

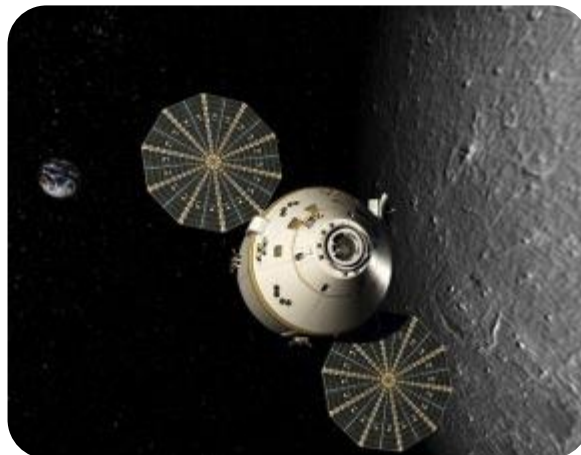
# **NASA Langley Advanced Materials and Processing Branch: Overview**

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**Dr. Catharine C. Fay – Branch Head**

**Dr. Terryl A. Wallace – Assistant Branch Head**

**Advanced Materials & Processing  
NASA Langley Research Center, Hampton, VA 23681**



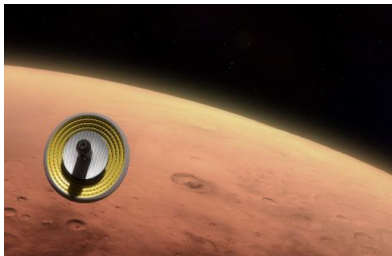
# The Langley Mission



**AERONAUTICS**



**EARTH SCIENCE**



**SPACE EXPLORATION**



**TRANSFORMATION**



Mission Statement : *"We innovate new materials and structural concepts that enable future aviation & space exploration, and develop the foundational technologies essential for manufacturing, design, validation & sustainment."*

## Technology Areas

- **Materials**
- **Structures**
- **Mechanisms/Manipulators**
- **Advanced Manufacturing Technology**
- **Flight Qualified Structures**
- **Advanced NDE and SHM Technology**

# Structures and Materials

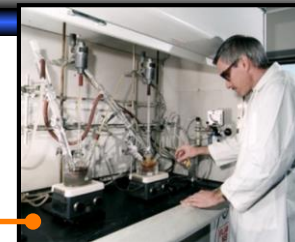


**Durability & Damage  
Tolerance**

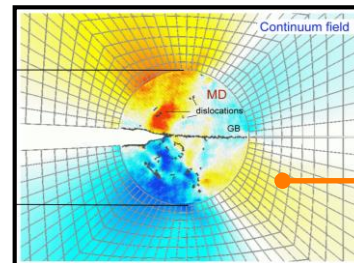
**Impact & Landing  
Dynamics**



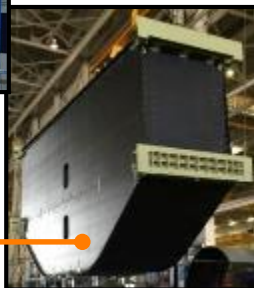
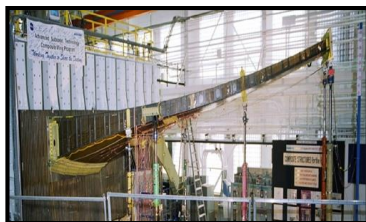
**Materials  
Synthesis  
& Processing**



