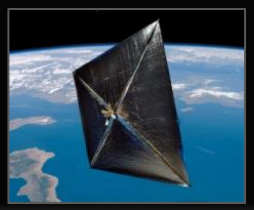
National Aeronautics and Space Administration

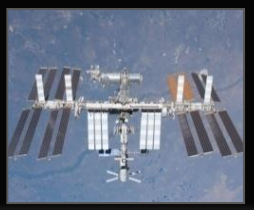
MSFC Center and Technology Overview (2013)

AIAA Greater Huntsville Section Lunch Meeting

23 January 2014






marshall

Andrew S. Keys
Center Chief Technologist

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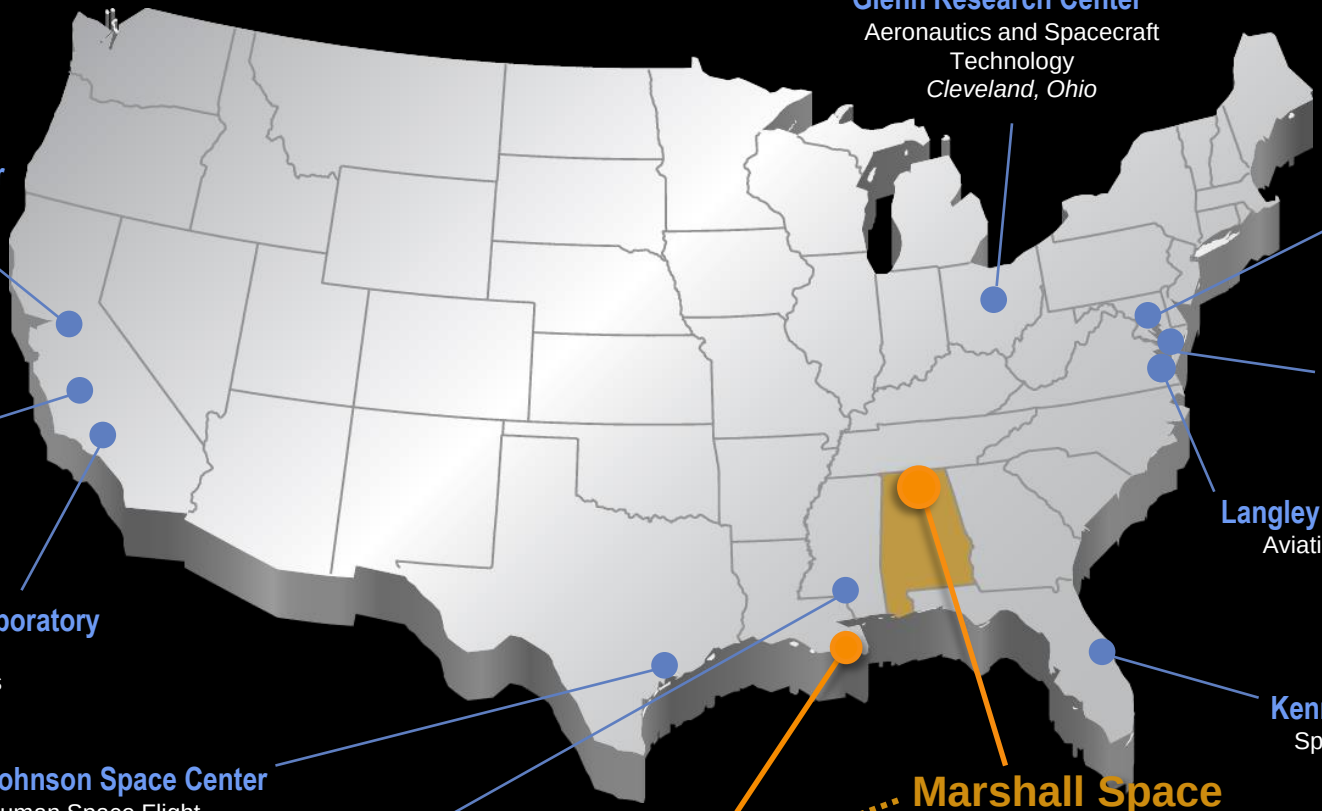
NASA Facilities



Glenn Research Center
Aeronautics and Spacecraft Technology
Cleveland, Ohio

Ames Research Center
Aerospace and Small Spacecraft
Moffett Field, Calif.

Goddard Space Flight Center
Science Missions and Telescopes
Greenbelt, Md.

NASA Headquarters
Washington, D.C.

Dryden Flight Research Center
Atmospheric Research and Testing
Edwards, Calif.

Langley Research Center
Aviation and Space Research
Hampton, Va.

Jet Propulsion Laboratory
Deep Space Robotic Rovers and Networks
Pasadena, Calif.

Kennedy Space Center
Space Vehicle Launch and Landing
Cape Canaveral, Fla.

Johnson Space Center
Human Space Flight Operations
Houston, Texas

Marshall Space Flight Center
Space Transportation, Propulsion Systems, Space Systems, and Science
Huntsville, Ala.

Michoud Assembly Facility
Large Vehicle Manufacturing
New Orleans, La.

Stennis Space Center
Vehicle Engine Testing
Bay St. Louis, Miss.

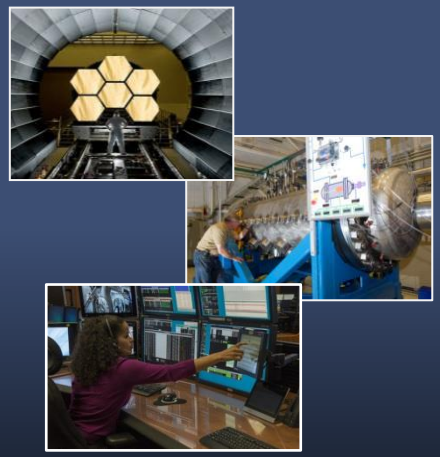
Supporting NASA's mission with unique engineering expertise.

Marshall Space Flight Center Profile

$2.3B expenditures nationally (FY2011)
$1.2B in Alabama

Nearly 6,000 employees
(FY13: 2,490 civil service)

2nd largest employer
in the Huntsville – Madison County area



26 core capabilities
and more than 125 unique and specialized facilities and labs

Part of a Technological Community

- Redstone Arsenal – home to 18 primary Federal organizations
- Cummings Research Park – 2nd largest in U.S. and 4th largest in the world
- Huntsville's concentration of high-tech workers is 2nd in the nation

Redstone Arsenal Major Organization Overview

Marshall's Role in Agency Missions

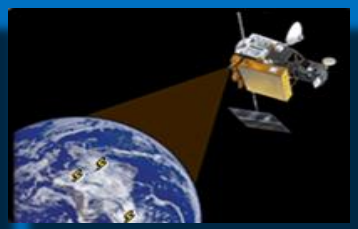
Four Core Technology Themes

Space Transportation/Launch Vehicle Technology and Development

Propulsion Systems Technology and Development

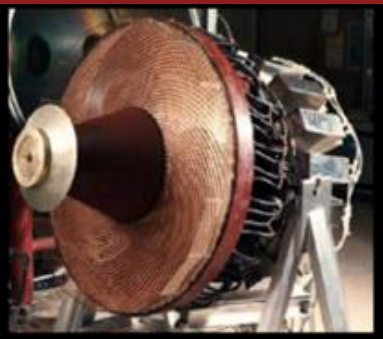
Space Systems Technology, Development, and Integration

Scientific Research



MSFC Technology Emphasis Areas

Advanced In-Space Propulsion and Cryogenic Technologies



In-Space Propulsion (Pulse Power, Electric)

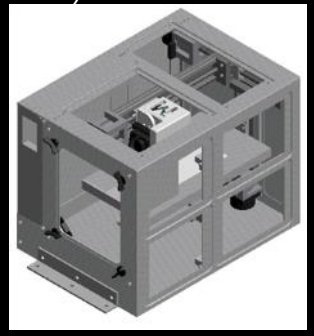
In-Space Propulsion (Nuclear)

In-Space Propulsion (Solar Sail, Tethers)

Affordable, Innovative Technologies for Landers and Sample Return

Low Cost/Responsive Launch for Small Payloads

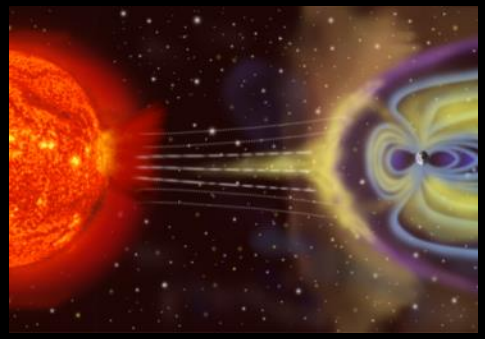
Innovations and technologies supporting small, affordable ISS payloads



Advanced manufacturing with emphasis on in-situ fabrication and repair

In-Space Habitation Technologies with emphasis on Nodes and Life Support Systems

X-ray Astrophysics and Telescope Systems



Space environments, space weather prediction and assessment

Small Satellite and Small Spacecraft Technologies

Rapid, innovative, affordable manufacturing of propulsion components

NASA's Space Technology Portfolio Perspectives and Process

What NASA could do.

Space Technology Roadmaps

- 140 challenges (10 per roadmap)
- 320 technologies
- 20 year horizon

What NASA should do.

NRC Study

Gives priority to:

- 100 top technical challenges
- 83 high priority technologies (roadmap-specific)
- 16 highest of high technologies (looking across all roadmaps)
- Immediate 5 year horizon

What NASA plans to do.

Space Technology Investment Plan

Updated ST Roadmaps:

- Incorporate NRC Study Results

Developing a Strategic Space Technology Investment Plan:

- Identify current investments
- Identify current MD/Office priorities
- Identify opportunities for partnership
- Analyze gaps against current budget and capabilities
- Develop immediate 4-year horizon

What NASA is doing.

Execution

Technology Portfolio Investments

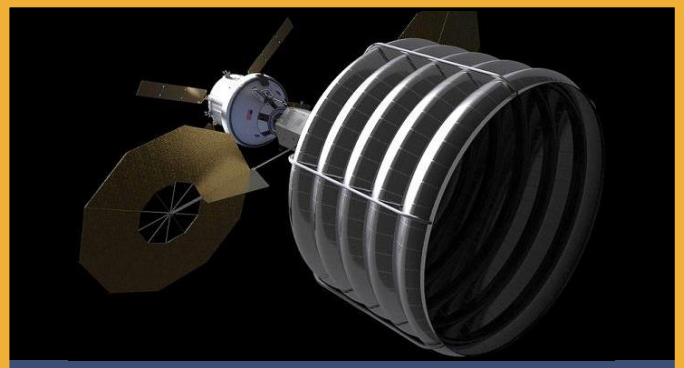
- Technology Developments (across full TRL spectrum)
- Flight Demonstrations

Must reflect:

- Affordability
- Technical Progress and Performance
- Mission Needs and Commitments
- Stakeholder Guidance

The National Aeronautics and Space Administration

Human Exploration and Operations



Space Technology

Science

Aeronautics Research

Marshall supports three of the NASA Mission Areas.

The National Aeronautics and Space Administration

Human Exploration and Operations

Science

MSFC Participation in **HEOMD Technology Divisions**:

Advanced Exploration Systems (AES):

- Atmosphere Resource Recover and Environmental Monitoring (ARREM)
- 3D Printing in Zero-G (3DP) —also funded by ISS and STMD/GCD
- Nuclear Cryogenic Propulsion Stage (NCPS)
- Advanced Neutron Spectrometer (ANS)
- Deep Space Habitat (DSH) Concept Demonstrators

Exploration Systems Development:

- Space Launch System Advanced Development Office (SLS-ADO)

Marshall supports three of the NASA Mission Areas.

Atmosphere Resource Recovery & Environmental Monitoring (ARREM)

CO_2 Removal

Oxygen Recovery

Trace Contaminant Control

Integrated Atmosphere Revitalization Test

Project Description:
Mature integrated Atmosphere Revitalization Systems and Environmental Monitoring Systems for future human missions beyond Earth orbit. Focus on key technologies that increase reliability, capability, and consumable mass recovery as well as reduce requirements for power, volume, logistics resupply, and crew involvement.

