National Aeronautics and Space Administration

Space Technology Mission Directorate

Game Changing Development

Stephen Gaddis

Game Changing Development Program Manager

June 3, 2015

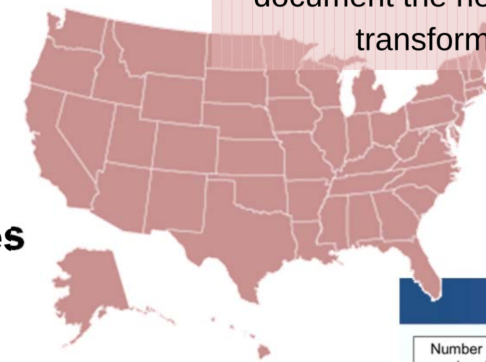
www.nasa.gov/spacetech

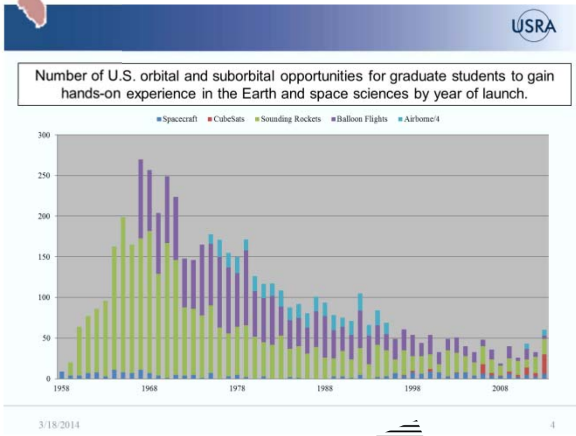
Space Technology…
…. an Investment for the Future

- **Enables a new class of NASA missions beyond low Earth Orbit.**
- **Delivers innovative solutions that dramatically improve technological capabilities for NASA and the Nation.**
- **Develops technologies and capabilities that make NASA's missions more affordable and more reliable.**
- **Invests in the economy by creating markets and spurring innovation for traditional and emerging aerospace business.**
- **Engages the brightest minds from academia in solving NASA's tough technological challenges**

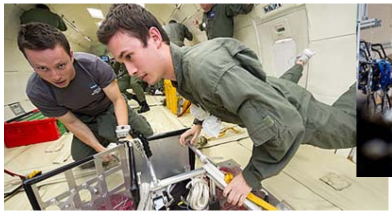
Addresses National Needs

A generation of studies and reports (40+ since 1980) document the need for regular investment in new, transformative space technologies.





Value to NASA **Value to the Nation**

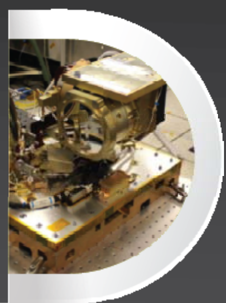


Who:
The NASA Workforce
Academia
Small Businesses
The Broader Aerospace Enterprise

Space Technology Portfolio

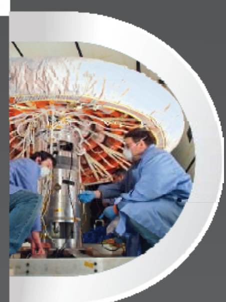
Transformative & Crosscutting Technology Breakthroughs

Technology Demonstration Missions bridges the gap between early proof-of-concept tests and the final infusion of cost-effective, revolutionary technologies into successful NASA, government and commercial space missions.



Small Spacecraft Technology Program develops and demonstrates new capabilities employing the unique features of small spacecraft for science, exploration and space operations.

Game Changing Development seeks to identify and rapidly mature innovative/high impact capabilities and technologies that may lead to entirely new approaches for the Agency's broad array of future space missions.

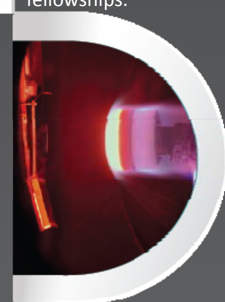


Pioneering Concepts/Developing Innovation Community

NASA Innovative Advanced Concepts (NIAC) nurtures visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace concepts–while engaging America's innovators and entrepreneurs as partners in the journey.

Space Technology Research Grants seek to accelerate the development of "push" technologies to support future space science and exploration needs through innovative efforts with high risk/high payoff while developing the next generation of innovators through grants and fellowships.

Center Innovation Fund stimulates and encourages creativity and innovation within the NASA Centers by addressing the technology needs of the Agency and the Nation. Funds are invested to each NASA Center to support emerging technologies and creative initiatives that leverage Center talent and capabilities.



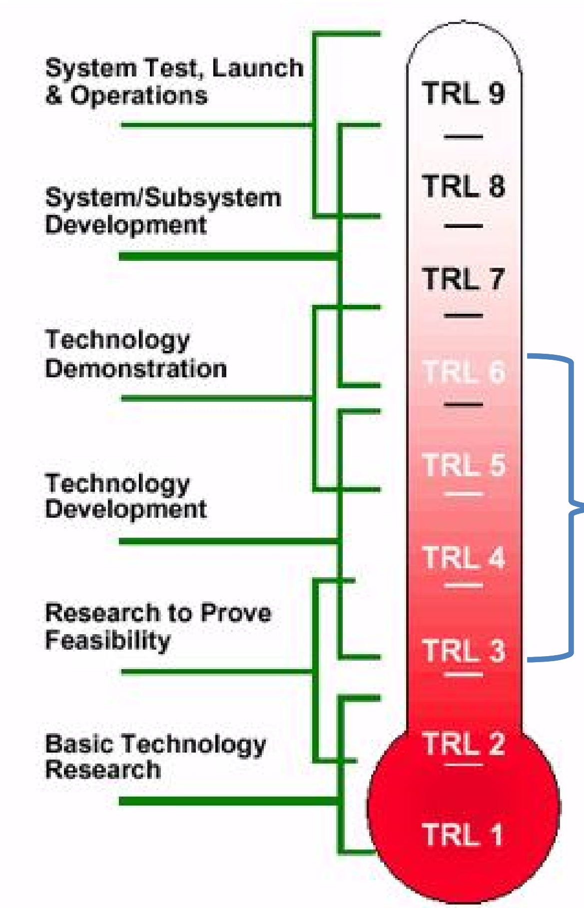
Creating Markets & Growing Innovation Economy

Centennial Challenges directly engages nontraditional sources advancing technologies of value to NASA's missions and to the aerospace community. The program offers challenges set up as competitions that award prize money to the individuals or teams that achieve a specified technology challenge.

Flight Opportunities facilitates the progress of space technologies toward flight readiness status through testing in space-relevant environments. The program fosters development of the commercial reusable suborbital transportation industry.

Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) Programs provide an opportunity for small, high technology companies and research institutions to develop key technologies addressing the Agency's needs and developing the Nation's innovation economy.

What is the Game Changing Development Program?



