National Aeronautics and
Space Administration

Space Technology Mission Directorate

Game Changing Development

Stephen Gaddis

Game Changing Development Program Manager

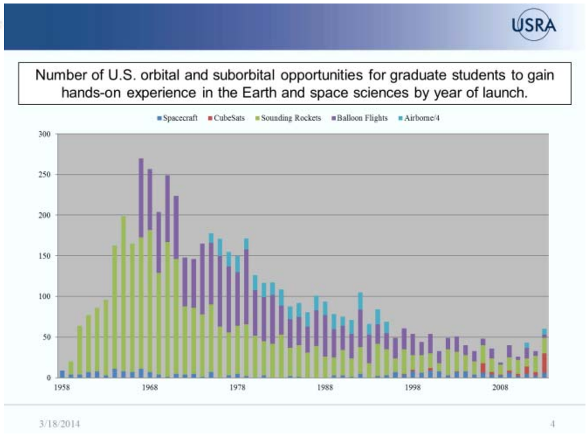
May 6, 2015

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

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

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

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)

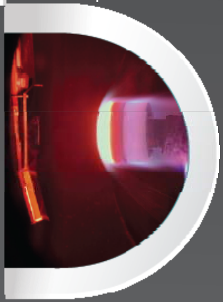
NASA Innovative Advanced Concepts (NIAC) nurtures visionary ideas that could transform future NASA missions with the creation of breakthroughs—radically better or entirely new aerospace concepts–while engaging America's innovators and entrepreneurs as partners in the journey.

Space Technology Research Grants

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

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

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.

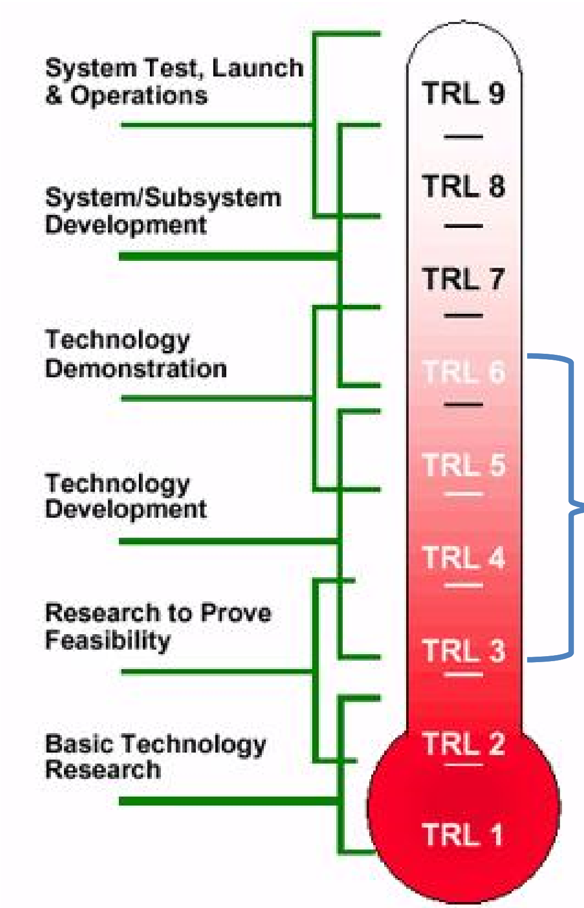
Flight Opportunities

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)

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?