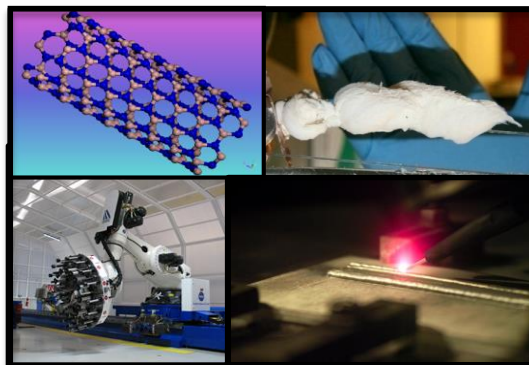
**Computational  
Materials Design**



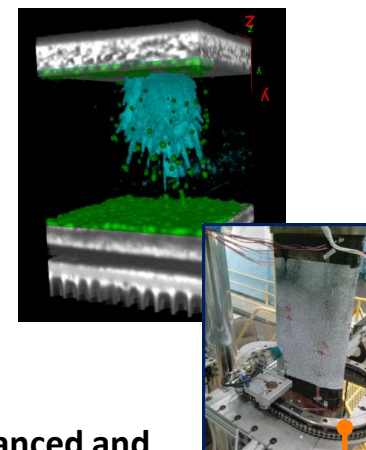
**Structural  
Concepts**



**Advanced  
Manufacturing**



**Advanced and  
Emerging NDE Solutions**



# Advanced Materials and Processing



## Tech Areas

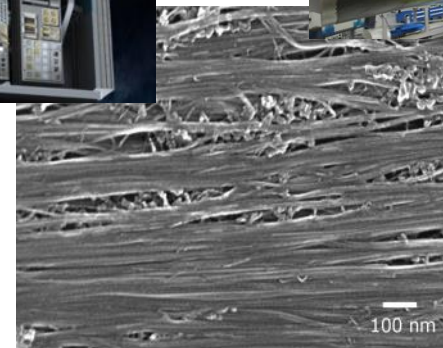
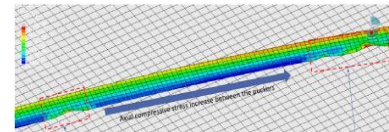
- New Materials Development
- Processing
- Characterization of Materials
- Computational Modeling and Simulation
- Aerospace testing of materials

## Strategic Objectives

- Increase performance and functionality of load bearing structures
- Expand the range of operational environments of component technology
- Develop and demonstrate advanced fabrication technology
- Develop validated computational models and simulations to guide materials design

## Capabilities

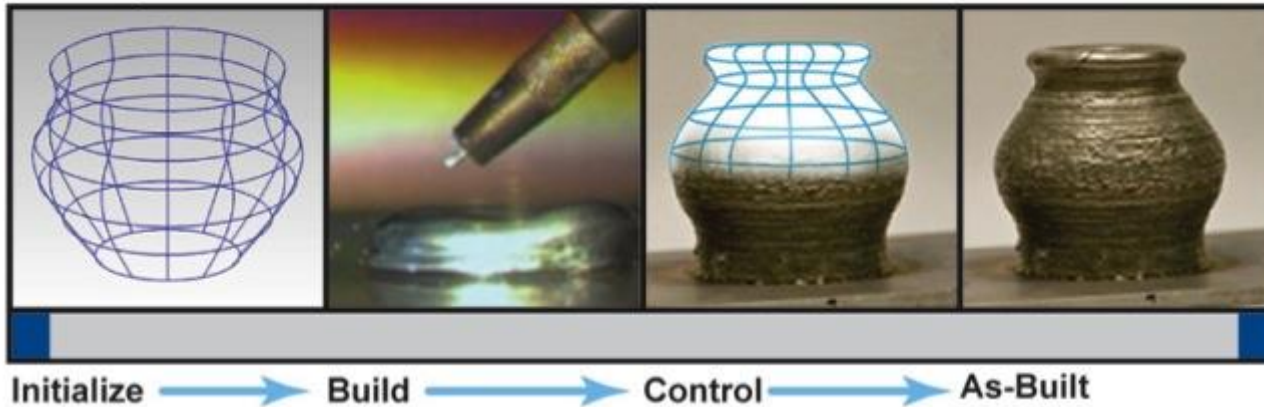
- Synthesis and Modification-Metals, ceramics, polymers, nanotechnology, coatings
- Materials characterization (mechanical, thermal, electrical, spectroscopy, microscopy, extreme environments....)
- Processing (EBF3, 3D printing, Advanced Fiber Placement, composites, ceramics, laser treatment, adhesive bonding, plasma spray, sputtering)
- Modeling and simulation