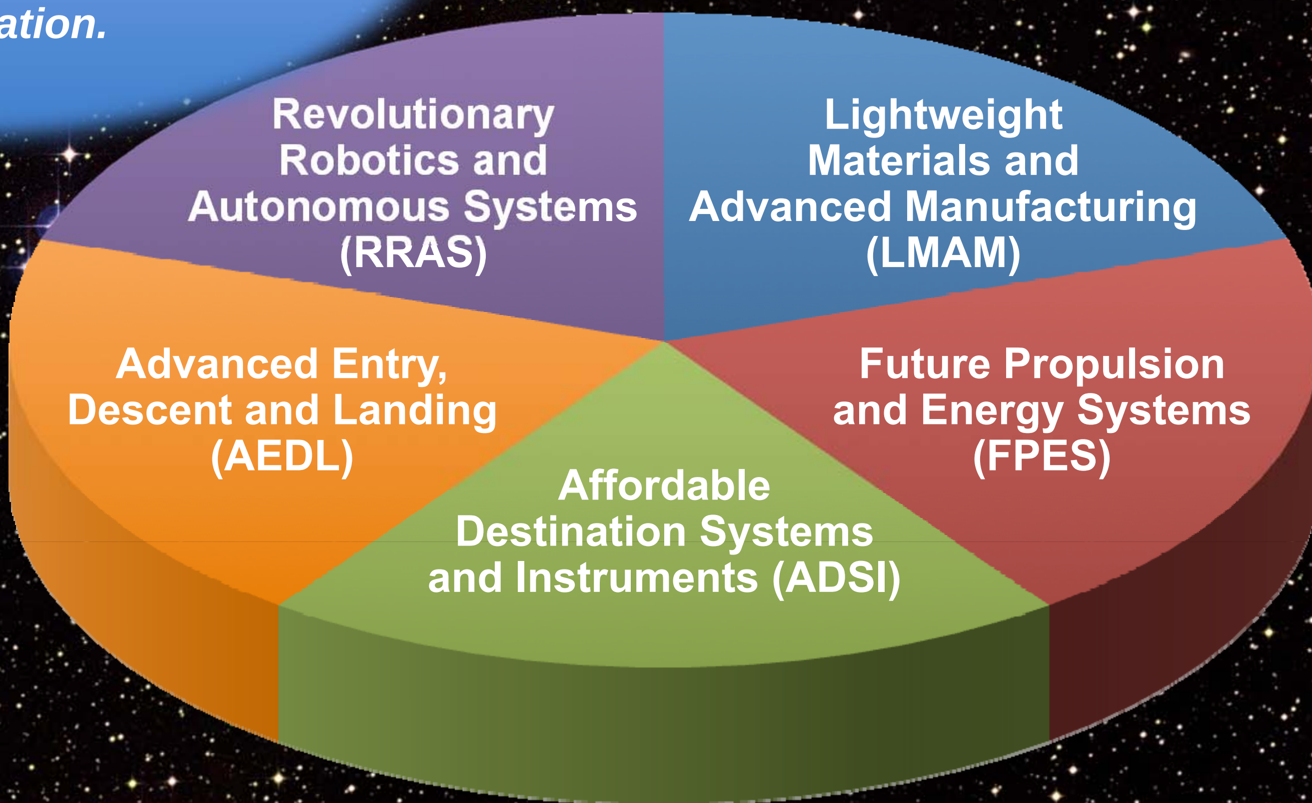
Space Tech's Game Changing Development Program focuses on mid-TRL. This is known as the "Valley of Death." Many technologies never make it from concept to flight.

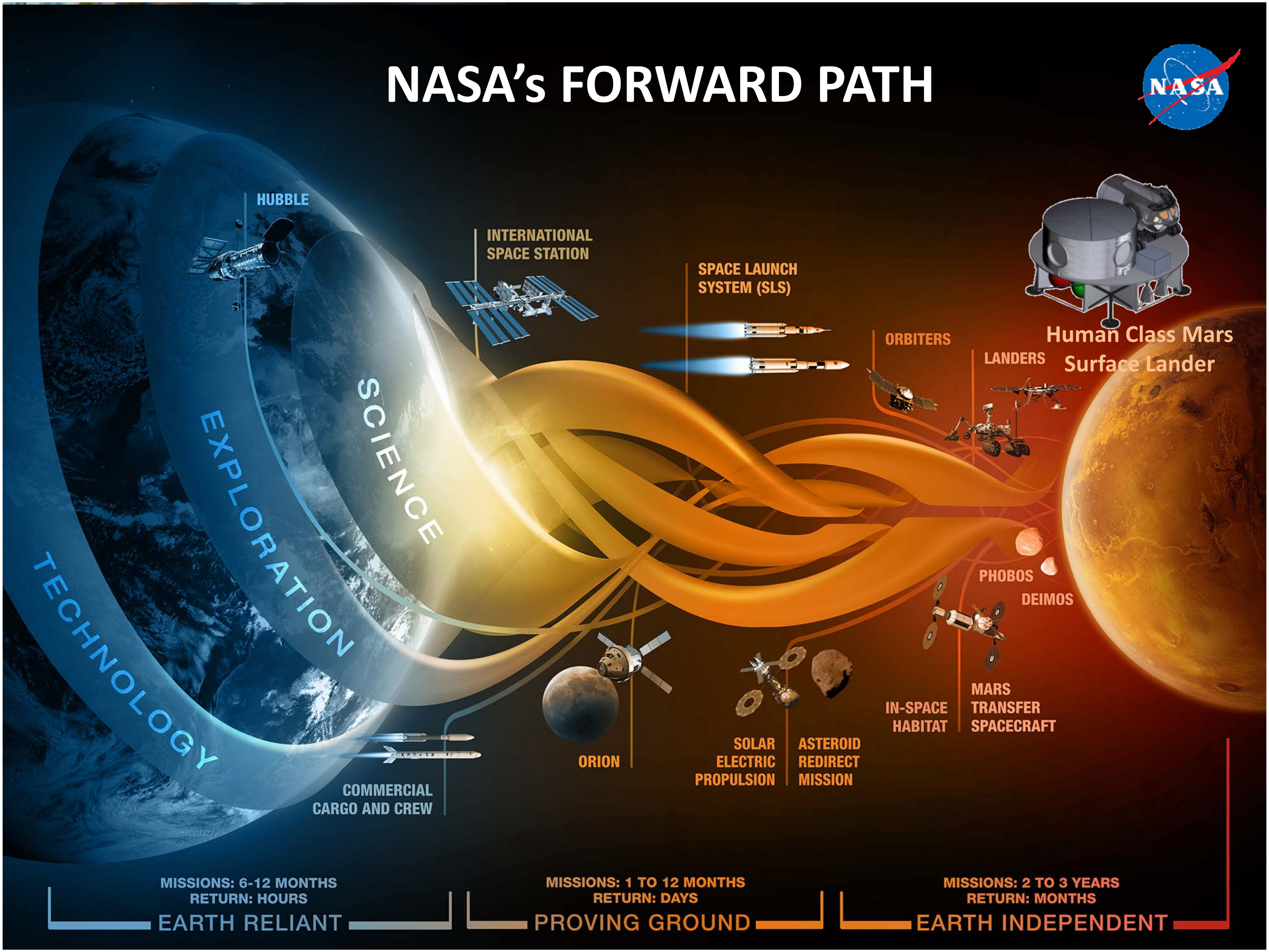
- **Disruptive** or **Transformative** Technologies
- **Orders of Magnitude** advancement enabling new missions and capabilities
- **Principal Investigator** led investment strategy
- Push for **rapid** technology **infusion** to future NASA missions
- **Partnerships** for cost sharing and infusion
- **Informed risk** management posture for developing **High Payoff** Technologies
- **Changing** the way a thing is done or made

GCD Program Vision and 5 Management Themes

GCD Vision

To be the premier organization within the Agency/Country to rapidly advance mid TRL disruptive space technologies from concept to demonstration.