MSFC Role:
Project management (Agency role); engineering design/analysis/testing

Customer: Advanced Exploration Systems

Accomplishments for 2013:

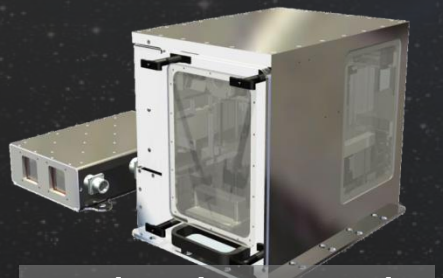
- Completed Cycle 1 closed-chamber integrated testing of Atmosphere Revitalization Systems for Exploration
- Started outfitting facility for Cycle 2 testing
- Completed ISS CDRA-4 flight-like ground unit for Cycle 2 integrated test
- Received 3rd Generation Plasma Pyrolysis Assembly from Umpqua Research (SBIR)
- Hosted Agency's Environmental Monitoring Technical Interchange Meeting (TIM)
- Participated in the NASA ECLS System Maturation Team (SMT) meeting
- Completed Agency roadmap drafts for NASA'S Microbial Monitoring, and Atmosphere Revitalization Systems

3D Printing in Zero-G (3DP)

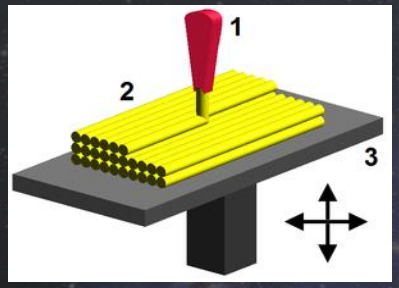
Project Description:
Deliver the first 3D printer to the ISS to investigate the effects of microgravity on melt deposition additive manufacturing and print parts in space. Payload will utilize Microgravity Science Glovebox, print multiple parts from polymer material, demonstrate nominal extrusion and traversing, and perform on-demand printing via CAD file uplink. Printed parts will be tested on the ground for quality and strength.

MSFC Role:
Project management (Made In Space, Inc. printer development), insight to ensure hardware meets minimum flight requirements, and performance of all flight qualification and acceptance testing

Customers: Space Technology Mission Directorate (STMD) Game Changing Development, Advanced Exploration Systems (AES)/HEOMD, and ISS



Engineering Test Unit



1 – Nozzle; 2- Printed Part;
3 – Print Tray

Vibe and EMI Testing

Crew Office Assessing 3D Print

Accomplishments:
- Awarded SBIR Phase III contract to Made In Space
- Completed Systems Requirements Review (SRR) / Preliminary Design Review (PDR)
- Completed EMI/EMC, Acoustic, and Vibe Testing on Engineering Test Unit and Ground Test Unit
- Held preliminary Human Factors Interface Team (HFIT) review with crew office representatives
- Completed the Critical Design Review (CDR) with no major issues
- Held Phase 0, I, and II Safety Reviews with ISS Payload Safety Review Panel (PSRP)
- Performing detailed materials analyses and testing
- Featured in over 300 national media articles and interviews

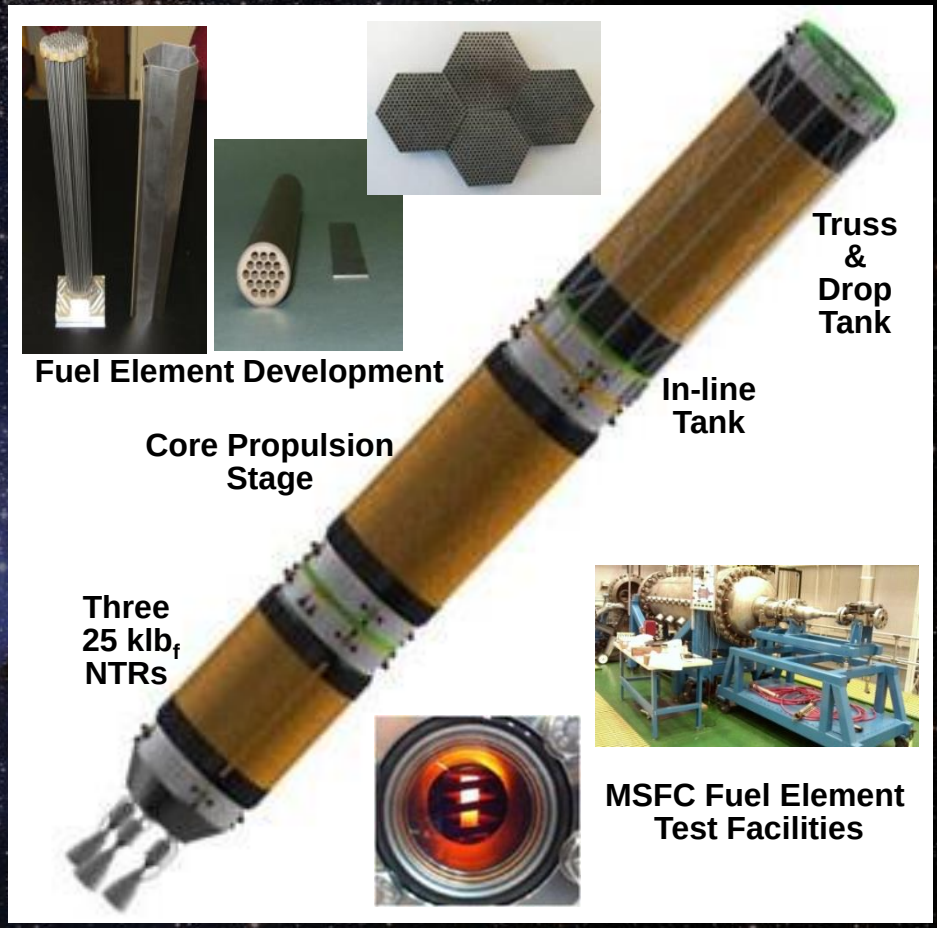
Nuclear Cryogenic Propulsion Stage (NCPS)

Project Description:
Demonstrate affordability and viability of a fully integrated NCPS. Accomplish stage design, fuel fabrication and testing, affordable development and qualification strategy. Enable NCPS to be considered a mainstream option for supporting human Mars and other missions beyond earth orbit.

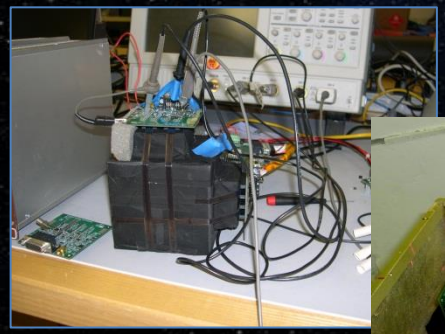
MSFC Role:
Provide management and oversight while working in and outside of MSFC to help ensure project success

Customers: Advanced Exploration Systems (AES)/HEOMD, MSFC AES Project Office; NASA Human Architecture Team (HAT)

Accomplishments for 2013:
- Fabricated tungsten-based CERMET fuels with both surrogates and depleted uranium
- Completed 50 kW upgrade of Compact Fuel Element Environmental Test (CFEET)
- Achieved sample temperatures in excess of 3500 K during CFEET system checkout
- Updated NCPS vehicle concept to fully utilize SLS
- Continued NCPS fuel design/fabrication
- Started CERMET fuel element testing in CFEET system
- Completed AES Fuel Element Development Review at Oak Ridge National Laboratory



Advanced Neutron Spectrometer (ANS) for Radiation Monitoring



Photos of various stages in the development of the ANS instrument. Lower right: The fully integrated ANS prototype during test exposures to 200 MeV protons.

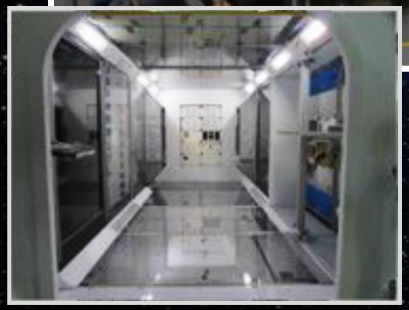
Project Description:
Going beyond LEO presents several new challenges for the safe execution of NASA's manned exploration plans beyond the protective layers of Earth's atmosphere and magnetic field. These challenges require advanced instrument designs to meet new requirements for monitoring radiation exposure under severe resource constraints. The Advanced Neutron Spectrometer (ANS) is being developed to address the neutron monitoring requirements and meet the future needs of exploring new destinations.

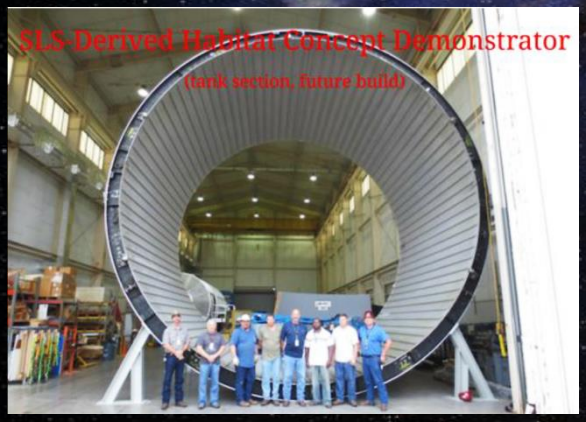
MSFC Role:
Principal Investigator; ANS instrument development

Customers: Advanced Exploration Systems (AES)/HEOMD; NASA JSC

Accomplishments for 2013:
- Completed side-by-side comparison of neutron detection techniques relevant to manned exploration
- Demonstrated advantages of the new measurement technique for fast neutrons employed in ANS
- Exposed ANS to high energy particles to demonstrate functionality in a radiation environment

Deep Space Habitat Concept Demonstrators





Project Description:
Develop, integrate, test, and evaluate Habitation Systems that will be utilized as technology testbeds and to advance NASA's understanding of alternative deep space mission architectures, requirements, and operations concepts. Utilize rapid prototyping and existing hardware to develop full-scale habitat demonstrators.

MSFC Role: Project management; hardware assembly; engineering support

Customers: Advanced Exploration Systems (AES)/HEOMD; NASA JSC

Accomplishments for 2013:
- Integrated mockup Environmental Control and Life Support Systems (ECLSS), power, and avionics subsystems with the Multi-Purpose Logistics Module (MPLM)-based habitat demonstrator
- Accomplished additional module buildup to complete the Cis-Lunar demonstrator
- Utilized inexpensive materials and existing hardware to allow rapid prototype builds
- Discovered limitations of Cis-Lunar concept, began evaluation of SLS-derived
- Completed on-site reviews with NASA JSC project management personnel (AES)
- Provided numerous tours of habitat demonstrators, several media interviews

Space Launch System Advanced Development Office (SLS-ADO)

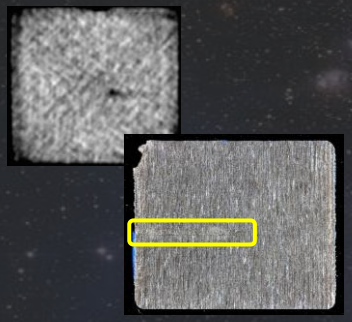
In-House Tasks

Al 2195 T8 Gore Development: Martin Volz

Objective: Develop manufacturing process for making gore panels from aluminum lithium alloy 2195, to achieve weight savings for potential SLS Block 1B. Optimize heat treatment and stretch parameters for thicker panels.

Accomplishments:
- Completed heat treatment and gore stretching Al 2195 plates of 0.525“ and 0.75” thickness
- Completed tensile strength and fracture toughness testing of 0.525" and 0.75” gores at room temperatures
- Verified improved mechanical properties of annealed panels

NDE of Selective Laser Melting Materials: David Brown



Objective: Characterize non-destructive inspection performance on powder bed fusion materials for additive manufacturing (AM) such as selective laser melting (SLM)

Accomplishments:
- Identified materials and developed specimens for NDE
- Reviewed limitations of NDE for AM parts
- Determined that Computed Tomography (CT) appears to be best method for SLM parts; work remains for planar defects

Cryoinsulation Development: Alison Protz

Objective: Develop closeout processes for low Global Warming Potential (GWP) foam insulation, and develop/characterize zero GWP materials. Develop S-180 Manual Spray Foam as risk mitigation for SLS Core Stage.