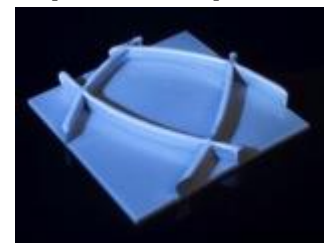
# EBF<sup>3</sup> Build Process



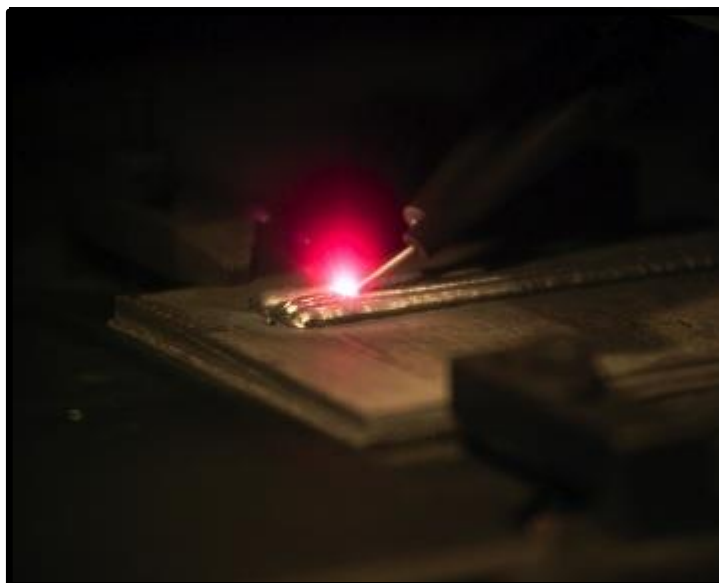
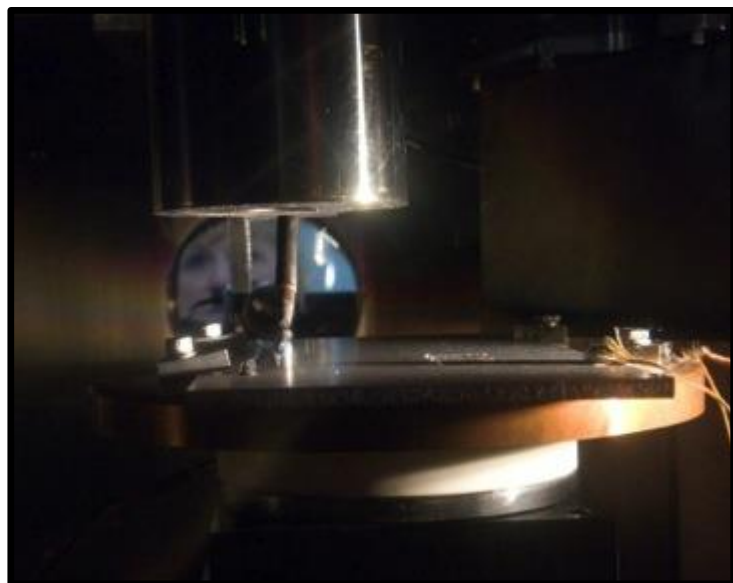
## EBF<sup>3</sup> System in ISPR