NASA's FORWARD PATH
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
Human Class Mars Surface Lander
SCIENCE
EXPLORATION
TECHNOLOGY
PHOBOS
DEIMOS
MARS TRANSFER SPACECRAFT
IN-SPACE HABITAT
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
ORION
COMMERCIAL CARGO AND CREW
MISSIONS: 6-12 MONTHS
RETURN: HOURS
EARTH RELIANT
MISSIONS: 1 TO 12 MONTHS
RETURN: DAYS
PROVING GROUND
MISSIONS: 2 TO 3 YEARS
RETURN: MONTHS
EARTH INDEPENDENT

Barriers to Human Exploration of Mars

- **Reduce cost of components and systems**
- **Reduce mass fraction of launch and space vehicles**
- **Requires in space assembly of components**
- **Requires Radiation protection for hardware and humans**
- **Requires Manufacture and repair during Trans-Mars Injection and Earth return**
- **Requires In-situ utilization of resources**

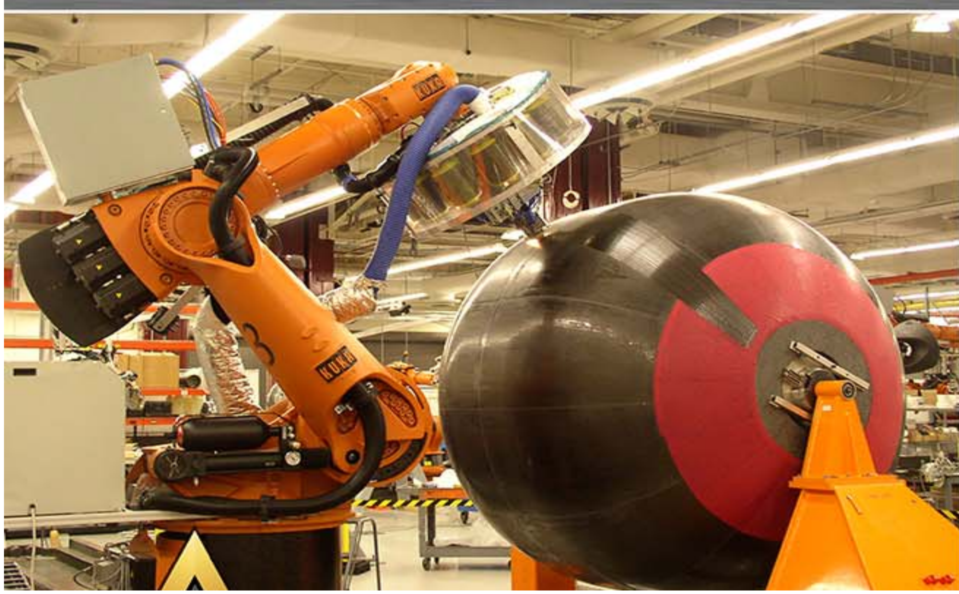
We must invest in Advanced Manufacturing processes and Advanced Propulsion systems

COMPOSITE CRYOTANK

TECHNOLOGIES & DEMONSTRATION

2011 - 2014

2.4 & 5.5 Meter Composite Cryotanks - Completed and Tested



CCTD Accomplishments: Manufacturing
Completed the Fabrication of 5.5m Cryotank

Technology Firsts:

1st successful large (5.5m), fiber placed test article using Out of Autoclave 5320-1/IM7 material. Completed fabrication on March 20, 2014.

CNT Composite Processing: Filament Winding Scale-Up

Purpose:

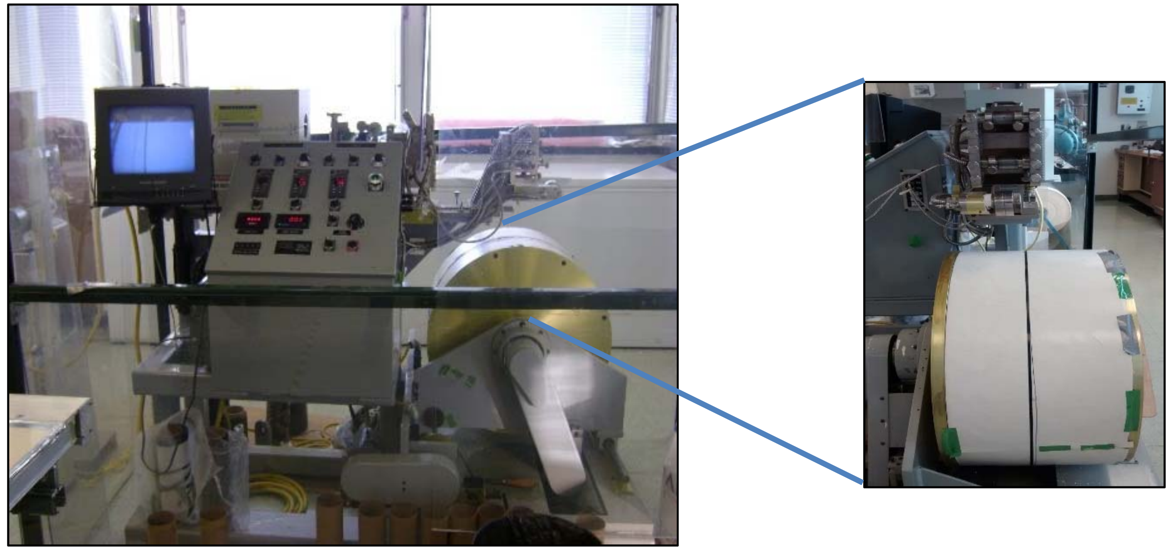
- Develop large scale fabrication paths for winding COPV liners to be used in flight tests

Status:

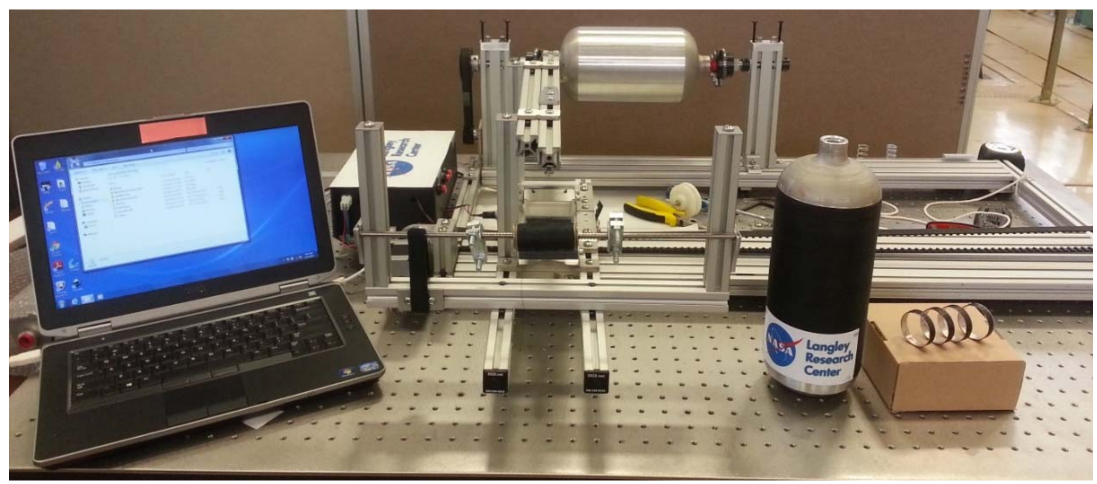
- Two manufacturing methods are under development
  - Filament winding on commercial winder using CNT yarn prepreg fabricated on commercial system
  - Filament winding on scaled down winder system equipped to continuously solution prepreg and wind prepreg onto pressure vessel
- Held technical exchange meeting at MSFC from Dec 9-10 to explore the use of large scale filament winder at MSFC for test and flight COPV articles
- Defined a test matrix to be used for screening performance of CNT composites on small cylinders as part of the downselect criteria to be used to select the manufacturing method for the COPVs

Next steps:

- Manufacturing method downselect to be conducted at meeting scheduled on February 6.



