systems for in-space and lander propulsion system technology. The approach was to use the fuel pump developed as part of the Additive Manufacturing Demonstrator Engine (AMDE) for an LCH₄ test series. This pump was designed for operation in liquid hydrogen, but its characteristics allow operation in LCH₄ at points that are close to those desired for current LCH₄ lander engine concepts.

Notable Accomplishments

The turbopump chill test yielded baseline data for conditioning turbomachinery in LCH₄. This data verifies turbopump conditioning methods and stand operation during chill. Once complete, TS116 will have the capability to test engine components in relevant LCH₄ environments, which is critical for engine system development. Conducting pump-fed tests in relevant LCH₄ environments will keep MSFC at the forefront of pump-fed engine technology development.



**Turbopump
LCH₄ chill
testing**

MSFC Technology Year in Review 2015

Optimization of Ultracapacitors

Project Manager(s)

Dr. Terry D. Rolin/ES43 - (256) 544-5579

Dr. Fat Duen Ho/University of Alabama Huntsville - (256) 824-6126

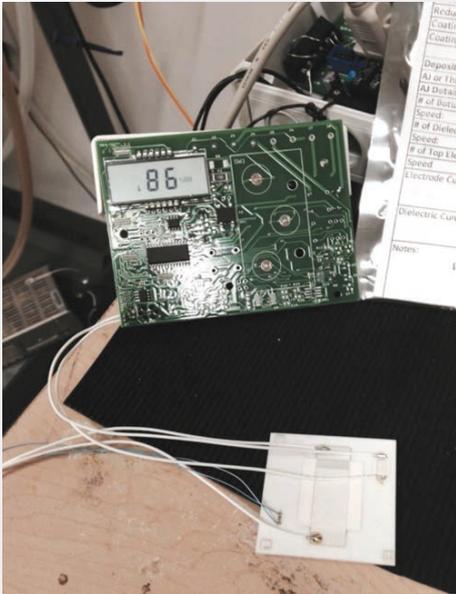
Caroline John/University of Alabama Huntsville - csj005@uah.edu

Project Description

The objective of this research is to develop critical design parameters that will aid in the design of ferroelectric ultracapacitors for optimal energy storage.

Notable Accomplishments

Ultracapacitors with calculated energy densities exceeding 8 J/cc have been produced. Devices have shown charging times in milliseconds, breakdown voltages as high as 900 V in a 30- μ m layer, and demonstrated the ability to activate light emitting diodes.



Test data from a commercial vendor testing the humidity response of ceramic humidity sensor built at MSFC. This material was a spin-off discovery from the ultracapacitor research and development project.

Low-Cost Plasma Micropropulsion Using 3D Printing and Off-the-Shelf Components

Project Manager(s)

Kunning G. Xu/UAH - (256) 824-5083

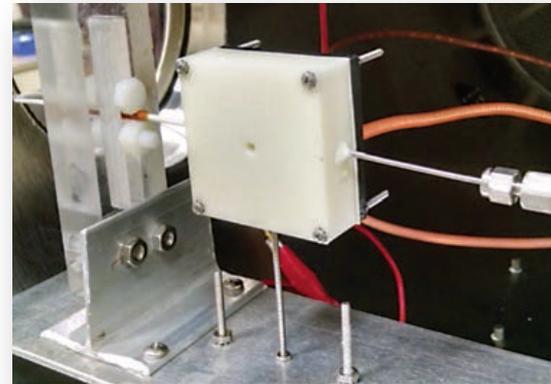
Kurt Polzin/ER24 - (256) 544-5513

Project Description

This project seeks to develop and study a new low-cost micro-propulsion concept for satellite propulsion called the Microwave Microplasma Micro Thruster (3MT). The thruster utilizes microwave resonators to generate a microplasma.

Notable Accomplishments

The 3MT has been tested with both argon and air as a propellant at 10-100 Torr with as little as 1 W of microwave power. The thruster body has been fabricated from ABS plastic and Inconel with additive manufacturing methods. An alternative SRR fabrication method was successfully tested using iron-on masks that greatly reduced the time from 4 hours in a clean room for photolithograph to just 30 minutes in a simple fume hood. Three conference papers on the project have been or will be presented at the 2015 AIAA Propulsion and Energy and 2016 AIAA SciTech Forums.



The ABS prototype made with fused deposition modeling mounted in the vacuum chamber

MSFC Technology Year in Review 2015

Liquid Oxygen Expansion Cycle—A Dual-Cooled Expander Cycle Engine Using Hydrogen and Oxygen

Project Manager(s)

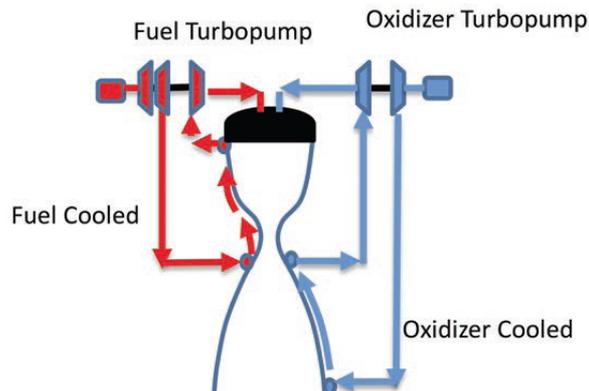
Joe Leahy / ER21- (256) 544-9202

Project Description

The primary objective of this effort is to develop a power balance model of a high performance dual cooled expander engine using LOX to cool the engine to validate the performance benefits and feasibility of the concept.