Accomplishments:
- Completed process development and specs for the S-180 manual spray foam
- Wrote manual foam sprayer organizational work instruction (OWI)
- Accomplished fab and testing of reformulated foam specimens

Chromium VI Free Primer Development: Michael Alldredge

Objective: Evaluate corrosion protection capability of multiple commercially-available hexavalent chromium-free non-hazardous primers for cryogenic applications

Accomplishments:
- Solicited industry for potential primer candidates
- Performed salt fog/ corrosion and cryoflex testing
- Selected 4 primer candidates out of 13 for further testing in second phase of project

Low-Profile Diffuser (LPD): Mike Martin

Objective: Develop a diffuser concept to replace existing types with a high performing, low profile design to enable more propellant capacity and increase SLS performance

Accomplishments:
- Used CFD methods to design LPD
- Completed machine shop work for LPD
- Developed test procedures
- Continued CFD analysis for LPD and Boeing diffuser to predict performance

Space Launch System Advanced Development Office (SLS-ADO)

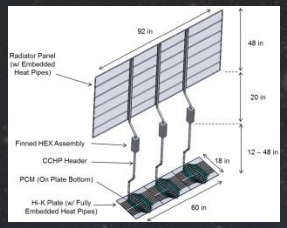
In-House Tasks

SLM Propulsion Hardware : Jason Turpin

Objective: Design, fabricate, and hot fire test an Integral Valve/Injector that is built using AM. Build partnership with Air Force for development of technologies that are synergistic with both NASA SLS and Air Force goals. Advance use of additive manufacturing (AM) technology for turbomachinery.

Accomplishments:
- Completed fabrication, water flow and hot fire testing of 28-element injector
- Completed fab of inducer, shrouded impeller, and shrouded turbine

Advanced Passive Avionics Cooling: Jeff Farmer



Objective: Develop and test advanced passive thermal control techniques to assess performance and affordability. Provide enhanced avionics cooling benefits for SLS baseline and upgrades.

Accomplishments:
- Completed survey of two-phase cooling technologies and identified concepts for SLS application
- Established design requirements for passive heat rejection through passive sublimator driven coldplate
- Received hardware based on findings of Phase 1 studies; obtained test area

High Voltage Electronic Parts Assessment: Griffin

Objective: Obtain high voltage electronic parts and conduct low-cost mechanical, electrical and environmental testing. Compile construction analysis of these parts and a documented qualification path for use on SLS future TVC upgrade.

Accomplishments:
- Completed construction analysis
- Received off-board parts and materials
- Completed circuit boards
- Inspected & removed rod end and roller-screw mechanism

GH2 Sensor Development: James Currie

Objective: Deliver flight ready gaseous hydrogen (GH2) detection sensors operable for use on SLS Block 1A. Produce stand-alone leak detection systems with minimal size, weight, and power consumption.

Accomplishments:
- Completed electromagnetic interference/ compatibility (EMI/EMC) and ESD testing
- Completed random vibration screening
- Completed sensor calibration
- Completed algorithm for both GN2 and air

Fluid Structures Coupling Damper: Rob Berry

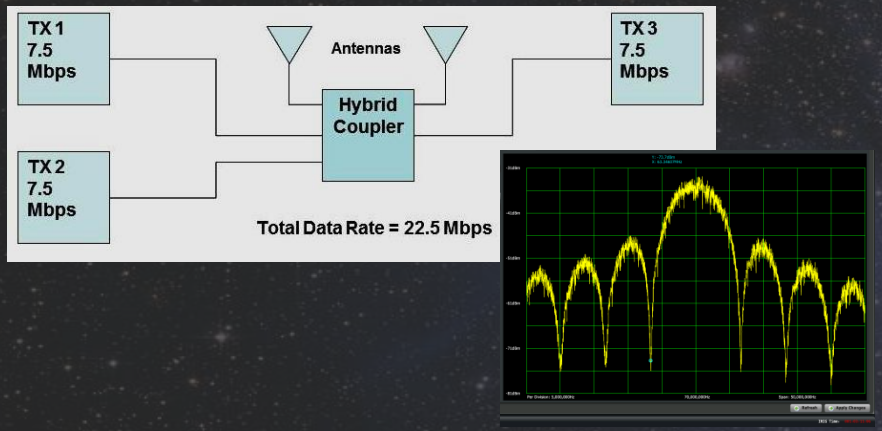
Objective: Assess feasibility and effectiveness of fluid structures coupling damper technology to control vehicle lateral modes, mitigate slosh, and SLS-unique axial mitigation

Accomplishments:
- Developed prototype design for mitigating vehicle axial modes
- Demonstrated axial mitigation for SLS through testing
- Derived lateral equations and correlated with test
- Anchored analytical abilities to properly capture physics

Space Launch System Advanced Development Office (SLS-ADO)

In-House Tasks

Advanced Telemetry System: Patrick Campbell and Bill Hopkins

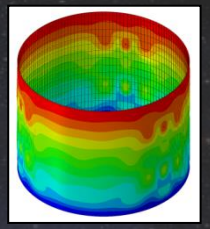


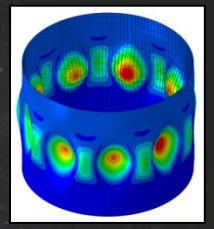
Objective: Investigate the use of advanced modulation techniques that allow (1) more data to be transmitted in a channel and (2) the use of fewer radios. Since SLS will use traditional RF telemetry systems to transmit data to the ground, high data rate requirements will necessitate multiple radios or high-bandwidth channels. Cost and spectrum constraints could make this approach difficult. This project could provide the telemetry solution.

Accomplishments include:

- Received the receiver/modulator hardware capable of up to 8 Phase Shift Keying (PSK) modulation and low-density parity check (LDPC) forward error correction
- Evaluated spectrum and developed RF architecture

Shell Buckling Knockdown Factors: Mark Hilburger





Objective: Develop and validate analysis-based shell buckling knockdown factor (KDF) updates for SLS-specific orthogrid and isogrid stiffened metallic cylinders. Seek reductions in design cycle time and reworks, enhance safety/reliability, and enable significant mass savings potential in the SLS core stage (>3-4mt).

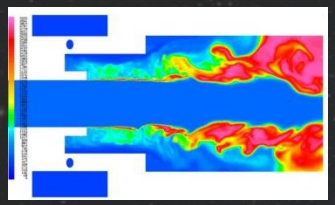
Accomplishments include:

- Designed, fabricated, and tested two orthogrid 8-ft diameter cylinder test articles
- Designed two isogrid 8-ft diameter cylinder test articles
- Completed buckling analysis
- Improved knockdown factors for combined mechanical, thermal, and pressure loads

Space Launch System Advanced Development Office (SLS-ADO)

In-House Tasks (NESC Funded/Managed)

Advanced Integrated Combustion Stability Capability: Kevin Tucker



Objective: Advance the predictive capability of tools used in SLS combustion stability assessments; facilitate identification/mitigation of combustion instabilities during SLS propulsion system development; reduce development costs

Accomplishments include:

- Completed CFD simulations of gas centered swirl coax injector elements
- Identified engineering tool needs for higher-fidelity inputs & model
- Completed scaling of hydrocarbon boost element; held CDR for testing of this element

Pyroshock Characterization of Composite Materials : David Ordway

Objective: Support potential use of composites in the evolved SLS vehicle; evaluate materials to insure they can withstand launch loads and pyroshock-induced stresses during stage separation

Accomplishments include:

- Completed pyroshock testing for solid and honeycomb composite panels
- Developed algorithms for export of data for statistical analytical tools
- Used output from the algorithms as input for the statistical analyses

Booster Interface Load Analysis: Greg Brauckmann

Objective: Research and optimize booster interference loads for advanced SLS booster configurations. Use CFD tools with wind tunnel experiments to characterize booster interference effects.

Accomplishments include:

- Completed pre-test numerical simulations
- Completed wind tunnel test
- Supported Buffet Loads Mitigation Team; provided CFD results to guide testing options
- Briefed CFD and testing results to chief engineer
- Provided buffet simulation results to SLS Aero team

Block IA Advanced Booster Composite Case/Internal Insulation: Jessica Chaffin

Objective: Evaluate processing through tensile strength, impact peel strength, and water burst testing. Develop NDE damage standards; determine NDE methods best suited to large-scale loaded motors. Evaluate high-energy propellants.

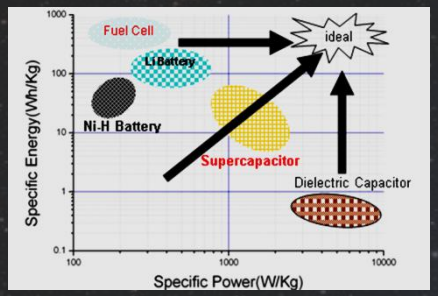
Accomplishments include:

- Evaluated 3 propellant types through testing for hazards, burn rate, tensile properties; selected 2 propellant candidates or scale-up
- Manufactured and completed NDE for 38 oven cured bottles
- Determined applicability of NDE methods for composite bottles

Space Launch System Advanced Development Office (SLS-ADO)

University Grants

High Electrical Density Device Survey: Auburn

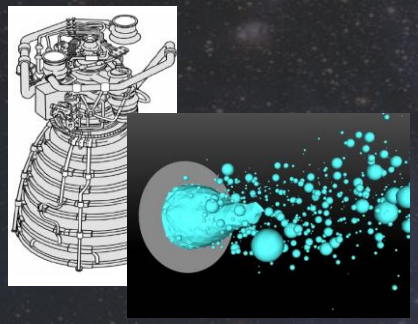


Objective: Conduct an assessment and develop database of commercial energy storage devices, to meet future SLS power requirements and minimize mass/volume

Accomplishments include:

- Completed survey of commercially available batteries, dielectric capacitors, and supercapacitors, and determined critical parameters
- Surveyed newly developed technologies
- Assessed new dielectric composites-based energy storage devices

Development of Atomization Models for Liquid Rocket Injectors: Florida

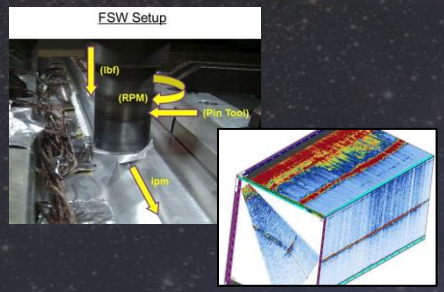


Objective: Deliver improved high-fidelity design tool for SLS liquid engine injectors, help improve combustion efficiency of the SLS liquid propulsion systems, and predict combustion instabilities

Accomplishments include:

- Completed stochastic modeling of subcritical primary atomization for steady case
- Integrated primary atomization stochastic model into Loci-CHEM

Improved Friction Stir Welds Utilizing On-line Sensing of Weld Quality: LSU

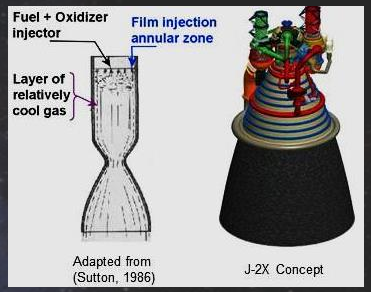


Objective: Create an on-weld quality sensing system to aid the manufacturing process of friction stir welding, and expedite the process to determine defect-free welding parameters

Accomplishments include:

- Determined that process variables are coupled, and that changing one variable alters entire weld
- Correlated initial data with theoretical models
- Determined that x-ray data and Phased Array Ultrasonic Testing (PAUT) results agree
- Proved that PAUT is best choice for on-line detection

Supersonic Film Cooling Numerical Simulations: Maryland



Objective: Develop a detailed understanding of film cooling fluid dynamics so that predictive CFD approaches can be developed