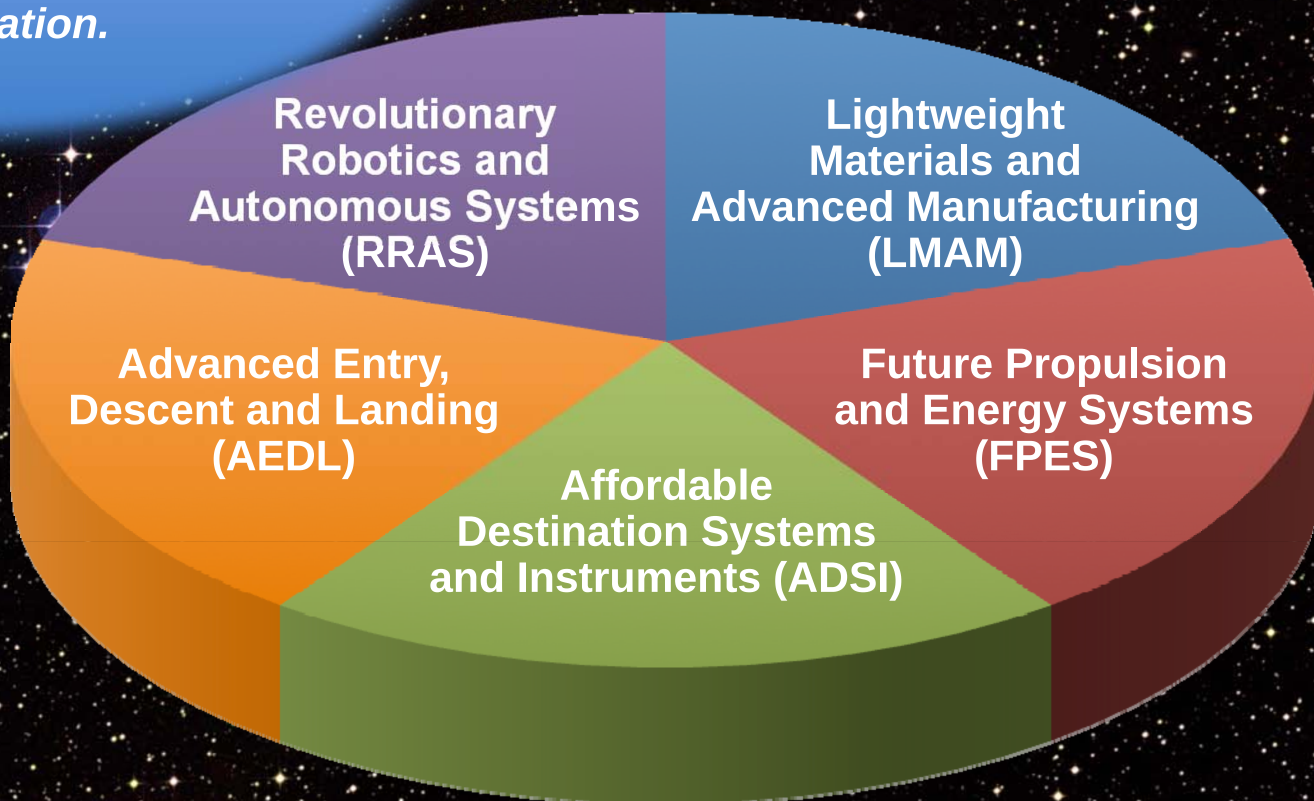
Space Tech's Game Changing Development Program focuses on mid-TRL. This is known as the "Valley of Death." Many technologies never make it from concept to flight.