Commercial prepregger used to fabricate CNT yarn prepreg



Continuous wet-winder developed in-house

Ultralightweight Cores for Efficient Load Bearing Structures

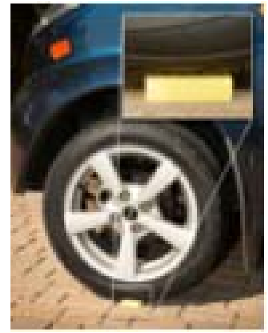
Goals: Reduce the mass and improve the performance of composite sandwich structures

Approach: Utilize ultralightweight cores (nanolattices, CNT honeycomb, nanoporous materials) and high strength CNT reinforced composites to produce ultralightweight, high performance composite sandwich structures

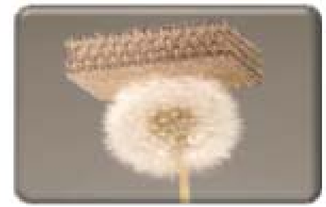
- Develop and demonstrate scalable approaches to produce ultralightweight cores (STMD NRA contract)
- Integrate CNT structural materials currently under development in GCD Nanotechnology Project, compare with conventional CFRP facesheets
- Demonstrate scalability and performance through the design, fab, and ground test of a CEUS skirt panel segment (**First ever application**) – Infusion Path to SLS

Benefits:

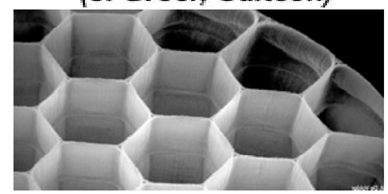
- 30+% reduction in skirt panel weight over conventional honeycomb



Polyimide Aerogels (MAB Meador, GRC)



Micro/Nanolattice Structures
(J. Greer, Caltech)



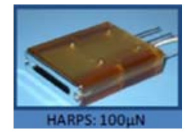
CNT Honeycomb (M. DeFolder, Cambridge)

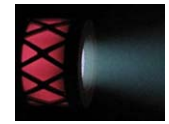
Milestones:

- Phase I Contract(s) awarded 5/15
- Complete fabrication and testing of 1’ x 1’ x 1” flat and curved core panels – 6/16
- KDP 1- Demonstrate core panels meet density and property targets + Phase II contract award -7/16
- Complete fab and testing of 2’ x 2’ x 1” flat and curved panels – 7/17
- Complete fabrication of 10’ x 11’ x 1’’flat and curved panels for scale-up production – 1/18

Advanced In-Space Propulsion

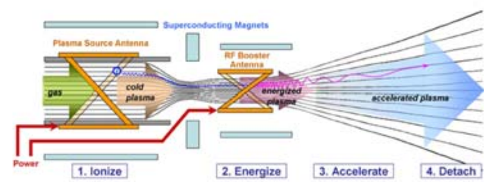
- **Small Satellite Propulsion**
  - ▪ **Focusing on three DRMs, Orbit Maintenance, Maneuver and Orbit Raising, and Lunar/Deep Space High ΔV missions**
  - ▪ **Technology space spans cold gas, mono/bi prop chem, to electrospray and small electromagnetic systems**

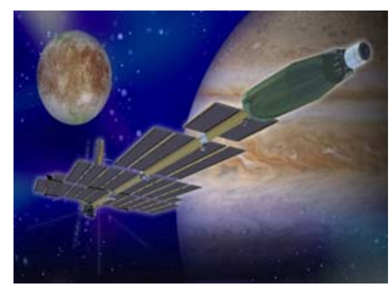


- **Space Science Applications**
  - ▪ **Improvements to traditional EP technologies, i.e. HIVHAC and NEXT Thrusters**
  - ▪ **Alternative propellants for EP systems, e.g. Iodine**
- **Iodine Hall Thruster Development**
  - ▪ **600W+ iodine enables very high ΔV for ESPA class (180kg) spacecraft and “Discovery Class” ESPA Grande class (300kg) spacecraft**
  - **3x – 5x reduction in total mission cost**

- **Mid to High Power “Conventional” EP**
  - ▪ **12 kW Hall Thruster is STMD development and backbone of ARM Project**
  - ▪ **Larger Hall system for Evolvable Mars Campaign, ~ 100kW**
  - ▪ **Nested Hall configuration possible solution**
- **Very High Power EP**
  - ▪ **NASA architecture studies examine Nuclear Electric Propulsion & Power > 2MW**
  - ▪ **At this level very large thruster technologies become attractive: VASIMR, & MagnetoPlasmaDynamic (MPD) Thruster**



- **Extremely High Power Nuclear Systems**
  - ▪ **At levels of power greater than 5WM Nuclear Thermal Solutions begin to dominate trade space**

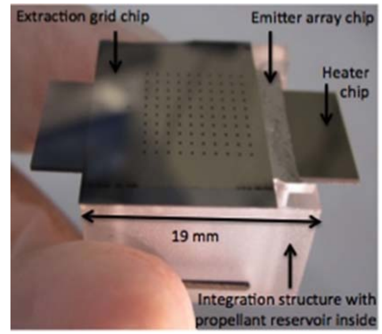


Advanced In-Space Propulsion

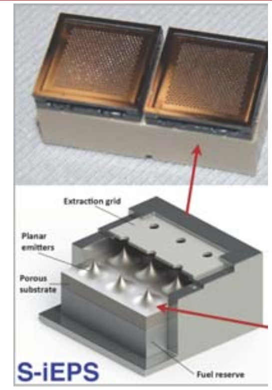
Microfluidic Electrospray Propulsion (MEP)

- **Awarded under NRA NNL12A3001N: Appendix D**
  - 18 month phase 1 awards. ATP 10/1/13
- **Three (3) Awards:**
  - **MIT**: Scalable Ion Electrospray Propulsion System (S-iEPS)
  - **Busek:** HARPS thruster (High Aspect Ratio Porous Surface)
  - **JPL:** Microfluidic Emitter with Indium propellant
- **Each contractor will deliver 3 thruster / power processing unit subsystems.**
- **NASA GRC to conduct independent testing of deliverable units by the end of FY15.**

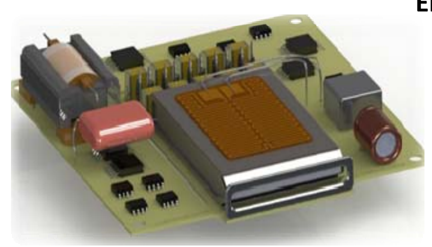
- **NASA Small Spacecraft Technology Program (SSTP) evaluating flight opportunities to test MEP concepts under the new Propulsion Pathfinder Program.**
  - Option as primary propulsion for 3-12U CubeSats
  - Excellent for precision pointing and proximity operations on larger spacecraft



JPL Indium Thruster



MIT: Scalable Ion Electrospray Propulsion System (S-iEPS)



Busek: HARPS thruster (High Aspect Ratio Porous Surface)

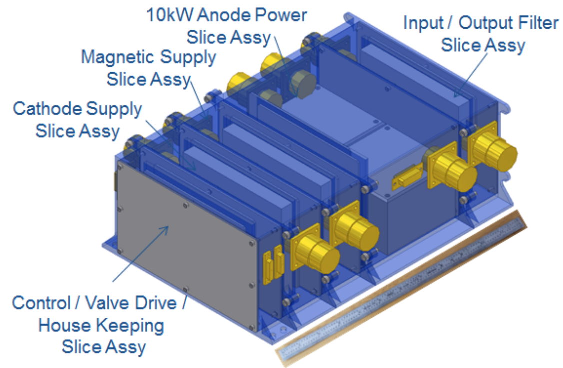
Metric	Goal
Specific Impulse (I_{SP})	≥ 1500s
Thrust	≥ 100µN
Power	≤ 10W
System Efficiency	≥ 70%
Mass	≤ 100g
Volume	≤ 100cm3
Demonstrated Life	≥ 200hrs