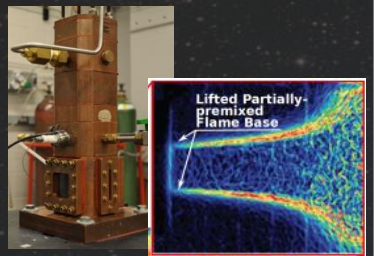
Accomplishments include:

- Compared measured to simulated wall heat flux
- Developed high frequency pitot probe for measuring velocity fluctuations in supersonic stream
- Developed high intensity pulsed light source for Schlieren images
- Validated simulation for film cooling flows

Space Launch System Advanced Development Office (SLS-ADO)

University Grants

Transient Combustion Processes in Rockets: Michigan and Stanford

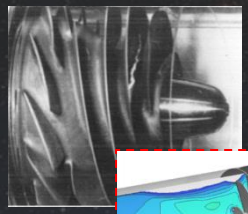


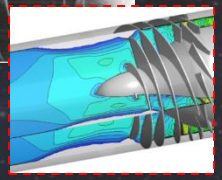
Objective: Accomplish computational and experimental research to develop validated simulation techniques for accurate prediction of unstable combustion processes in rocket engines

Accomplishments:

- Brought planar laser-induced fluorescence (PLIF) system online for diagnostics; made progress on particle image velocimetry (PIV) system
- Worked toward PIV/PLIF system with wall temperature and chamber pressure measurements
- Developed combustion model with flame-normal heat-loss effect

Cavitation Challenges in Turbopump Inducers : MIT Gas Turbine Lab



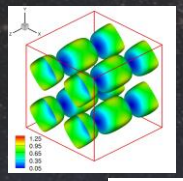


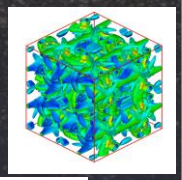
Objective: Mitigate higher order cavitation in SLS turbomachinery to improve rocket engine reliability and performance. Develop new methodology for quickly assessing inducer designs to suppress cavitation.

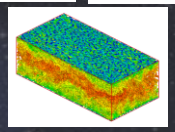
Accomplishments:

- Defined new turbopump inducer blade passage model and established body force methodology
- Designed inducer and verified performance agreement with SSME
- Computed cavitation performance of inducer

Enhancements for Hybrid RANS-LES: Mississippi State





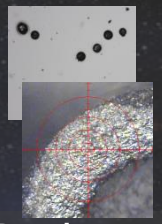


Objective: Achieve improvement to hybrid Reynolds Averaged Navier Stokes/Large Eddy Simulation (RANS/LES) CFD modeling, for practical solutions to problems of interest to SLS

Accomplishments:

- Implemented a kinetic-energy-consistent algorithm into Loci-CHEM
- Implemented a high-resolution gradient calculation method into Loci-CHEM
- Delivered updated CHEM version to NASA; further testing and validation ongoing

Aluminum/Alumina Carbon Interactions in Rockets: Penn St.

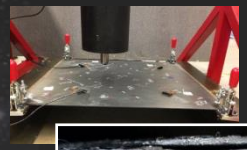


Objective: Develop fundamental understanding of Al/Al_2O_3/carbon thermochemical reactions likely to be important for SLS motor applications by performing basic experiments

Accomplishments:

- Conducted CO2 laser heating experiments for Al/Al_2O_3/carbon using graphite crucible
- Observed general behavior with temperature using video, along with gas sampling and post-test sample analysis performed on select test samples

Acoustic Emission-Based Health Monitoring of SLS Structures: Utah



Objective: Develop a structural health monitoring system for SLS structures. Increase reliability of the structure by accurately identifying location and type of damage due to impacts during transportation and assembly.

Accomplishments:

- Examined sensor response on panels due to actual and simulated impacts
- Evaluated acoustic emission sensors
- Conducted impacts at different temperatures and evaluated location algorithm
- Continued work on location estimation

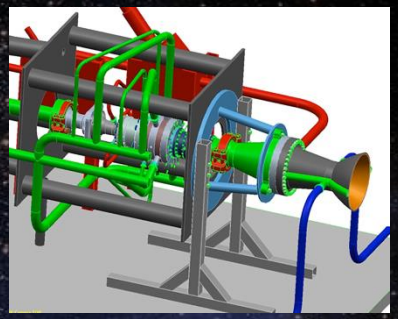
Advanced Booster Engineering Development Risk Reduction (ABEDRR)

Program Description:
Reduce risks leading to an affordable advanced booster that meets evolved capability requirements of SLS, and enable competition by mitigating targeted advanced booster risks to enhance affordability

MSFC Role:
Program Management

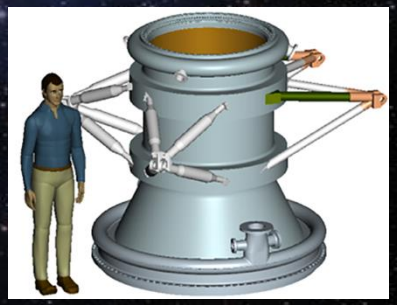
Accomplishments for 2013:

- Aerojet LOX/RP Engine: Developed system requirements and initiated preliminary design
- ATK Advanced Booster Performance, Reliability and Affordability: *(1) Propellant liner insulation (PLI)*: tailored liner formulation; tested PLI bondline; *(2) Case damage tolerance*: released drawings for 92-in composite case; *(3) Nozzle flex bearing*: released drawings of assembly and primary components; *(4) Avionics and controls*: defined test methods; assessed actuator sizing; *(5) Static fire test*: developed test plan and built igniter
- Dynetics Modernized F-1 Engine and Cryotank Cost Risk Reduction: *(1) F-1B engine:* hot-fired heritage gas generator (GG); produced F-1 GG injector using low-cost SLM manufacturing techniques; completed PDR for power pack assembly and F-1B main combustion chamber; *(2) Cryotank structures:* completed final design review and released all drawings; tested schedules for welding domes to dome/tank end rings
- Northrop Grumman Composite Common Bulkhead Tank: Completed composite demonstrator design review, held kickoff for test fixture build, built out-of-autoclave test panels with <1% void content



Aerojet Test Rig

ATK Test Motor



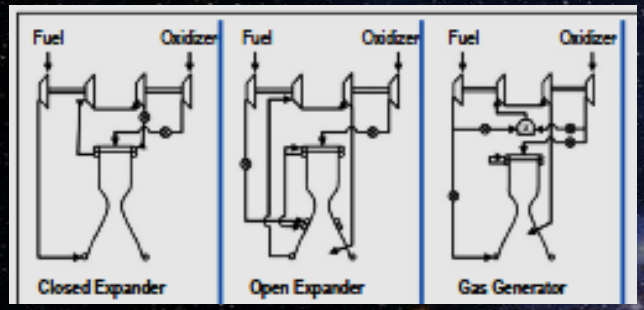
Dynetics F-1B Main Combustion Chamber

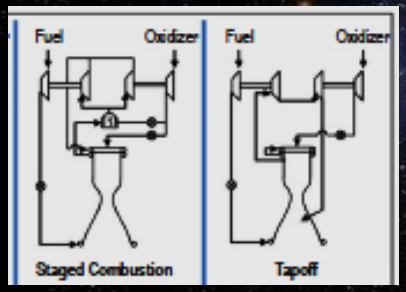
Northrop Grumman Tank Demonstrator

Advanced Upper Stage Engine Program (AUSEP) Industry Projects

Aerojet AUSEP Engine Concept

Moog Valve Body Produced at MSFC





Pratt & Whitney Rocketdyne Engine Cycle Trades

Program Description:
Develop affordable upper stage engine as replacement for RL10, with increased thrust and reduced size and weight for SLS CPS to provide additional mission capture. The Human Spaceflight Architecture Team (HAT) determined that AUSEP requirements are an enabler for the CPS.

MSFC Role:
Program Management

Accomplishments for 2013 include:

- Aerojet Next Generation Engine System Study: Finalized initial major subsystem requirements documents; completed power balance analyses for AUSEP; finalized figure of merit weighting to emphasize affordability
- Exquadrum Dual-Expander Aerospike Engine: Completed trade studies to identify optimum engine configuration; completed conceptual design of engine; developed modular thrust cell design
- Moog High Pressure LOX Control Valve: Completed valve design based on flow/pressure parameters from potential upper stage developers; completed PDR; produced valve body using additive manufacturing at MSFC
- Northrop Grumman Liquid Engine Requirements Study: Completed broad engine system trades; initiated detailed trades and design studies; selected point of departure engine system concept; performed thrust chamber trades
- Pratt & Whitney Rocketdyne Engine Trade Study: Evaluated all planned cycles and created power balance models for candidate architectures; created utility function balancing factors such as cost, reliability, performance

The National Aeronautics and Space Administration

MSFC Participation in technology development for **SMD Divisions**:

Planetary Science Division:

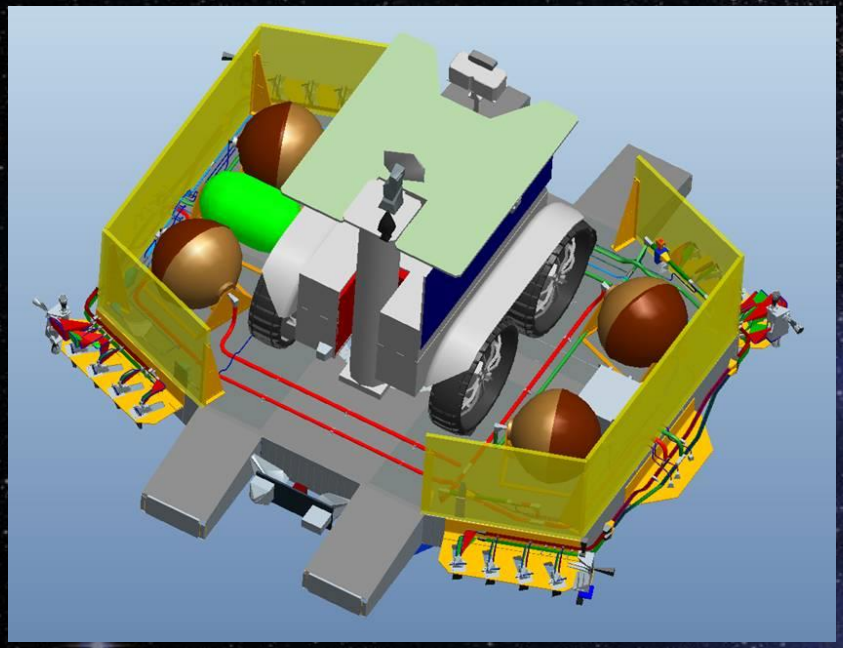
- Robotic Lander Development

Astrophysics Division:

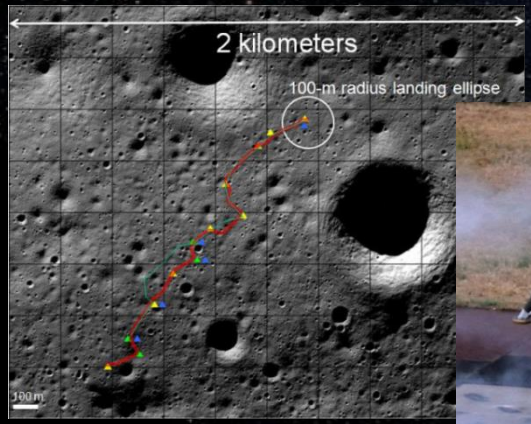
- Advanced Mirror Technology Development

Marshall supports three of the NASA Mission Areas.

Robotic Lander Development



Resource Prospector Lander Concept



Mighty Eagle Testing

Project Description:
Provide robotic lunar lander development for the Resource Prospector (RP) Mission to demonstrate in-situ resource utilization (ISRU) with the Regolith and Environment Science and Oxygen and Lunar Volatiles Extraction (RESOLVE) payload. Mature the RP lander as much as possible prior to FY15 to enable NASA partnership on lunar lander.