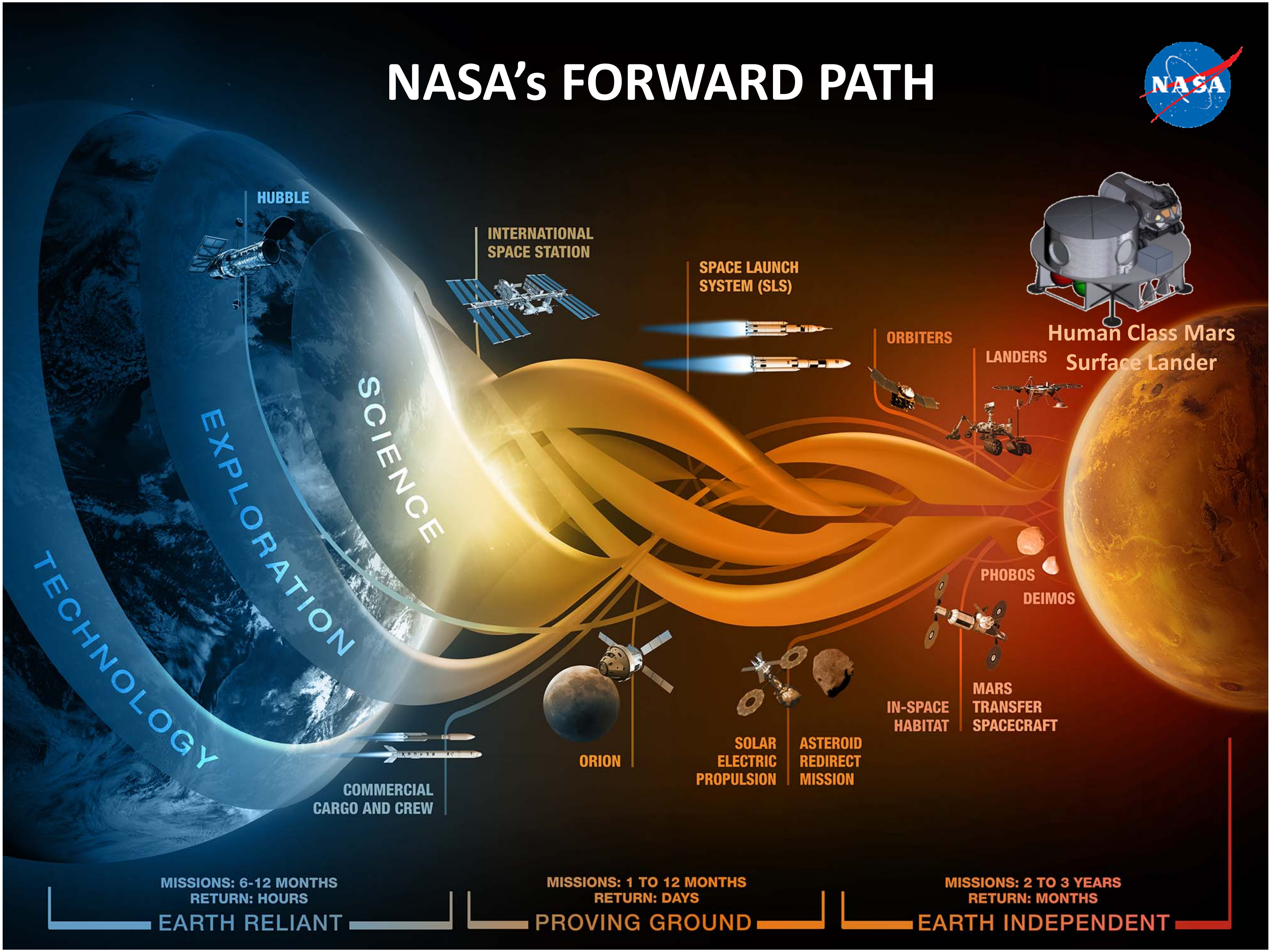
- **Disruptive** or **Transformative** Technologies
- **Orders of Magnitude** advancement enabling new missions and capabilities
- **Principal Investigator** led investment strategy
- Push for **rapid** technology **infusion** to future NASA missions
- **Partnerships** for cost sharing and infusion
- **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
NASA
HUBBLE
INTERNATIONAL SPACE STATION
SPACE LAUNCH SYSTEM (SLS)
ORBITERS
LANDERS
Human Class Mars Surface Lander
TECHNOLOGY
EXPLORATION
SCIENCE
PHOBOS
DEIMOS
COMMERCIAL CARGO AND CREW
ORION
SOLAR ELECTRIC PROPULSION
ASTEROID REDIRECT MISSION
IN-SPACE HABITAT
MARS TRANSFER SPACECRAFT
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

NASA’s Use of Composites

NASA’s Use of Composites

Future Composite Space Vehicles (NASA’s Composite Crew Module)