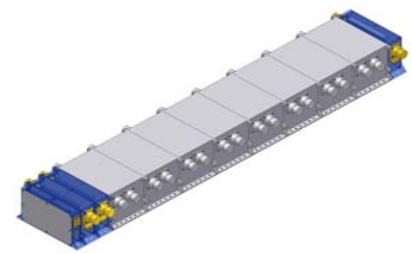
Target Performance Goals from GCD contracts

Advanced In-Space Propulsion

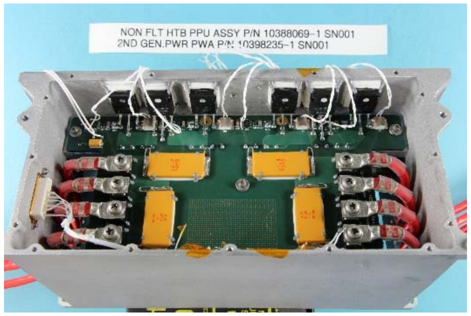
High Temperature Boost Power Processing Unit

- **Increasing PPU operational temperature by 50^{o}C radically alters mass of heat rejection system**
  - High temperature operation with lowered switching loss at high frequency to reduce mass and volume with comparable or better efficiency
    - Lower switching loss of SiC technology allows switching frequency greater than 100kHz to reduce the magnetic mass
    - Lower thermal resistance by advanced packaging technology enables the increase of power dissipation capability
    - Operation at 100C baseplate temperature leads to reduction of radiator size and mass and total power system mass
    - Non-isolated conversion topology
      - Simple boost with fewer component count, easy control
- Reduction in specific mass and volume (SOA)
  - 73% in-space mass savings for PPU and radiator (SOA) at 300kw assuming the same efficiency
    - From 2.8kg/kw to 0.5kg/kw in specific mass
    - From 1054 in^3 at 4.5kw to 453 in^3 at 10kw in volume per kW
- **In-house team: NASA – Langley, Kennedy, Goddard, and JPL**





Modular and Scalable 10-80kW/PPU, up to 320kW/4-thruster without redesign



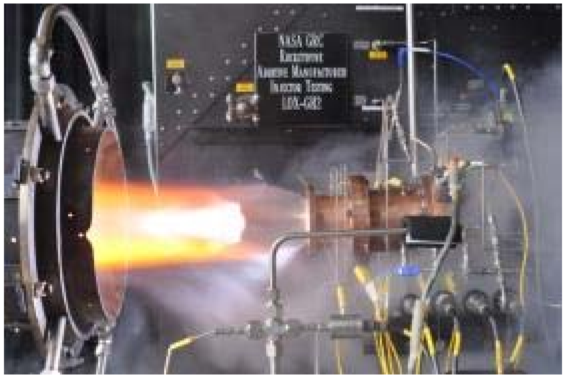
Demonstration discharge module during bench testing

Additive Manufacturing Strategic Goals

- Revolutionize design, development, and manufacturing for affordable aerospace systems and in reduced-gravity environments by developing, demonstrating, and evolving Additive Manufacturing (AM) as a key component of an integrated engineering solution
  - Demonstrate order of magnitude improvement in design and manufacturing, cost and schedule
  - Develop new design tools
  - Develop repeatable manufacturing processes
  - Characterize material properties
  - Establish certification criteria
  - Establish evaluation techniques, NDE
- Mature technologies through relevant demonstrations
- Fully integrated component Lifecycle elements – design, material characterization, manufacturing, inspection and test
- Emphasize collaboration and interdependencies
- Work with Agency program/project offices, identify and embrace high risk/high payoff areas that lead to reductions in risk
- Spin off to Industry without boundaries – Develop manufacturing processes and “best practices” to offer to industry to assure consistently high quality productions
- Grow national industrial capability through NASA partnerships with other government agencies, industry, and academia
- Establish and share a consolidated, readily available open source data base of material properties, and AM process parameters

Rocket Engine Injector Hot-Fire Characterization Task (GRC)

Funded by STMD/GCD FY11-13



Aerojet Rocketdyne Injector successfully tested June 7, 2013

Propulsion Component Characterization

Objective:

Partner with industry to design, fabricate & test, in a relevant environment, a LOX/H2 injector built with an additive manufacturing process

Key Accomplishment/Deliverable/Milestone:

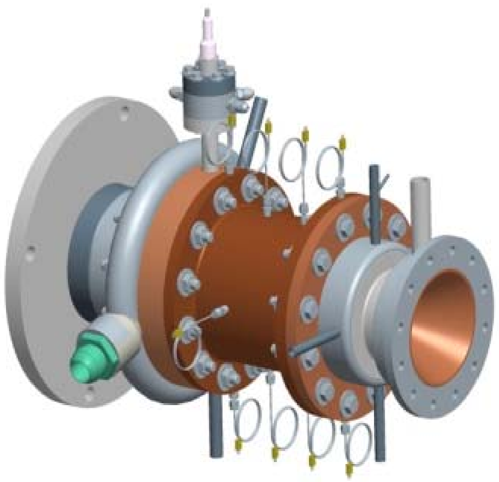
- Successful Execution results in low cost combustion components and accelerates component type TRL from 3 to 4/5

Significance:

First hot fire test of an additive manufactured injector

Near term potential on-ramps and high ranking as a NASA technical challenge

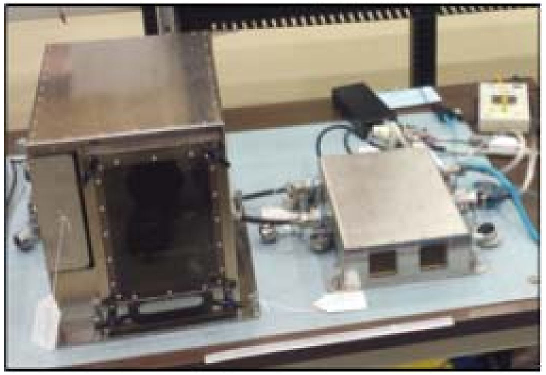
- **The Air Force has initiated the Advanced Upper State Engine Program (AUSEP) to replace the RL-10**
  - **RL-10 supply runs out in 2018/USAF goal is to qualify AUSE by 2018**
- National Academy of Sciences OCT roadmap review ranked upper stages engines as a top technical challenge with LOX/LH_2 propulsion as 3rd out of 32 as a technical priority



Rocket Engine Assembly

3D Printing In Zero-G

- Delivered the first 3D printer to the space
- Arrived on ISS 9/20/14 to investigate the effects of consistent microgravity on melt deposition additive manufacturing and print parts in space.
- 3D Print Primary Objectives
  - Successfully perform extrusion-based AM on-orbit by printing multiple parts from polymer material with print quality comparable to Earth-based parts
  - Demonstrate nominal extrusion and traversing
  - Perform ‘on-demand’ print capability via CAD file uplink for requested parts as they are defined
  - Demonstrate Utilization of Meaningful Parts
  - Mitigate Functional & Design Risks for Future Facilities