MSFC Role:

Resource Prospector Mission lander lead

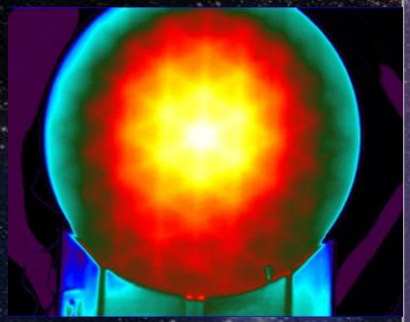
Customers: Science Mission Directorate; Advanced Exploration Systems (AES)/HEOMD (FY14); MSFC TIP (Mighty Eagle)

Accomplishments for 2013:

- Fostered MSFC/JSC lander partnership
- Completed RP lander trade studies for propulsion and avionics subsystem
- Completed RS34 module design and thruster hot-fire test prep
- Completed CDR for Pratt Whitney Rocketdyne In Space Engine 100 lb thruster
- Supplied requirements for pallet lander TIP
- Accomplished work with Mighty Eagle testbed, including hazard avoidance algorithm design and flight testing. Integrated software to allow Moon Express to fly the lander autonomously.
- Led NASA wide technical assessment of RFI seeking US industry partnership on landers

Advanced Mirror Technology Development (AMTD)

Subscale Deep Core Mirror Static Load Testing



Thermal Image of Mirror Front Surface Thermal Gradient

Subscale Deep Core Mirror at XRCF

Project Description:
Mature the TRL of 6 key technology challenges for the primary mirror of future large-aperture space telescopes. Multiple design paths include monolithic and segmented optics. Prototype development, testing, modeling, and demos. Metrics are traceable to science mission error budget.

MSFC Role:
Principal Investigator, Dr. H. Philip Stahl; Testing, Project Management

Customers: Strategic Astrophysics Technology (SAT) Program; Dr. Mario Perez, Science Mission Directorate; OCT

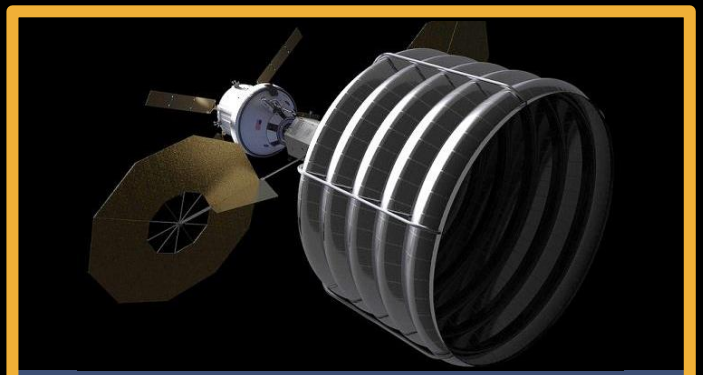
Accomplishments for 2013:

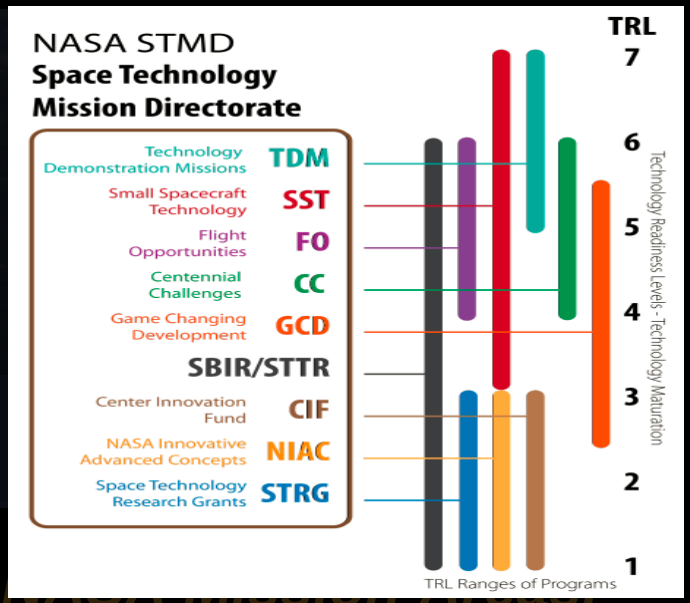
- First demonstration of the stacked-core process for making deeper, stiffer mirrors
- First demonstration of multiple replication process
- Demonstrated ability to polish deep core mirror to ultraviolet/optical (UVO) quality
- Characterized thermal performance of deep core mirror consistent with UVO performance
- Validated thermal model via test at XRCF
- Validated mechanical model via static load test
- Developing powerful design modeling and analysis tools

The National Aeronautics and Space Administration

MSFC Participation in **Space Technology Programs:**

- Technology Demonstration Missions (TDM)
  - Level II Program Management
  - Cryogenic Propellant Storage and Transfer (CPST)
- Centennial Challenges
  - Level II Program Management
- Game Changing Development (GCD)
  - Composite Cryotank Technologies and Demonstration (CCTD)
  - Soldier-Warfighter Operationally Responsive Deployer for Space (SWORDS)
  - Synthetic Biology and Next Generation Life Support (NGLS)
- Center Innovation Fund (CIF)





Marshall supports three of the NASA mission areas.

Technology Demonstration Missions (TDM) Program

Program Description:
Flight projects to "bridge the gap" between development and first use by maturing crosscutting, system-level space technologies through demonstration and mission infusion.

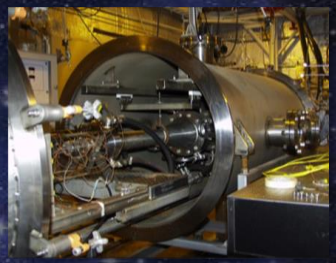
MSFC Role:
Level II Program Management/STMD

Accomplishments for 2013 (CPST on separate chart):

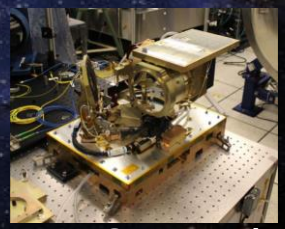
- Held TDM Program Annual Review at Gray Research in Huntsville, with 80 attendees, including STMD managers
- Completed TDM Annual Performance Assessment and report
- Brought new TDM Lessons Learned database online
- Deep Space Atomic Clock (DSAC): Completed system and clock PDR; obtained ride on US Air Force launch vehicle
- Solar Sail Demo (SSD): Completed fabrication, integration, and deployment testing of Engineering Test Unit Sail
- Green Propellant Infusion Mission (GPIM): Fabricated and tested 1N & 22N thruster units; completed SRR and PDR
- Low Density Supersonic Decelerator (LDSD): Completed supersonic sled testing; completed two subsystem CDRs
- Laser Comm Relay Demo (LCRD): Completed SRR; completed design for Control Electronics, Optical Module
- Human Exploration Telerobotics (HET): Demonstrated crew teleoperation of Robonaut 2, crew/ground control of Smart SPHERES, crew control of surface telerobotics
- Mars Entry Decent and Landing Instrumentation (MEDLI): Completed flight data reconstruction; released data


Atomic Clock


Solar Sail Demo


Green Prop Infusion


Supersonic Decelerator


Laser Comm Relay


Telerobotics


Mars EDL Instrum.

Cryogenic Propellant Storage and Transfer (CPST)

Project Description:
Demonstrate the capability to store, transfer, and measure cryogenic propellants both on the ground and in orbit for a duration which proves extensible to enable long term human space exploration missions beyond low Earth orbit.

MSFC Role:
Execution of the WBS 5.0 Element Cryogenic Fluid System Payload design, development, fabrication, assembly, test, and delivery. Level II Program Management role also covers CPST.

Customers: CPST Project Office (NASA GRC); Technology Demonstration Mission Level 2 Program Office; Cross-Cutting Capability Demos Office; Space Technology Mission Directorate (STMD)

Storage Tank Assembly (STA) Engineering Development Unit (EDU)

STA EDU in Foam Spray Booth

Accomplishments for 2013:

- Completed project reformulation to get within funding limits
- Completed CPST SRR/MDR milestone review and Key Decision Point (KDP)-B: Standing Review Board (SRB) concluded that CPST met all SRR/MDR success criteria and should proceed to Phase B; STMD gave approval for CPST to proceed to PDR
- Progressed with Storage Tank Assembly Engineering Development Unit (STA EDU): Completed dome-to-barrel welds, developed trimming process for Spray-On Foam Insulation (SOFI), completed tank assembly, passed acceptance testing (proof and cryogenic testing), completed NDE of welds with no anomalies, began SOFI application
- Kicked off Design Analysis Cycle 2: Initiated Preliminary Design phase for Payload System, initiated trades and systematic change process/control

Centennial Challenges Program

Program Description:
Offers incentive prizes to generate revolutionary solutions to problems of interest to NASA and the nation. The program seeks innovations from diverse and nontraditional sources of citizen inventors, private businesses and academia. Competitors are not supported by government funding, and awards are only made to successful teams when the challenges are met. NASA partners with non-profit organizations to conduct the challenges at no cost to the government.

MSFC Role:
Level II Program Management

Customer: Space Technology Mission Directorate (STMD)

Sample Return Robot Challenge

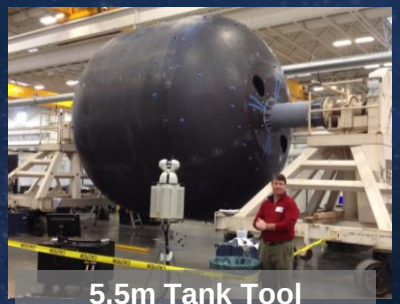
Accomplishments for 2013:
- Awarded Level 1 prize money of $5000 for Sample Return Robot (SRR) Challenge at Worcester Polytechnic Institute (WPI); Touch Tomorrow science/robotics festival drew 10,000+ people
- Received Telly Award and a regional Emmy Award for NASA 360's video "Robots, Rocks & Rovers" featuring the Sample Return Robot Challenge
- Served as speaker (Level II Program Manager Sam Ortega) at New York City Maker Faire 2013; exhibited Centennial Challenges alongside NASA HQ Grand Challenge
- Toured Indiana Army base which will be the site of the Unmanned Aircraft Systems Airspace Operations Challenge in 2014, and continued planning with WPI for the 2014 SRR Challenge

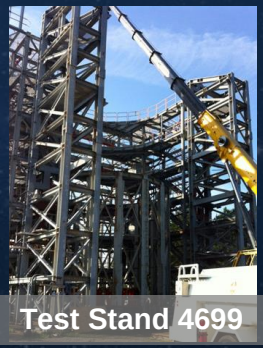
Composite Cryotank Technologies and Demonstration (CCTD)

Project Description:
Mature technology readiness of composite out of autoclave (OoA) cryogenic propellant tanks at diameters that are suitable for future heavy lift vehicles and other in-space applications. Produce a major advancement to demonstrate TRL 6; successfully test a 5-meter diameter composite hydrogen fuel tank in a relevant environment, and achieve 30% weight savings and 25% cost savings compared to state-of- the-art.