Structurally optimized panel



Microgravity testing



# Electron Beam Freeform Fabrication (EBF<sup>3</sup>) Functionally Graded Rocket Nozzle

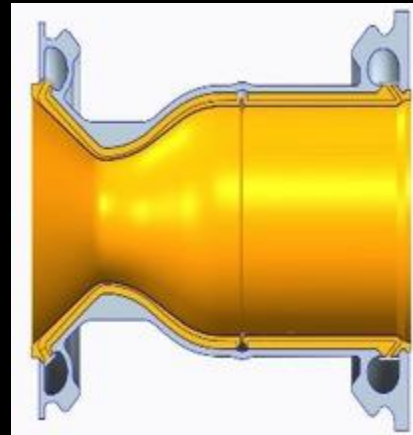


## Additive manufacturing for next generation rocket engine components

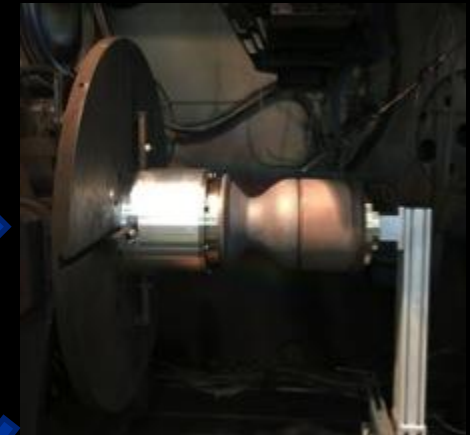
- Copper combustion chamber and nozzle produced via Selective Laser Melting (SLM)
- **Functionally graded** from copper to nickel for structural jacket and manifolds enabled using **Electron Beam Freeform Fabrication (EBF<sup>3</sup>)**

## Benefits:

- **Reduce injector manufacture time** from months to weeks
- **Increased performance** through improved cooling with conformal passages enabled by additive manufacturing
- Potential to **reduce full scale injector cost** by nearly an order of magnitude (~90% reduction)



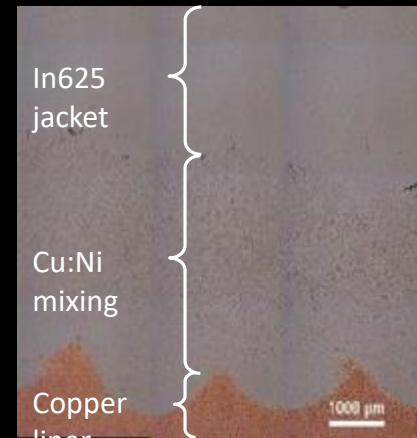
Schematic of Cu-Ni graded rocket nozzle



EB weld SLM Cu liner in LaRC EBF<sup>3</sup> chamber



Structural Inconel 625 jacket EBF<sup>3</sup> deposited onto SLM Cu liner



Microstructure of graded interface



# Integrally Stiffened Cylinder (ISC)

**FY11-12**  
Proof of Concept  
with Al-Li Alloy



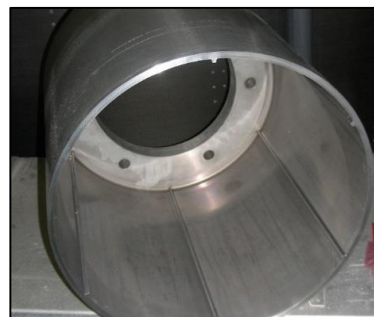
- 0.2 in. tall stiffeners
- 8 in. diameter

**FY12-13**  
Increased Stiffener  
Spacing and Height



- Multiple stiffener shapes
- 0.75 in. tall stiffeners
- 8 inch diameter

**FY15**  
Scaled-up 6061 Aluminum  
Stiffened Cylinder



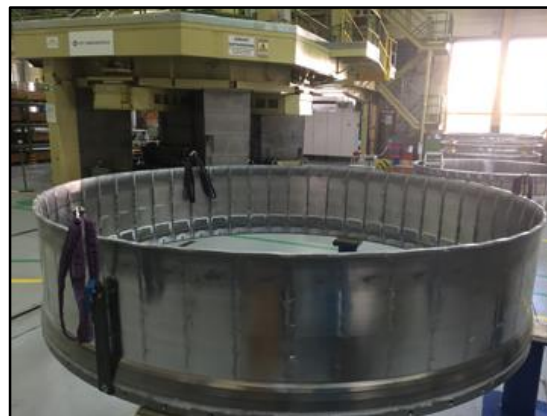
- 17 in. diameter
- 20 in. length
- Structural testing
- Successful flight demo