Notable Accomplishments

The model has been adapted to the Dual Cooled Expander Cycle Engine and efforts to verify the modeling approach are underway. The RL-10a-3-3a is modeled and will be compared with experimental results to validate the tool. The results from the validated RL-10 modeling effort will provide the needed grounding for this model. Several key features of the ModelCenter optimization scheme have been incorporated into the DCEC engine model.



DCEC concept

Enabling Fast-Responding Pressure-Sensitive Paint Systems in Blowdown Wind Tunnels

Project Manager(s)

James Aaron/ET20 - (256) 544-9098

Dr. Jim Crafton/Innovative Scientific Solutions, Inc. - (937) 630-3012

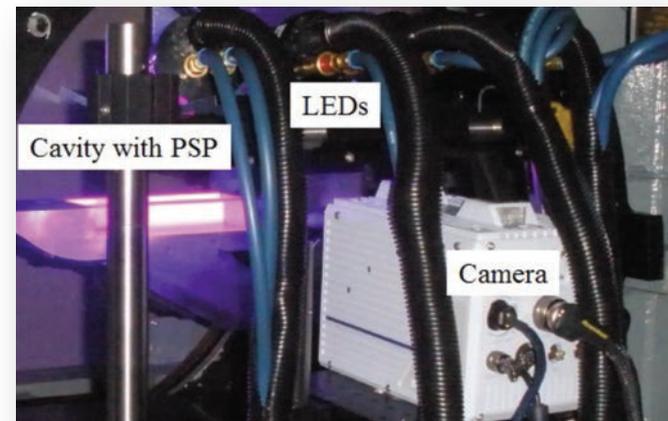
Dr. Paul Hubner/University of Alabama - (205) 348-1617

Project Description

The overall objective of this project is to develop and demonstrate a fast Pressure-Sensitive Paint (PSP) system for use in a blow-down wind tunnel such as the MSFC Aerodynamic Research Facility (ARF). The proposed fast PSP technology is based on several proven pieces of hardware, such as fast cameras and ultra-bright lighting, and has been demonstrated in similar-scale transonic wind tunnels.

Notable Accomplishments

Completed plans for the first wind tunnel tests at the University of Alabama using the PSP on a cone cavity model supplied by Dr. Semih Ölçmen's research team.



Wind tunnel setup for fast PSP

MSFC Technology Year in Review 2015

Multi-Mode Micropropulsion for Small Spacecraft

Project Manager(s)

Kurt Polzin/MSFC / ER24 - (256) 544-5513

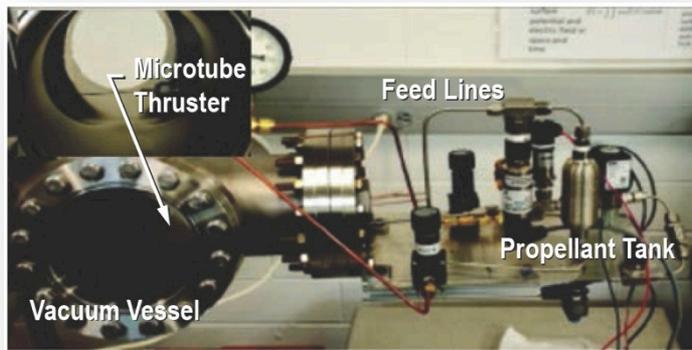
Joshua L. Rovey, Ph.D. Missouri University of Science and Technology - (573) 341-4613

Project Description

The Missouri University of Science and Technology in partnership with Marshall Space Flight Center is developing multi-mode micro-propulsion for small spacecraft. The goal of the project is to experimentally quantify the performance of a multi-mode micro-propulsion system for small spacecraft. Current efforts are focused on fundamental burn rate measurements of our novel multi-mode propellant and optimizing chemical mode operation.

Notable Accomplishments

Demonstrated chemical reactivity of our novel multi-mode propellant and demonstrated chemical-mode operation and electric-mode operation of the multi-mode micro-thruster in separate test setups, with identical hardware. Designed the integrated multi-mode micro-thruster.