MSFC Role:
Project management, with subject matter expert support from NASA GRC, KSC, LaRC, and MSFC

Customers: STMD/Game Changing Development Program Office (Steve Gaddis/LaRC), HEOMD/Space Launch System (SLS) Office

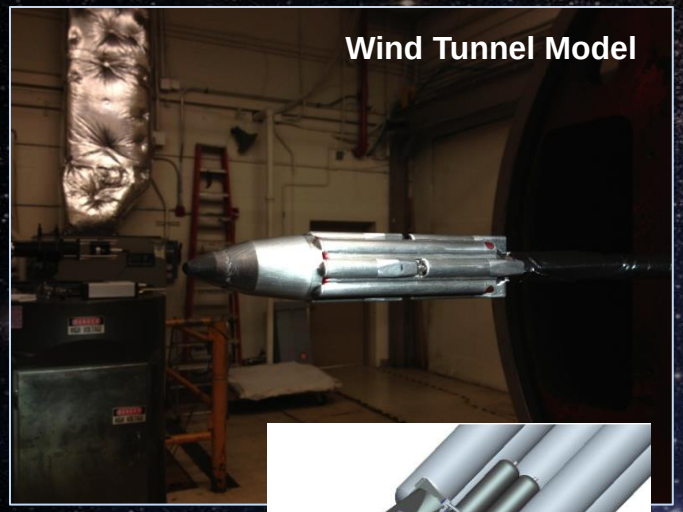

5.5m Tank Tool

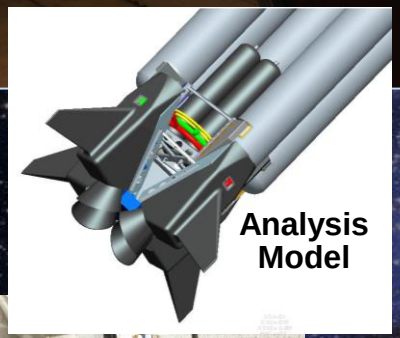

Test Stand 4699

Accomplishments:

- **2.4m Tank Status**: Completed fabrication (by Boeing) of first successful large fiber placed tank using OoA 5320-1/IM7 material and shipped to MSFC. Completed helium leak test and spray foaming of the tank. Completed the tank integration into test facility; completed TRR; successfully completed pressure tests in ambient and cryogenic (LH2) conditions. The tests met project requirements: stepwise fill with liquid hydrogen (LH2) to 90% volume capacity followed by pressurizing the tank to 135 psig. The tank was then cycled through 20 pressure/vent cycles, measuring hydrogen gas permeation on the tank dome.
- **5.5m Tank Status**: Completed the materials allowable program, optimization of the OoA Thin-Ply Prepreg and manufacture of 5.5m tool. Completed the CDR, MRR and delta CDR. Completed fabrication of four fluted core panels (288 full length flutes) and 5.5m pressure shell. Completed skirt alignment fixture installation and the automated fiber placement of the Inside Mold Line (IML) and Outer Mold Line (OML) skirt plies. Completed major refurbishment of MSFC Test Stand 4699 to accommodate CCTD 5.5m composite tank including fabrication and integration of Special Test Equipment.

Soldier-Warfighter Operationally Responsive Deployer for Space (SWORDS)


Wind Tunnel Model


Analysis Model


Test Stand 500 Mods for Horizontal Engine Testing

Project Description:
Develop an affordable, responsive, dedicated launch system for nano- and micro-satellites. Partner with US Army Space & Missile Defense Command (SMDC) to (1) develop a launch vehicle capable of lifting 25kg to 750km circular orbit, (2) target recurring production costs of ~$1.5M, and (3) reduce personnel and inventory requirements.

MSFC Role: Project management; lead 4 NASA centers providing expertise in areas such as Avionics, Aerosciences, Propulsion, Launch Services, Vehicle System analysis

Customers: STMD Game Changing Development; Advanced Exploration Systems (AES)/HEOMD; US Army SMDC

Accomplishments for 2013:
- Provided significant participation in second design review (PDR)
- Completed wind tunnel testing, delivered aero database
- Completed two Load Cycle reviews
- Continued Mass Properties database
- Developed models for pressurization and feed systems analysis, engine operations analysis, and engine nozzles
- Defined Flight Safety System architecture
- Prepared Test Stand 500 for horizontal engine testing

Synthetic Biology and Next Generation Life Support (NGLS)

Project Description:

Synthetic Biology: Develop concept designs and collect baseline performance data on carbon dioxide removal and oxygen production using biological systems, including genetically engineered organisms
NGLS: Develop and mature the Bosch CO2 reduction hardware for future integration into an atmosphere revitalization architecture

MSFC Role: Supporting center to ARC (Synthetic Biology) and JSC (NGLS)

Customer: STMD Game Changing Development

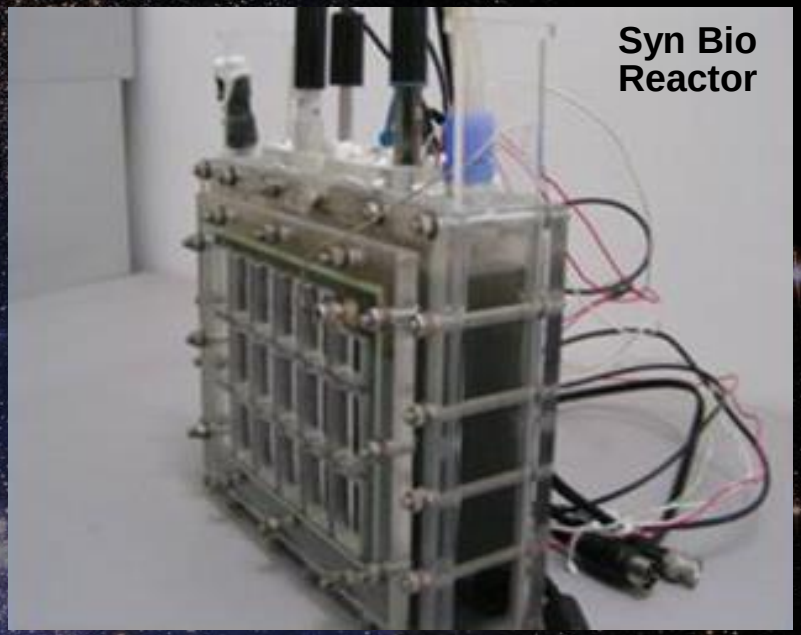
Accomplishments for 2013 include:

Syn Bio

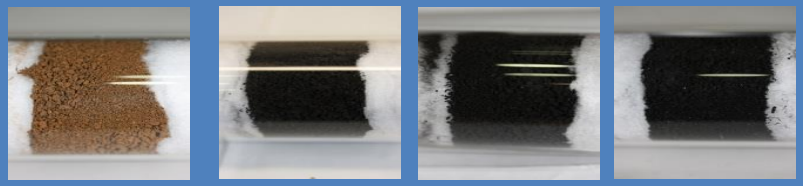
- Worked with ARC to define new objectives and tasks; MSFC has role in developing test stand to evaluate Syn Bio reactor
- Specified components for items to test feed and separation processes ancillary to the bioreactor for testing

NGLS

- Completed Series-Bosch test stand and software package
- Completed Reverse Water-Gas Shift test stand build-up; started testing
- Completed testing of Lunar and Martian regolith as carbon formation catalysts
- Produced Lunar & Martian regolith bricks



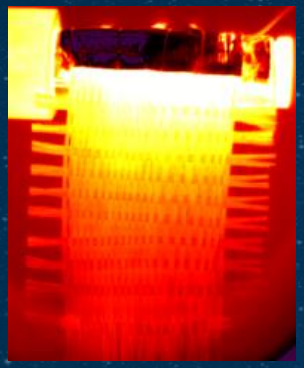
NGLS Results



Bosch reaction carbon formation on Martian regolith after 0hrs, 1hr, 4hrs, and 16hrs (left to right)

Center Innovation Fund (CIF)

Lightweight Radiators for Nuclear Electric Propulsion: Paul Craven

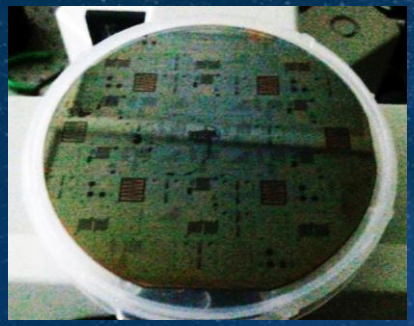


Objective: Develop lightweight carbon-fin heat rejection system to operate from cryogenic to 1000ºC temperatures. Capability is enabling for game-changing power and propulsion technologies .

Accomplishments include:

- Improved radiator construction
- Demonstrated operations to 600°C
- Characterized carbon fiber fin performance

Day and Night Energy Harvesting: Angela Shields



Objective: Develop plasmonic nano-antennas to capture earth's re-emitted IR energy and convert into DC power for spacecraft. Offers major reduction in spacecraft power system weight.

Accomplishments in FY13:

- Transitioned concept from visible to IR wavelength
- Developed lithography process for antennas
- Continued diode fabrication and testing

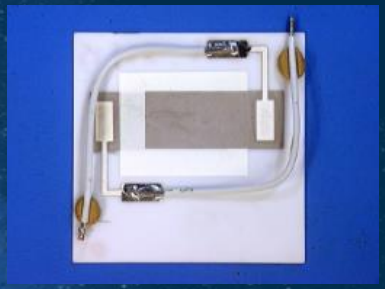
Electrically-Controlled Extinguishable Solid Propellant: Jeremy Rousseau

Objective: Electrically-controlled extinguishable solid propellant. Innovation could allow NASA to demonstrate throttleable, solid rocket motor that could replace multi-mode propulsion systems.

Accomplishments include:

- Static motor test firing with embedded graphite electrodes
- Based on first test results, designed second test series with fewer electrodes and GN2 purge

A Solid State Ultracapacitor to Replace Batteries: Terry Rolin



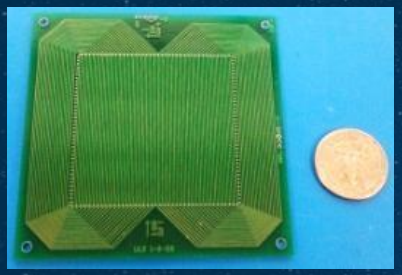
Objective: Develop internal barrier layer capacitor leading to solid-state replacement for batteries. Design offers 50X decrease in upmass and eliminates failure modes in many designs.

Accomplishments include:

- Fabricated numerous thick film ultracapacitor devices for testing
- Verified testing process by comparison to calculated values
- Established two new laboratories at MSFC

Center Innovation Fund (CIF)

Small Satellite Attitude Determination and Control: Steven Peeples



Objective: Modular attitude determination and control system (ADCS) to reduce volume by factor of five and power draw by two orders-of-magnitude. Advances CubeSat emerging science.

Accomplishments include:

- Completed magnetic torquer and ADCS PCBs design/fab/test
- Completed preliminary CubeSat proximity operations testing
- Designed adapter for ADCS IMU upgrade

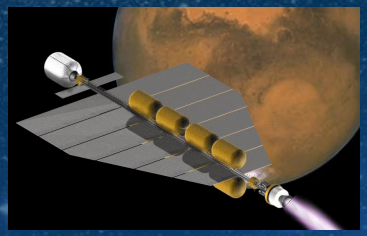
On-Orbit UV Cured Hybrid Inflatables: Alex Sobey

Objective: Develop hybrid composite inflatable structures to be cured in-orbit. Maintain advantages of inflatables, while adding the structural integrity and rigidity of a hard-shelled composite.

Accomplishments include:

- Introduced new resin and fiber; cured laminates
- Improved material consistency using Vacuum Assisted Resin Transfer Molding
- Performed impact testing of inflated articles
- Analyzed results and concluded positively on viability of material

Lighting the Fission Fragment Rocket Engine (FFRE) Afterburner: Bob Werka



Objective: Add afterburner to previously studied FFRE to achieve greater thrust while maintaining very high Isp. Innovation offers potential for 100-day Mars mission.

Accomplishments include:

- Completed analysis that predicts 1046lbf thrust at 32,000s Isp
- Synthesized FFRE-propelled spacecraft with 170mT payload to predict round trip 290 day Mars Exploration mission
- Verified FFRE modeling with independent code

Aligned Carbon Nanotube Tape for Sensors: Dennis Tucker

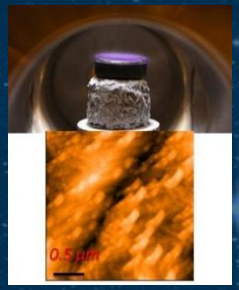
Objective: Demonstrate feasibility of producing piezoelectric carbon nanotube tape for use as sensing elements in small satellites. Advantages include low weight and superior mechanical/ thermal properties.

Accomplishments include:

- Fabricated multi-functional CNT tape and measured piezoelectric response
- Improved performance by adding barium titanate nanopowder to matrix material solution
- Designed accelerometer and gyroscope

Center Innovation Fund (CIF)

Carbon Formation for Life Support and *in situ* Fab: Morgan Abney



Objective: Investigate technologies to recover hydrogen from methane on ISS while generating useful forms of carbon using chemical vapor deposition. Potential for *in situ* fabrication using carbon.