**Sounding Rocket Flight**  
Oct. 7, 2015



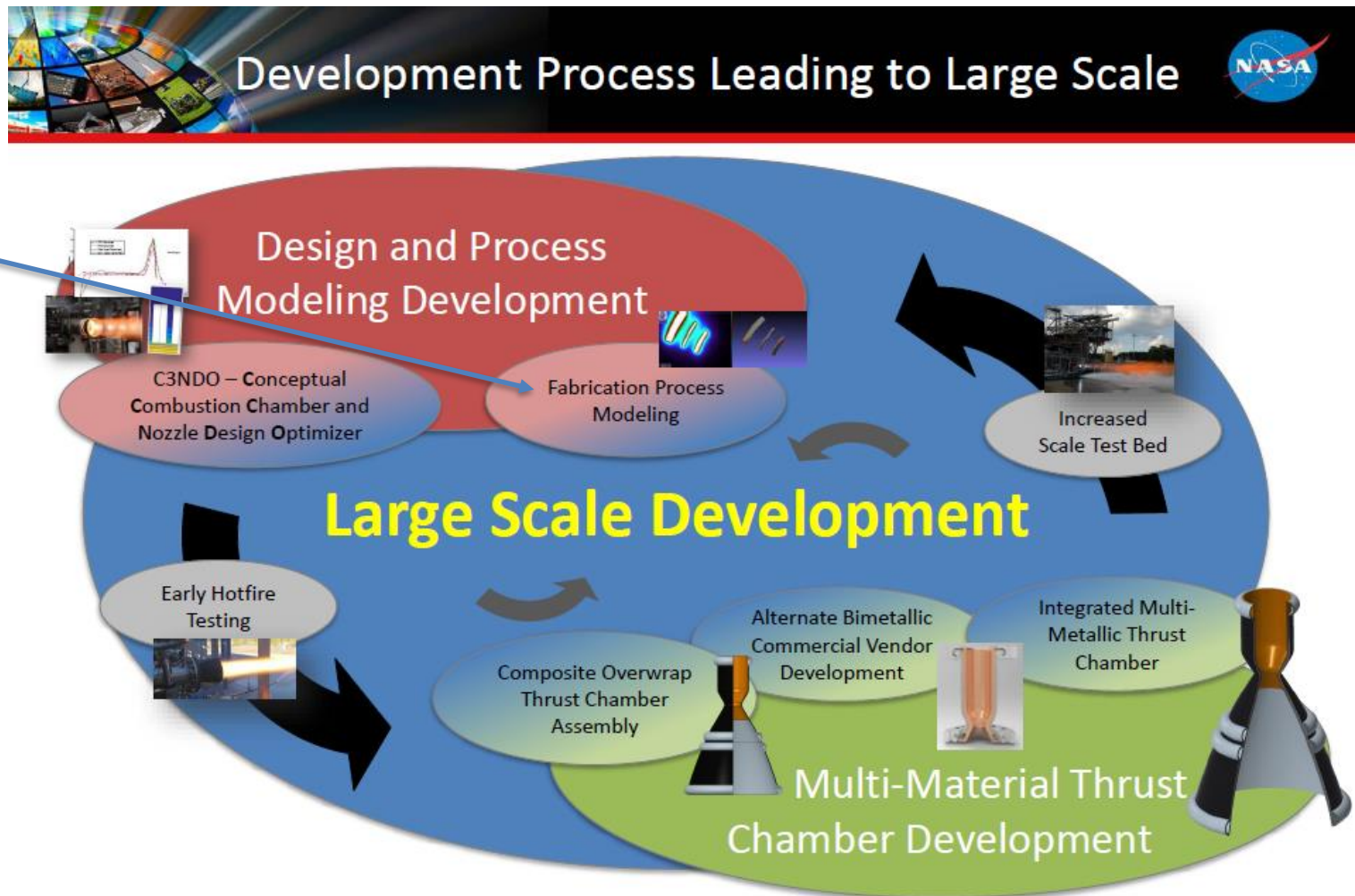
## FY17 Demonstration at Commercial Launch Vehicle Scale