Experimental setup being used to test the chemical operating mode of the micropropulsion system

Topic Mapping

Project Manager(s)

Mark Rogers/ED04

Pat Hunt/ED04

Gregory Funaro/ED04 - (256) 544 - 3747

Thomas Marsh/ai-one, inc. - (858) 531 - 0674

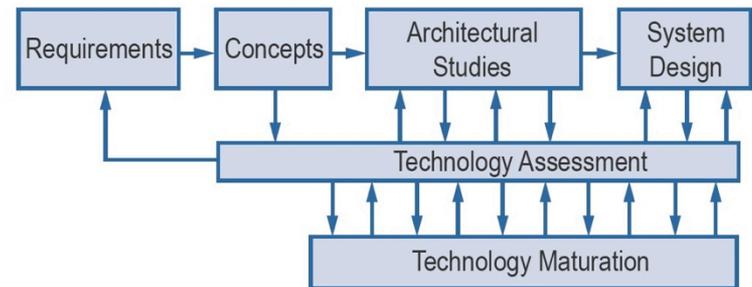
Jeremy Toor /ISC Consulting Group - (520) 508-8501

Project Description

The Advanced Concepts Office (ACO) performs conceptual design and analysis on many far-reaching missions to help guide NASA's technology development programs and quantify through analysis the benefits of those technologies. The Agency requires the development and infusion of new technological advances to meet mission goals, objectives, and resulting requirements.

Notable Accomplishments

With the help of the ai-one technology and support from ISC Consulting Group, ACO created 45 agents to represent various avionics system designs. 10,000 paragraphs were evaluated by each agent and scored on how well the wireless sensor paragraphs matched the capabilities described by the avionics system amounting to 450,000 assessments.



Relationship between concepts, architectural studies, and technology assessments

MSFC Technology Year in Review 2015

Printing Outside the Box: Additive Manufacturing Processes for Fabrication of Large Aerospace Structures

Project Manager(s)

Gregg Jones/ER32 - 256-544-2225

Majid Babai/EM42 - 256-544-2795

Judy Schnieder / Mississippi State University - 256-824-5186

Project Description

To achieve NASA's mission of space exploration, new innovative additive manufacturing processes are needed to reduce the cost and fabrication time of large propulsion components like a liquid rocket engine (LRE) nozzle. Metal Direct Deposit Manufacturing (MDDM) with a robotic pulsed source has the capability to build large structures like a LRE Nozzle. This program explored material properties of samples built with the MDDM process and with a powder bed.

Notable Accomplishments

Demonstrated high strength and ductility for samples created with a robotic arc and the MDDM process. Demonstrated a new thermal model of the build process which can be used to model and optimize the MDDM process.



Typical MDDM
Inconel® 718 build-up

Improving the Interlaminar Shear Strength of Out-of-Autoclave Composites

Project Manager(s)

Justin Jackson/EM42 (256) 961-2215

Project Description

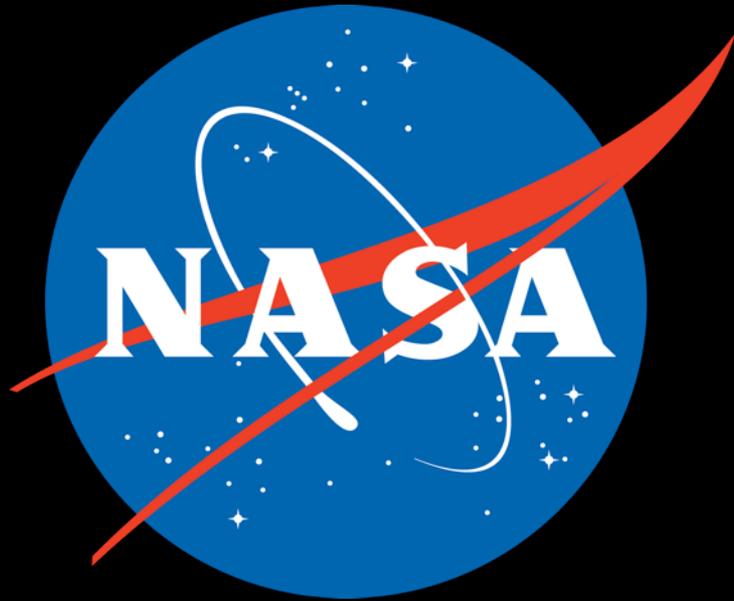
Use of fiber-reinforced, polymeric composite tanks are known to reduce weight while increasing performance of propulsion vehicles. Maximizing the performance of these materials is needed to reduce the hardware weight to result in increased performance in support of NASA missions.

Notable Accomplishments

Use of short beam shear tests on coupon specimens indicated that both the shear strength and energy absorption were improved at both room and cryogenic temperatures. The most noticeable improvement was in the flexural strain to failure, which indicated increased resistance to debonding. Both acetone and isopropanol appear to be suitable suspension and dispersion agents. No degradation of properties was observed with either dispersant. This study was presented at the SAMPE/CAMX Conference in Baltimore, MD, in October 2014.



Fabrication of the
18-ft- (5.5-m-)
diameter, all-
composite tank at
the Boeing facility



www.nasa.gov