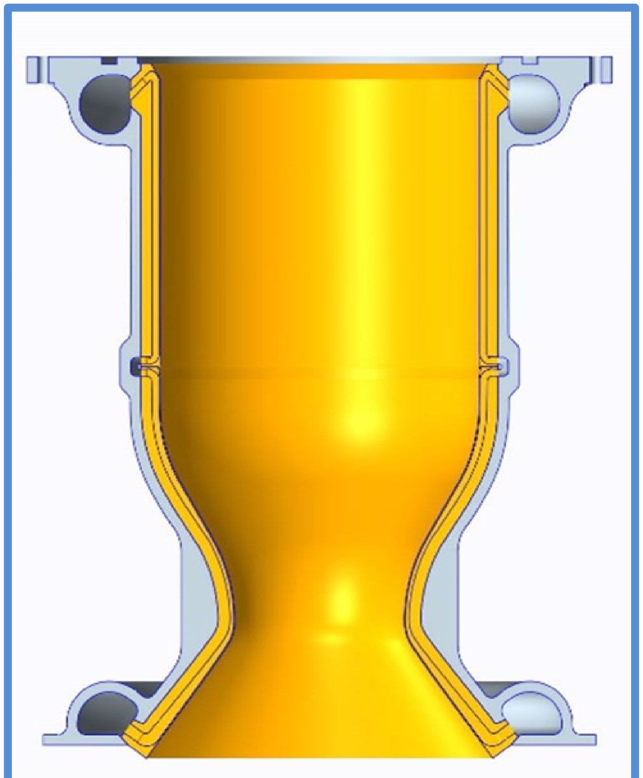
Advanced Manufacturing Technology:
Low Cost Upper Stage Propulsion (LCUSP)

- **LCUSP is a multi-center partnered project funded by the Space Technology Mission Directorate Game Changing Development Program with the goal of making liquid engine combustion chambers more affordable**
  - 4X to 10X Savings Expected
- **The technical approach for the LCUSP project element is:**
  - Develop materials properties and characterization for SLM manufactured copper alloy, GRCop. [GRC]
  - Develop and optimize Selective Laser Melting (SLM) manufacturing process for a full component GRCop chamber and nozzle. [MSFC]
  - 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 nozzle. [LaRC]
  - Hot Fire Test at MSFC

Advanced Manufacturing Technology:
Low Cost Upper Stage Propulsion (LCUSP)

- **Spacecraft propulsion systems typically comprise more than 70% of the total vehicle cost and account for a significant portion of the development schedule.**
- **High pressure/high temperature combustion chambers and nozzles must be cooled.**
  - Closed coolant passages and thermally conductive materials are required.
  - Thermal characteristics of copper make it an ideal material for this application.
  - However, those same thermal characteristics, especially its high thermal conductivity, makes *additive manufacturing with copper alloys highly technically challenging*.
- **The first GRCop component has recently been additively fabricated at MSFC, material characterization at GRC show excellent properties**
- **The second component will be joined to the first, then shipped to LaRC for Inconel deposition**

LCUSP Images



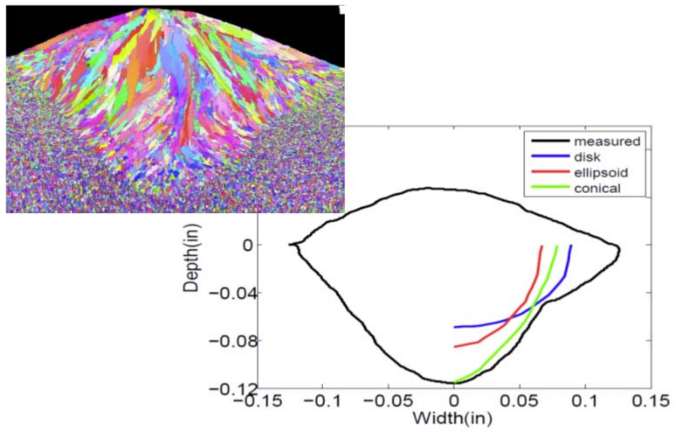
LCUSP: Sketch of Inconel-clad copper combustion chamber and nozzle.

LCUSP: Successful additive fabrication of first component!

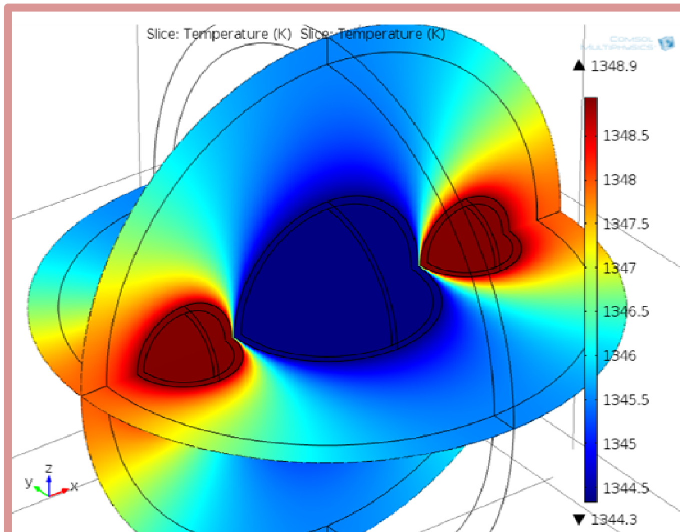
Advanced Manufacturing Technology:
Materials Genome Initiative (MGI)

- **Objective: Develop computational tools to assist in the manufacture, design and certification of new materials and processes.**
  - Reduce the time and costs to infuse new materials while also improving/ensuring reliability.
  - Focus on *additive manufacturing:* high payoff for NASA with huge design space that can benefit from computational tools.
- **Challenge: The manufacture of components via additive manufacturing is a dynamic process that can result in a wide variation in material behavior.**
  - This requires understanding how process parameters affect the formation of the material from the molten state to solidification and thermal history.
  - Develop validated thermal models to predict thermal history of as manufactured components.
  - These models will be used to predict microstructural evolution, part distortion and residual stress.
  - These computational tools will be used to tailor process parameters, and guide certification processes and design components with highly tailored properties via additive manufacturing in the future.

MGI Images/Video

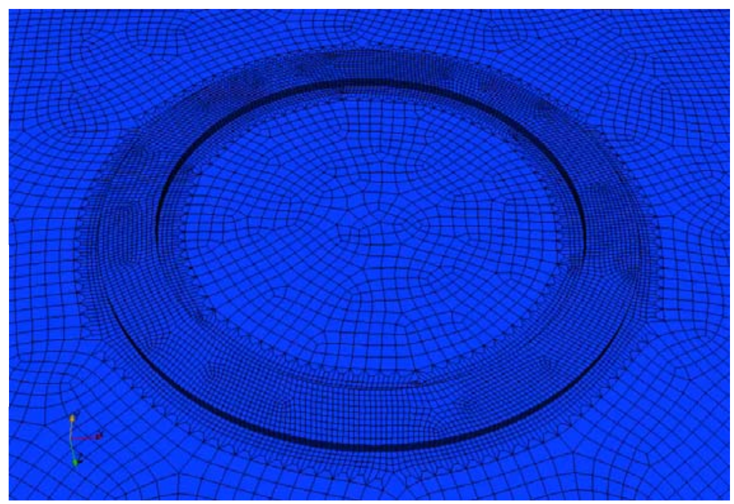


MGI: Prediction of melt pool shape for selected input models compared to observed melt pool cross section.



MGI: Laser heating model using laser scattering and only nearest neighbor influence.

MGI VIDEO: Thermal model of powder bed additive process (powder is not shown in graphic).