ISC mandrel and  
forming machine



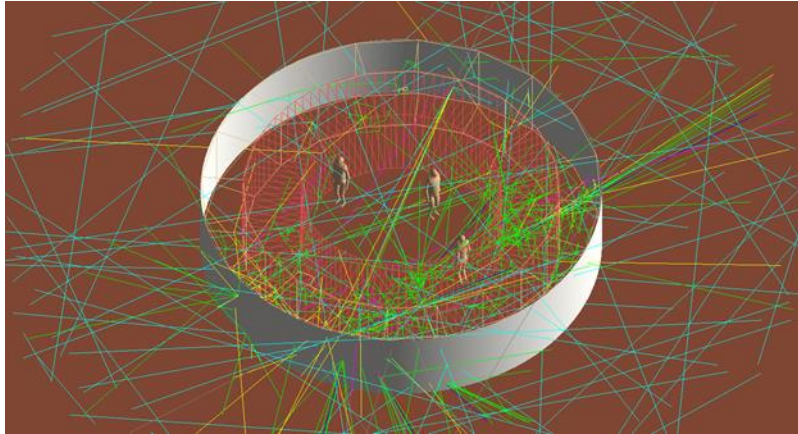
**10-ft. diameter ISC**  
fabricated on  
May 29, 2017

# Rapid Analysis and Manufacturing Propulsion Technology (RAMPT) Project



Iterative process development, subscale testing and test bed hot fire testing to develop technologies feasibility, anchor data and reduce overall project risk

# Materials International Space Station Experiment (MISSE)



Radiation Shielding Materials



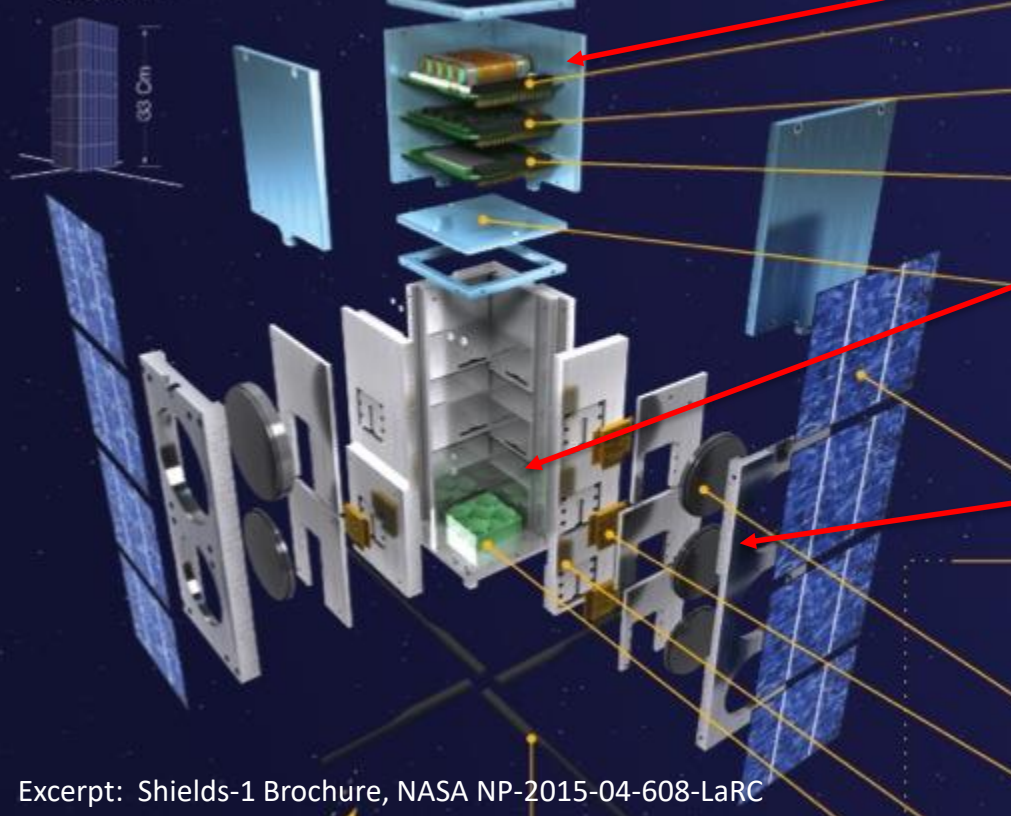
Materials for Space and other Extreme Environments