Growth in Composite use

Future	NASA Space Technology Roadmaps	Composite is Cross cutting technology, TA12, TA7
Today	NASA’s COTS & CCDEV Vehicles	Composite Pressure Vessels Composite Structure
Today	Space Launch System	Composite Pressure Vessels Composite Structure
Today	Orion	Composite Pressure Vessels
1990s	International Space Station	Composite Pressure Vessels
1970s	Space Shuttle	Composite Pressure Vessels Composite Wing Leading Edge
1960s	Apollo	Pre-composites

Accelerated Growth in Composites

- Barriers to Growth
  - Funding limitations
  - Cross disciplinary technological challenges
  - Maturity required to meet roadmap dates
- Steps to Accelerate Growth
  - U.S. intra-government collaboration
  - Government industry partnerships
  - International communication and collaboration
  - Globally harmonized roadmaps for key technologies

NASA Commercial Collaboration
Charlie Bolden (NASA) and Elon Musk: (Space X)

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.

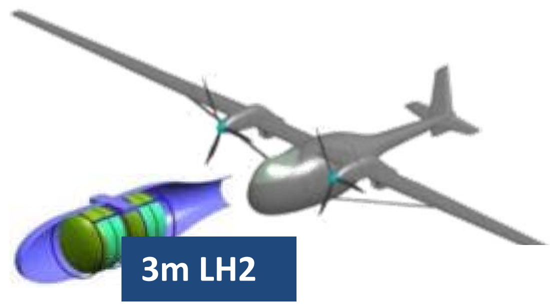





Composite Cryotank Potential Transitions

Exploration Upper Stage (EUS)

- A high confidence for CCTD (Composite tanks and Out of the Autoclave) technology infusion into SLS EUS, DoD and commercial applications.



High Altitude Long Endurance (HALE) Aircraft

Boost and Upper **Stages &**
Low Cost Launch **Vehicles**

Operationally Responsive
Space Access

CNT Composite Processing: Filament Winding Scale-Up

Purpose:

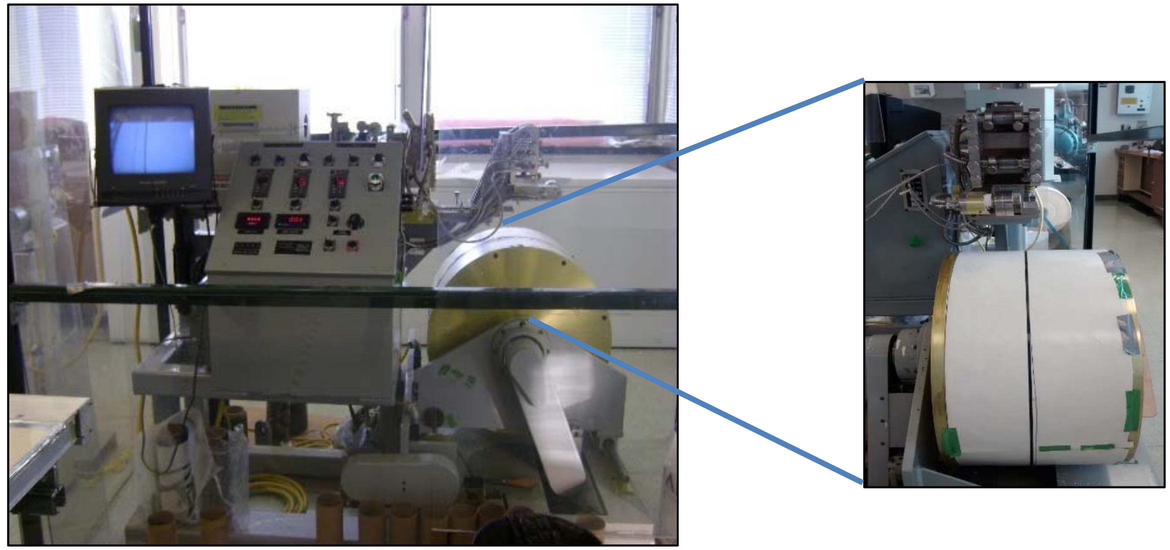
- Develop large scale fabrication paths for winding COPV liners to be used in flight tests

Status:

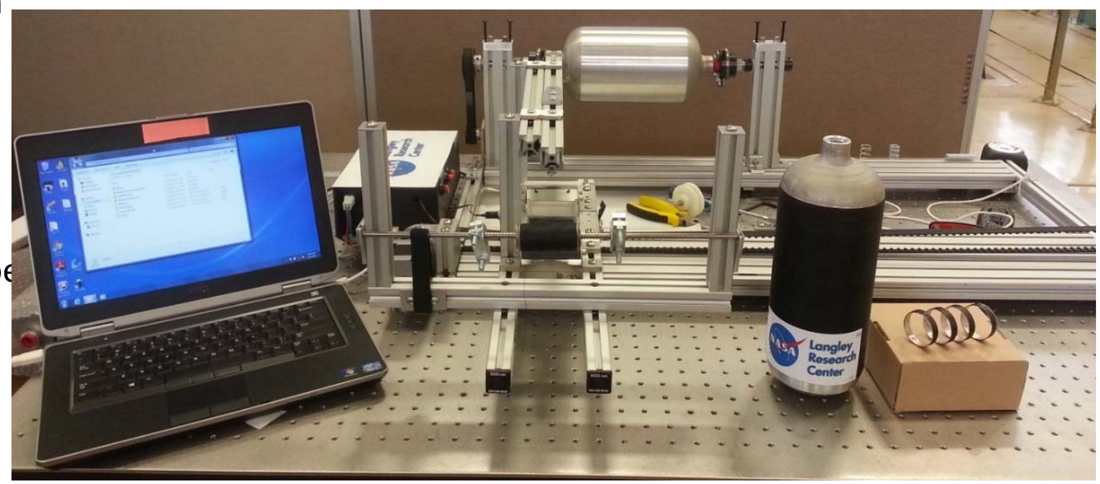
- Two manufacturing methods are under development
  - Filament winding on commercial winder using CNT yarn prepreg fabricated on commercial system
  - Filament winding on scaled down winder system equipped to continuously solution prepreg and wind prepreg onto pressure vessel
- Held technical exchange 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

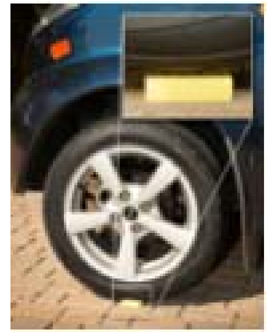
Goals: Reduce the mass and improve the performance of composite sandwich structures

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

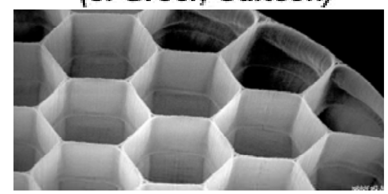
Benefits:

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



Polyimide Aerogels (MAB Meador, GRC)

Micro/Nanolattice Structures
(J. Greer, Caltech)



CNT Honeycomb (M. DeFolder, Cambrigde)

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

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.

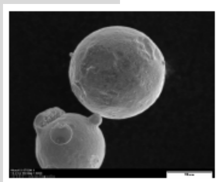
AMSII: Knowledge Required for Certification of Critical AM Hardware

Foundational M&P
(knowledge gaps)

Powder

Chemistry, Morphology, Distribution

Recyclability



Builds

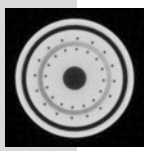
Thermal processing

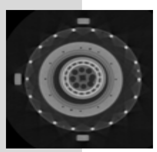
Material characterization

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.

NASA Advanced Manufacturing Technology
Composites

- NASA's goal in large scale composite structures for Space is to **develop low cost, lightweight, and thermally efficient structures, materials** and manufacturing technologies for potential applications beneficial to NASA Missions.
- NASA aims to gain better understanding of the entire trade space. Be a ***smarter buyer*** and a more effective, more relevant partner to the entire Aerospace Industry.
- NASA plans **continued interest and investments** in advanced composite systems and leverage knowledge for future projects.

Advanced Manufacturing is Critical to all NASA Mission Areas

Find out more!

GAMEON.NASA.GOV