Accomplishments:
- Processed depositions of carbon on Ni and Fe substrates
- Found that Ni and Fe substrates have different carbon forms under same conditions
- Established protocols for controlled carbon deposition from methane

Fission-Fragment Dust Experiment: Dennis Gallagher

Objective: Characterization of radioactive dust charging properties during decay and fission to enable the development of new type of fission fragment in-space rocket engine.

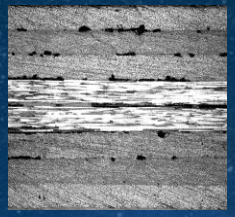
Accomplishments:
- Delivered FFDE electrostatic particle levitator apparatus and test equipment to Oak Ridge National Laboratory
- Conducted levitation tests for radioactive Californium 252 particles

Ultra-High-Resolution X-Ray Optics: Mikhail Gubarev

Objective: Improve x-ray mirror fabrication process by forming naturally-flat, thin silicon wafers through torque bending into very-lightweight, high-resolution mirrors ready to be installed in a telescope.

Accomplishments:
- Demonstrated viability in first year by building mirror bender and forming wafers into conical surface
- Designed and 3D printed second generation bender
- Demonstrated that coating stress can be measured by in-situ monitoring of wafer curvature

Boron/Graphite Hybrid Composites: John Fikes



Objective: Develop a composite laminate with 50% more compression after impact (CAI) strength by incorporating boron fibers with the carbon fibers in a laminate. Also seek to greatly reduce the cost and time needed to develop material allowables.

Accomplishments:
- Achieved 50 ksi CAI strength with two material plies, and 53 ksi with 3 plies (goal 61 ksi)
- Found that reduced allowable testing preliminary results were encouraging for elastic constants

Simulated Martian Exposure to Propellant: Jeremy Rousseau

Objective: Condition a new solid propellant formulation for the Mars Ascent Vehicle. Subject propellant to space vacuum for six months, and to an atmosphere replicating the Martian environment.

Accomplishments:
- Procured, built, assembled, and started entire test system
- Achieved savings of $250-500K through non-aerospace COTS equipment
- Started testing of 200lb of propellant

The National Aeronautics and Space Administration

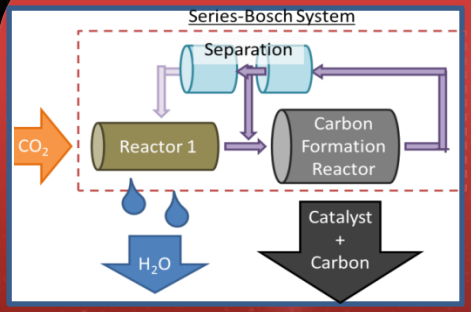
MSFC also expends **Internal Research and Development** (IRAD) resources on strategic technology efforts:

- Technology Investment Program
- Center Discretionary Funds

Marshall supports three of the NASA Mission Areas.

Technology Investment Program (TIP)

Bosch for Space &Terrestrial Applications: Morgan Abney



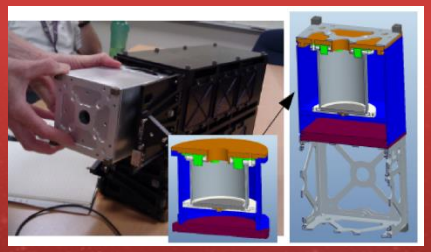
Purpose

Advance Bosch CO2 reduction technology for (1) life support systems using regolith catalyst, and (2) reduction of CO2 emissions in cement industry

Accomplishments

- Tested Martian and Lunar Regolith simulants and produced bricks
- Tested cement from two U.S.-based plants and produced bricks
- Developed concepts for regolith-based carbon formation reactor and Bosch-based CO2 reduction in a cement plant

Collimated Photoelectron Gun (CPEG): Linda Krause



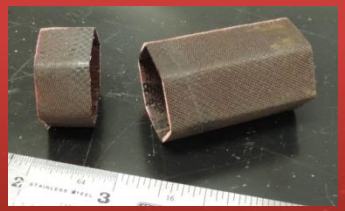
Purpose

Design, develop, and test collimated photoelectron gun, a novel electron source for spaceflight applications

Accomplishments

- Completed electrical design of system, and modified mechanical design based on vibe test results
- Completed final design and assembly of CPEG system
- Adapted design for flight as external CubeSat payload

Superior Epoxies for Cryo Composite Tanks: Richard Grugel



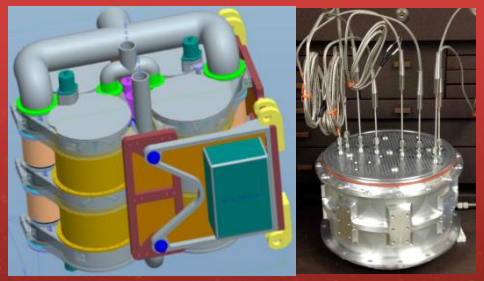
Purpose

Improve strength and fracture toughness of novel ionic-liquid-based epoxy for application in composite cryotanks. Offers potential game-changing technology.

Accomplishments

- Established procedure to mix, “cast”, process, and extract ionic liquid (IL) epoxy test samples
- Incorporated nano-scale Core-Shell-Rubber (CSR) particles into IL epoxy matrix to toughen it
- Verified increased fracture toughness through impact testing; repeated cycling in LN2 showed no evidence of cracking/delamination

Bench Test of Orion Air Revitalization System: Jim Knox



Purpose

- Demonstrate viability of a MSFC approach for Orion carbon dioxide and humidity control
- Fabricate, assemble, and test modified adsorbent beds & test stand to demonstrate performance with improved vacuum conductance

Accomplishments

- Engineering Development Unit: Completed fabrication of bed components
- Seal Test: Completed housing fabrication, test stand assembly and integration, and test stand leak check
- Vacuum Characterization Test: Fabbed second-gen test article

Technology Investment Program (TIP)

Ionic Liquid Extraction of Metals from Meteorite: Laurel Karr

Purpose
Use acidic ionic liquid (IL) system to extract metals from meteorite. In year 2, scale up the process and produce material for use in additive manufacturing.

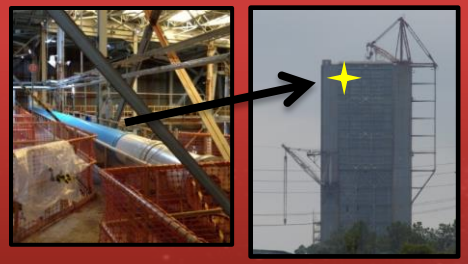
Accomplishments
- Synthesized and tested new ionic liquids
- Designed and built larger scaled-up electrolysis cell
- Produced enough metal for several gears
- Attempted additive manufacturing (AM) of parts from extracted metal; magnetic iron did not work in AM equipment
  - In future work, use meteorite with more nickel and separate out nickel for use in manufacturing

SPRITE Small Satellite HIL Testbed: Ashley Lee

Purpose
Advance MSFC's capabilities to support small spacecraft and payloads work by enhancing capabilities of the Small Projects Rapid Integration and Test Environment (SPRITE) Lab. Develop portable Hardware-in-the-Loop (HIL) integration and verification testbed.

Accomplishments
- Ran simulation system on portable test bed providing the ability for the SPRITE lab to test hardware at customer's site
- Created library of both generic and specific models, ranging from physics models to hardware models
- Used ARTEMIS framework for synchronization, passing of data, and calls to hardware

Active Lateral Fluid Harmonic Absorber (AFLHA): Rusty Parks



Purpose
Apply fluid-structure coupling technology to systems such as space launch vehicles and commercial buildings. Develop active absorber to account for building frequency shifts.

Accomplishments
- Defined and used attenuation factor as ratio of un-attenuated to attenuated building response to an input at building first bending mode
- Achieved attenuation factors of 4.4 to 5.8 in as little as 160 seconds with active system (ALFHA); exceeded modern day building system attenuation factor of 2.2

Selective Laser Melting (SLM) Produced Hermetically Sealed Isolation Valve: James Richard

Purpose
Use SLM technology to achieve a hermetically sealed valve to replace expensive, difficult to handle, and potentially problematic pyrotechnic valves.

Accomplishments
- Developed valve designs to replace pyrotechnic devices near the propellant of launch or space systems; conducted trades
- Completed and built two detailed designs, using SLM techniques where possible
- Completed test plans

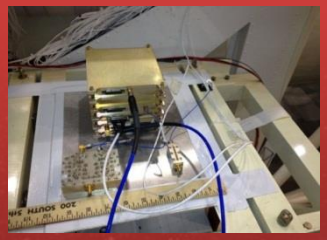
Technology Investment Program (TIP)

CubeSat Proximity Operations: Devon Sanders

Purpose
Accomplish autonomous rendezvous of a CubeSat prototype with another CubeSat or FASTSAT mock-up in MSFC's Flight Robotics Lab

Accomplishments
- Completed micropropulsion design and delivery (Univ. of Arkansas)
- Accomplished systems engineering t asks: ConOps analysis and trades, power budget, and card stack layout
- Completed structural design/analysis and thermal analysis
- Accomplished avionics, most of software, and GN&C tasks

Programmable Ultra-Lightweight System Adaptable Radio (PULSAR): Herb Sims & Kosta Varnavas



Purpose
Continue development of software defined radio technology through ground station compatibility testing, integration into a flight relevant platform (HOPE HEROES high altitude balloon) and flight(s) of the platform.

Accomplishments
- Completed integration of PULSAR onto HOPE/HEROES platform – achieved TRL 6
  - Completed subsystem level compatibility testing of unit on HOPE/HEROES
- Flew on HOPE/HEROES flight
  - Experienced minor problems with some loss of data

Oxygen Generator Assembly (OGA) Recombiner: Kevin Takada

Purpose
Investigate recombiner (catalytic reactor) replacement technology for existing hydrogen sensor in ISS Oxygen Generator Assembly, due to reliability issues and frequent calibration

Accomplishments
- Completed benchtop testing of two recombiner units under a variety of dew point temperatures and input mixtures. Units manufactured by Resource Systems Inc (RSI) and Precision Combustion Inc (PCI).
- Selected RSI unit for installation into OGA testbed, due to its superior performance in benchtop testing for hydrogen reaction and response time

Hazard Avoidance Demonstration for a Robotic Lander: Mike Hannan

Purpose
Demonstrate use of a low-cost, lightweight COTS stereo camera to identify landing hazards and guide Mighty Eagle to safe landing site

Accomplishments
- Completed 4 free flights over high fidelity lunar terrain field
- Integrated a secondary processing unit, COTS stereo camera, and additional networking components on the Mighty Eagle
- Gathered 22 terrain field only images with a total of 80+ images in flight
- Achieved limited success with inflight hazard avoidance
  - Image data had insufficient accuracy to process for hazard detection, due to limited quality in the 3D stereo depth map

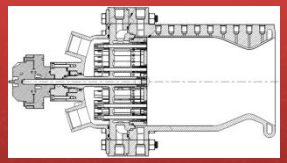
Technology Investment Program (TIP)

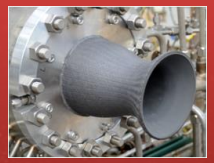
Lightweight Inflatable Solar Array: Les Johnson

Purpose
Prove feasibility and potential benefits of Lightweight Inflatable Solar Array compared to conventional spacecraft power systems

Accomplishments
- Completed three concept design studies establishing concept feasibility:
  - Kestrel Eye Demonstrator mission
  - 3U CubeSat mission
  - Saturn concept
- Designed and fabricated test article
- Conducted successful inflation test

Low-Cost 4000lb Morpheus/SWORDS Thrust Chamber: Gregg Jones

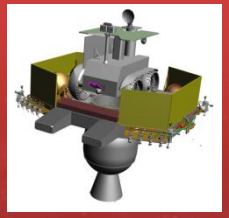


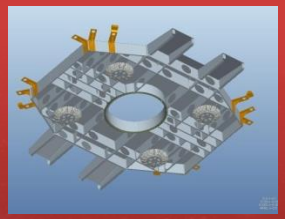


Purpose
Provide high performance, 4000 lb_f thrust, LOX/CH4 injector and regeneratively cooled chamber for applications like Morpheus and SWORDS

Accomplishments
- Completed design of injector and regeneratively cooled chamber
- Completed design and initiated fabrication of uncooled iridium/rhenium chamber
- Continued work on alternate regen chamber design to provide copper liner for fuel cooling; maintains low cost fab and will be assembled into 3D printed structural jacket

"Down-in-the-Dirt" Pallet Lander: Andy Wayne



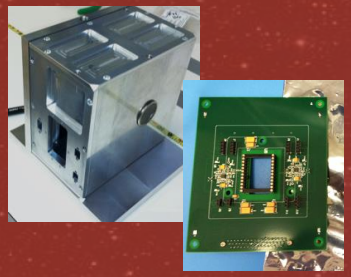


Purpose
Design and build cost efficient riveted sheet metal lunar lander structure in-house. Optimize the placement of structural members to mitigate strength and vibration concerns.