Additive Manufacturing Structural Integrity Initiative (AMSII)

- **The aerospace industry is embracing Additive Manufacturing technologies for their potential to increase the affordability of rocket propulsion parts and components, by offering significant schedule and cost savings over traditional manufacturing methods.**
- **In the absence of Agency, government, or industry standards for AM technology, NASA Program Offices are relying on detailed Certification Requirements as the primary channel for conveying the measures required to ensure the structural integrity of AM parts and components.**
- **In the drafting of these Certification Requirements, a number of knowledge gaps have emerged – knowledge underpinning the requirements – creating sources of potential technical risk to the adopting program. For example,**
  - How we declare the AM process acceptable & in-control?
  - What constitutes an acceptable powder feedstock?
  - What is a characteristic AM defect structure?
- **Bridging these knowledge gaps is the purpose of the Additive Manufacturing Structural Integrity Initiative (AMSII).**

The AM Certification Requirements Document is the keystone that holds the knowledge pieces in place. Without requirements AND foundational knowledge, the structural integrity of an AM part cannot be assured.

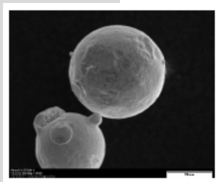
AMSII: Knowledge Required for Certification of Critical AM Hardware

Foundational M&P
(knowledge gaps)

Powder

Chemistry, Morphology, Distribution

Recyclability



Builds

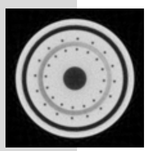
Thermal processing

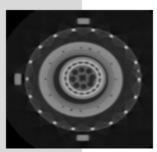
Material characterization

Characteristic defects / NDE

Surface finish improvement

Geometric dimensioning & tolerancing / Thin sections





Quality

Build factor interactions

Machine-to-machine variability

Certification RQMTs
(in draft)

Model Controls

Powder Controls

Material Property Development

Build Execution Rqmts

Lot Acceptance Methodology

Part Verification Rqmts
- Proof test methodology
- First article methodology
- NDE / PODs

Part Development Plans

PBF Flight Hardware
(potential for risk)

Commercial Crew Program

SpaceX's SuperDraco regeneratively-cooled Engine Chamber printed in IN718.

Launch 2017

Space Launch System RS-25E

Trade study underway. IN718 ducts, nozzles, and baffles are early candidates for print.

Launch 2023+

Knowledge gaps exist in the basic understanding of AM Materials and Processes, creating potential for risk to certification of critical AM Hardware.

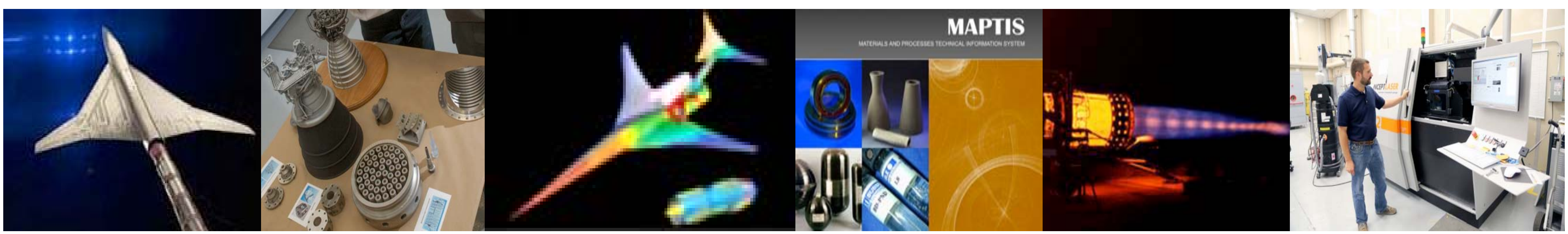
AMSII: Project Goal & Objectives

Goal

- **Develop powder bed fusion (PBF) as a reliable and routine alternative to traditional manufacturing methods for human-rated flight hardware.**

Objectives

- **Mature a jointly-defined, resource-loaded technology project to close the knowledge gaps that underpin our drafted AM requirement document.**
  - Effort not to exceed 3 years, $10M.
  - Emphasis on activities required for flight certification.
  - Initial focus on Inconel 718 produced with powder bed fusion technology.
- **Develop an inter-center team to pool knowledge and provide peer review of AM technology development and activities.**
- **Mature NASA-wide or local requirement document(s) in order to enhance standardization of AM for flight hardware.**



President's Manufacturing Initiative Support for Additive Construction

America Makes announced a challenge at the White House Maker Faire on 6/18/14

NASA and America Makes will utilize additive manufacturing to build on-demand shelters that perform in space and have terrestrial applications for disaster relief. We believe by tapping the collective knowledge and expertise of Americans, we can find a solution that satisfies the requisite performance requirements of: strength, cost, reliability, scalability, size, speed, quality, and toxicity. The challenge will align with the research objectives for both America Makes and NASA. By ensuring efforts are optimized for both entities, this opportunity will serve to advance both NASA and America Makes' technical roadmaps.

Additive Construction Goals & Objectives

Army CoE Goals:

- **Reduce construction time** from 4-5 days to 1 day per structure
- **Reduce construction personnel** requirements from 8 to 3 per structure
- **Reduce logistics impacts** associated with materials shipped, personnel, and resources to sustain the structures and personnel
- **Decrease material shipped** from out of theater from 5 tons to less than 2.5 tons
- **Reduce operations**/maintenance personnel and cost
- **Reduce construction waste** from 1 ton to less than 500 pounds
- **Improve security** during construction
- Improve local **population acceptance** by mimicking local construction

NASA Goals:

- **First demonstration** of additive construction using planetary analog materials
- **Analyze materials** for additive construction on different planets, including radiation shielding potential
- **Mature** additive construction hardware and processes
- Fabricate **structures on demand** in space with in-situ resources, reducing the need for sizeable structure up-mass
- **Enable future NASA missions** not feasible without the capability to manufacture structures in situ and doing so with significant external leverage
- **Enable additive construction** for use on Deep Space Missions
- **Demonstrate tele-operations** to reduce testing operations cost and show applicability to planetary surfaces

Find out more!

GAMEON.NASA.GOV

Back up

Advanced Manufacturing Technology:
Materials Genome Initiative (MGI)

- **Three Early Stage Innovation awards have been approved for funding and the program is currently awarding the grants.**
  - Development of Physics-Based Numerical Models for Uncertainty Quantification of Selective Laser Melting Processes - Univ. Cal. Davis
  - Computational Modeling of Nondestructive Evaluation, Defect Detection, and Defect Identification for CFRP Composite Materials - Iowa St. Univ.
  - Control of Variability in the Performance of Selective Laser Melting (SLM) Parts through Microstructure Control and Design - Texas A&M Univ.
- **Three STTR's have completed phase I**
  - T12.04-9903 (ARC) Physics and Statistics Based Selection of SLM and EBM Process Parameters to Mitigate Defects and to Control Deposit Microstructure
  - T12.04-9972 (LaRC) In-Process Monitoring of Additive Manufacturing
  - T12.04-9977 (MSFC) Multiple High-Fidelity Modeling Tools for Metal Additive Manufacturing Process Development
- **Collaborations:**
  - Participate on National MGI subcommittee
  - Working with NIST to develop standard material property measurements (powder and as manufactured)
  - Developing potential SAA with Alcoa Technical Center (work on chemistry modifications for improved properties)

Advanced In-Space Propulsion

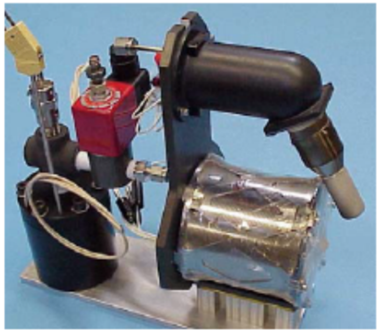
Iodine Hall Thruster

- **Leveraging previous SBIR work with Busek for development and testing of**:
    - 600W Hall thruster based on BHT-200
    - Brassboard modular power processing unit
    - Iodine compatible cathodes and feed system components
  - NASA GRC developing high flow iodine propulsion vacuum test facility for evaluation of up to 4-kW systems

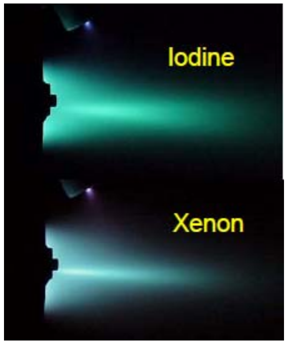
- **600W+ iodine enables very high ΔV for ESPA class (180kg) spacecraft and "Discovery Class" ESPA Grande class (300kg) spacecraft**
    - 3x – 5x reduction in total mission cost
    - Iodine properties are ideal for secondary payloads: benign propellant, quiescent until heated, launches and stores unpressurized
    - High density ~6g/cm^3 and high Density – I_{SP} ~ 8,000 g-s/cm^3 (Xe ~3,000 g-s/cm^3) – **2.4X better than xenon**

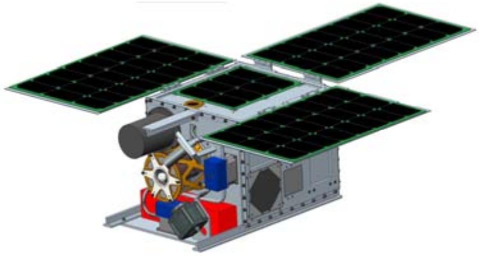
- **GCD task will address critical Technology Gaps and Risks**
    - Scale up to higher power
    - Engineering/material changes and validation, valve wetting surfaces and seals
    - Propellant flow rate and metering is critical to achieve required performance
    - Wear testing >1000hrs for both thrusters and cathodes
    - Spacecraft / plume interactions testing and analyses

- **Leveraging development with NASA SSTP iSAT 12U demonstration mission**
    - 200W iodine Hall propulsion system flight demonstration through NASA Small Spacecraft Technology Program



Initial Iodine Demonstration System (Based on Flight Model BHT-200)





iSAT 12U spacecraft – PDR rendering

AMSII: Center Roles and Technical Objectives

Build the standard level of information on AM powder bed fusion processes that is required for certification of any new critical process used for aerospace applications. Better understanding of controlling process parameters and process failure modes will be achieved through completion of this study.

1. **Certification Requirements – MSFC/JSC/KSC (committee) Objective: Develop an Agency-wide accepted practice for the certification of AM processes for aerospace hardware.**
2. **Powder Influence – GRC/LaRC/MSFC Objective: Understand how basic powder feedstock characteristics influence a PBF part's physical, mechanical, and surface properties.**
3. **Build Interactions – MSFC/GRC/JSC/KSC/LaRC Objective: Use DOEs to understand how basic AM build factors influence part properties. (Answers how we declare the PBF process acceptable & in-control; e.g. microstructural criteria, density criteria, laser/power effects, process FMEA, mitigation of process failure modes)**
4. **Characteristic Defects – LaRC/GRC/JSC/KSC/MSFC Objective: Identify, catalog, and reproduce defects characteristic of the AM process.**
5. **Thermal Processing – GRC/LaRC/MSFC Objective: Establish an understanding of how post-build thermal treatments affect build quality, microstructural evolution, and mechanical properties.**
6. **Surface Improvement – LaRC/MSFC Objective: Understand how as-built and improved AM surface texture influence part performance and fatigue life.**
7. **Characterization in Environment – MSFC/GRC/KSC/JSC/LaRC Objective: Understand mechanical behavior of AM Inconel 718 in representative aerospace environments.**

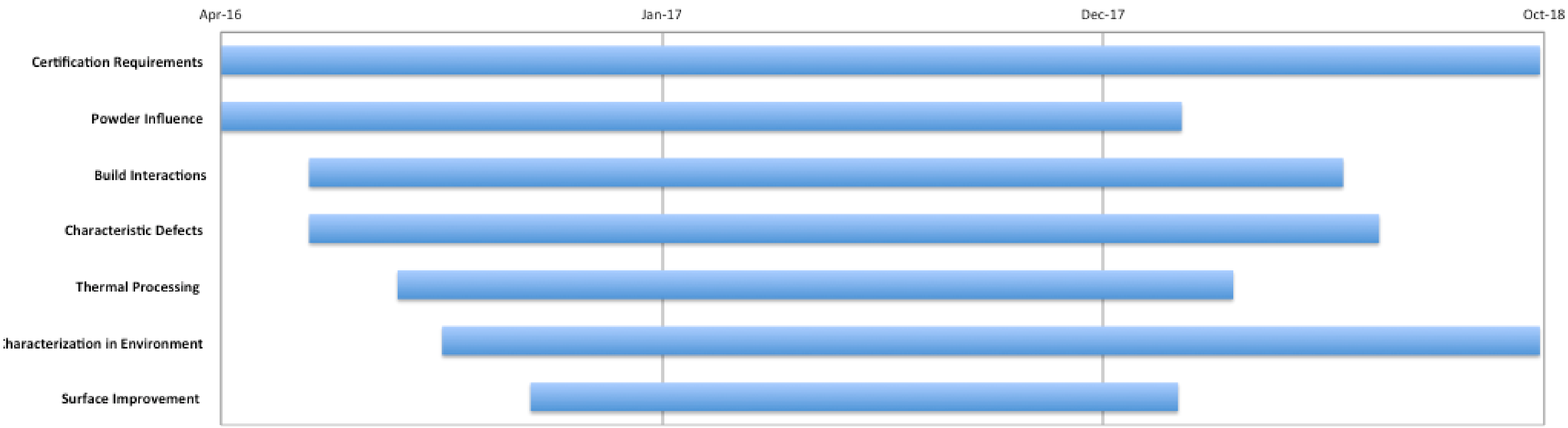
- **Related Task: NASA NDE Working Group Additive Manufacturing Proposed Tasks – Various Centers Objective: Assessment of NDE Capability for AM parts and creation of NDE standards and models. (sponsored by OSMA)**
- **Related Task: Process Modeling – ARC/GRC/MSFC Objective: Determine Global Energy Input parameter as function of build factors. Validate model against test data from different AM machine systems. (to be proposed)**

Project designed to leverage Centers' critical skills, knowledge, and expertise.

Notional Schedule and Milestones

Additive Manufacturing Structural Integrity Initiative (AMSII)

Notional Schedule



	Surface Improvement	Characterization in Environment	Thermal Processing	Characteristic Defects	Build Interactions	Powder Influence	Certification Requirements
Estimated start	1-Nov-2016	1-Sep-2016	1-Aug-2016	1-Jun-2016	1-Jun-2016	1-Apr-2016	1-Apr-2016
Duration (days)	448	759	578	740	715	664	912

Milestones

Completed AM P-FMEA	Oct 2017
AM Powder Requirements	Oct 2017
AM 718 Microstructural Catalog	Oct 2017
AM 718 Characteristic Defect Catalog	Mar 2018
AM Surface Finish/Fatigue Correlation	Mar 2018
Draft NASA Standard for AM	Oct 2018
Completed AM 718 Material Database	Oct 2018