Accomplishments
- Completed work with vendor to determine most cost effective/engineering sheet metal stiffening bead/lightening hole dimensions
- Completed structural optimization for loads & frequencies
- Completed "Build-to-Print" models & issued 40 drawings

Center Discretionary Fund

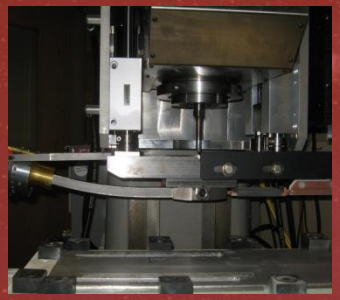
Camera Development and CLASP Support: Jonathan Cirtain



Objective: Enable CLASP and prototype camera development for future missions. Mature CLASP instrument. Raise TRL of MSFC high speed, low noise, low cost camera and control software. Obtain a marketable MSFC niche technology– detector systems.

Accomplishments:
- Progressed in design of avionics, camera imaging systems, cables and harnesses; electrical ground support equipment, and manufacturing; integration, test, and evaluation of prototype

Ultrasonic Stir Welding (USW) Prototype Upgrade: Jeff Ding



Objective: Integrate upgrades into the USW prototype system, to increase system stiffness under action of welding forces, pulse ultrasonic power on/off at different rates, permit real-time trimming of process parameters, and provide real time data acquisition

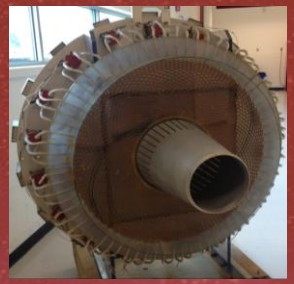
Accomplishments:
- Developed USW procurement specification; detailed scope and requirements
- Submitted other procurement documents

Iodine Feed System and HiVHAc Qual: John Dankanich

Objective: Establish iodine feed system requirements; complete preliminary thermal analysis, tank design, and controlled flow demonstration. Develop credible proposal for HiVHAc system qualification.

Accomplishments:
- Prepped vac facility
- Manufactured iodine reservoir
- Developed control schemes and Simulink models
- Initiated functional testing of thermally controlled system
- Completed HiVHAc systems analysis

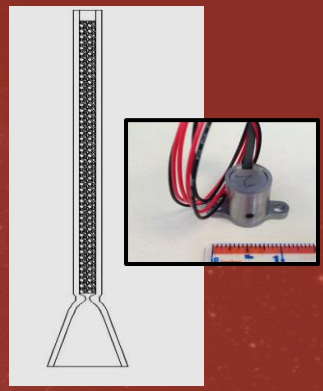
Pulsed Inductive Thruster MkVI Testing: Kurt Polzin



Objective: Retrofit / refurbish Pulsed Inductive Thruster MkVI to get systems operational. Test in single-pulse mode to verify operation; measure performance in thrust stand; attempt operation at repetition rate.

Accomplishments:
- Progressed in repairing coil and pulser units, testing pulsed gas valve hardware, acquiring replacement hardware for gas & electrical systems and thrust stand, replacing damaged components

Green Propellant Micro-Thruster: Rachel Garces



Objective: Develop a green propellant micro-thruster suitable for small satellites; position MSFC to lead in advanced satellite propulsion systems

Accomplishments:
- Completed procurements for test setup (such as sensors, tubing, fittings, pump)
- Established Phase 3 SBIR for micro-thruster, injectors, catalyst, bed heater
- Received green propellant from Air Force Research Lab

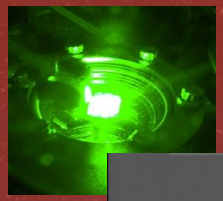
Center Discretionary Fund

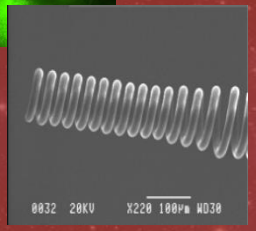
Charger-1 Pulsed Power Facility Activation: Rob Adams

Objective: Assist UAH in setting up the pulsed power facility, for use in propulsion, astrophysics, radiation protection and other fields. Provide unique high power research capability for MSFC.

Accomplishments:
- Mated major components
- Developed ignition system
- Refurbished Marx generator bank
- Surveyed available diagnostics

High Pressure Laser Chemical Vapor Deposition: Mike Houts





Objective: Partner with Dynetics to develop far reaching HP-LCVD capability. Use lasers to grow solid fibers from precursor gases and simultaneously weave into finished cables, fabrics, and composites. Provide ultralightweight, nano-engineered materials for wide variety of applications.

Accomplishments:
- Provided lab space for HP-LCVD use, including optical table
- Procured all major optical components

Informatics System for ISS Science: Reagan and Miller

Objective: Capture, analyze, and perform diagnostics of metals/materials research using an informatics system. Utilize Athena platform, which supports the MAPTIS system, to build this informatics system. Provide larger dissemination of ISS data.

Accomplishments:
- Completed Informatics System pilot concept and populated with sample data
- Used pilot concept to request ISS funding to continue development

Urine Processor Assembly Testing: Schneider and Carter

Objective: Determine operational limits of the Urine Processor Assembly (UPA) to provide valuable data to support changes in size and architecture. Seek significant savings in water recovery weight/ power/volume for long duration deep space exploration.

Accomplishments:
- Performed CFD analysis for Distillation Assembly (DA) stationary bowl
- Developed RFP for wireless instrumentation for temperature measurement of DA rotating components
- Started additional modeling tasks

Nanolite Launcher: Jonathan Jones

Objective: Develop and/or assemble components of Nanolite launcher, including new case, flight computer, aeroshell. Perform static motor and flight tests. Team with SLS to test adaptive control.

Accomplishments:
- Completed 2nd static test of the PSRM-10 motor
- Completed burst test of subscale PSRM-120
- Accomplished KSC Pathfinder Flight Tests from Pad 39A
- Completed Avionics integration

Benefitting Life on Earth – Technology Spinoffs

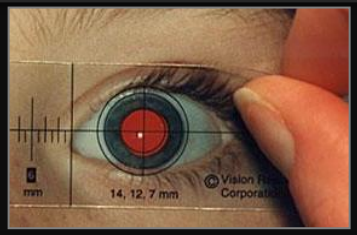
Space technology improves neonatal care

Technologies developed at Marshall touch our lives in many ways.

Weather & Climate Monitoring

High-pressure fire hose nozzles

Kevlar™ Body Armor



Improving Vision Screening

Healing Treatments

Water Filtration Systems

Science and exploration improves our lives and our planet.

Science, Technology, Engineering, and Math (STEM)

Marshall reaches out to all ages to encourage STEM educations and careers.

Public Engagement

Observe the Moon Night

Student Launch Projects

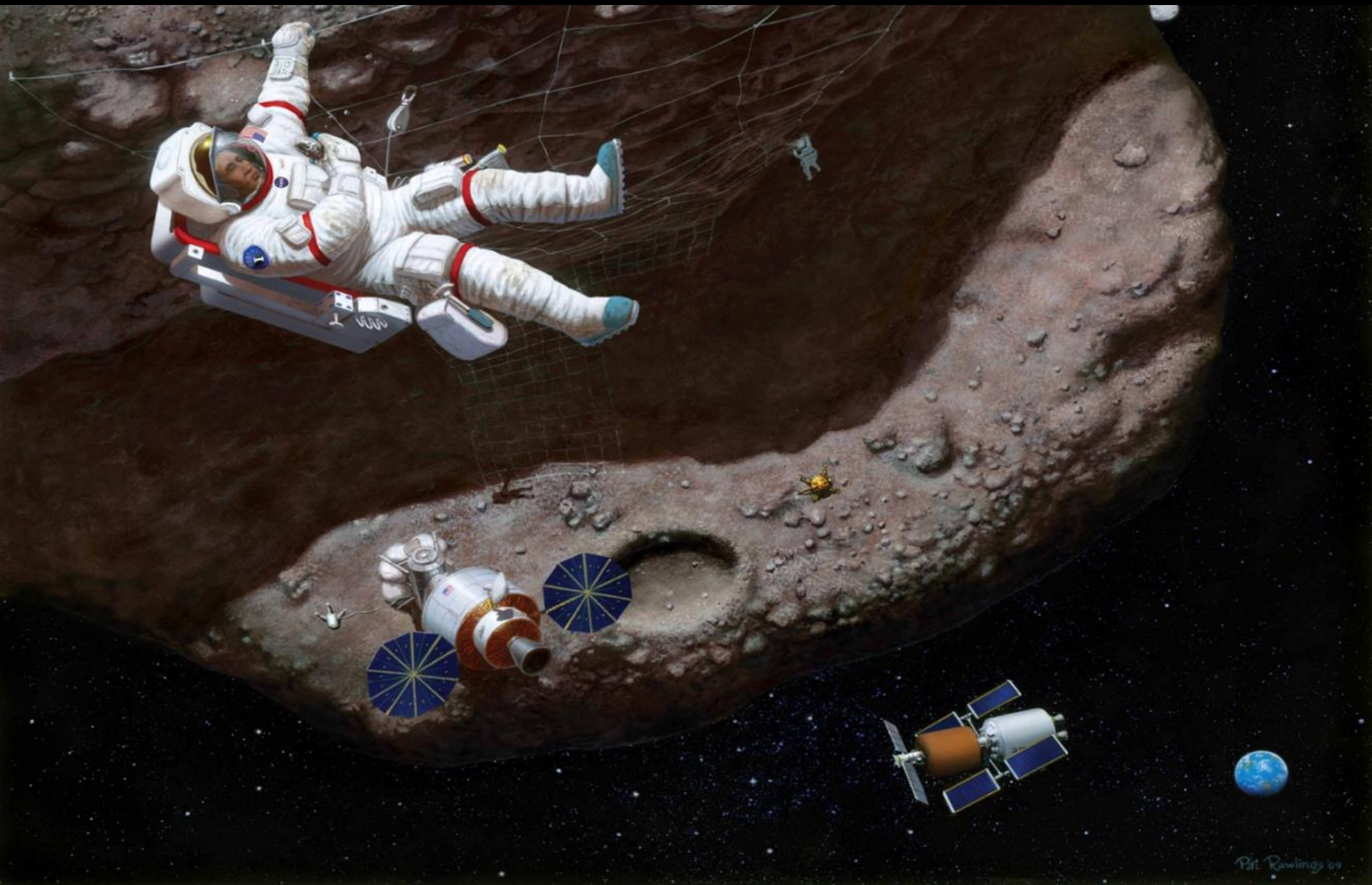
Moonbuggy Race

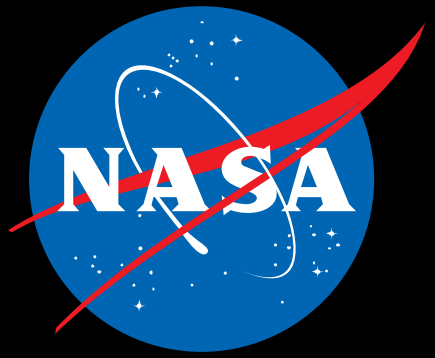
Co-op and Intern Programs

Marshall is inspiring a new generation of explorers.


Somewhere, something
Incredible is waiting to be known.
— Carl Sagan

Let’s Boldly Go!





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