# Space Durable Hardware Experiments



## Shields-1

Mass: 5.5 kg  
Cube Size: 3U



Excerpt: Shields-1 Brochure, NASA NP-2015-04-608-LaRC

- **Vault Electronics**
  - To measure total ionizing dose (TID) over time and monitor system electronics performance.
- **Charge Dissipation Film Resistance**
  - Measure the resistance over time
- **Atomic Number (Z)-Grade Radiation Shielding**
  - To measure total ionizing dose of Z-grade radiation shielding and compare to baseline aluminum for at least 3 samples each.

Reference: D. Laurence Thomsen III, Wousik Kim, James W. Cutler, "Shields-1, A SmallSat Radiation Shielding Technology Demonstration", 29th Annual AIAA/USU Conference on Small Satellites, SSC15-XII-9, 8-13 August 2015, Logan, UT, p.1-7.

# NASA Advanced Composites Project (ACP)



NASA has partnered with the U.S. Aerospace industry with the goal of reducing the time to develop and certify composite materials and structures:

- Progressive damage predictive tools
- Automated and streamlined NDE techniques
- Manufacturing Process Predictive tools

- **Objective: Develop physics-based process model to predict the Automated Fiber Placement processing parameters which contribute to “tape-buckling” defects (wrinkles and puckers) during deposition and steering of thermoset prepreg tape over complex contour structure**

- **Approach:**

- Conduct AFP process characterization trials utilizing state-of-the-art AFP six-axis robotic placement machines at LaRC and industry labs.

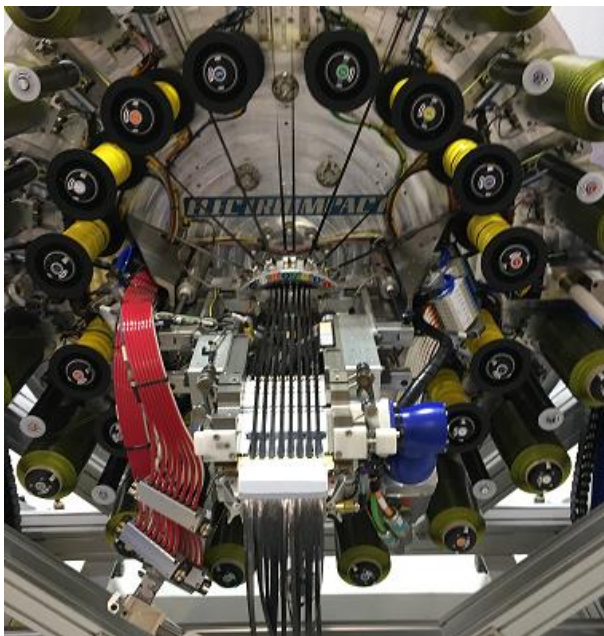


NASA LaRC robotic AFP machine



“Pucker” defect formed during steering of 0.25” wide tape on complex-contour part

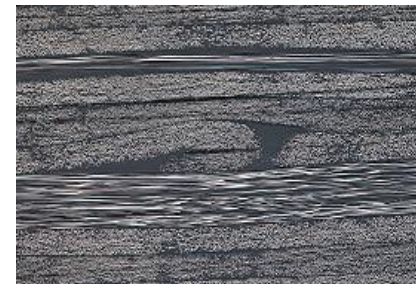
# AFP Tape-buckling Defects and Preliminary Model



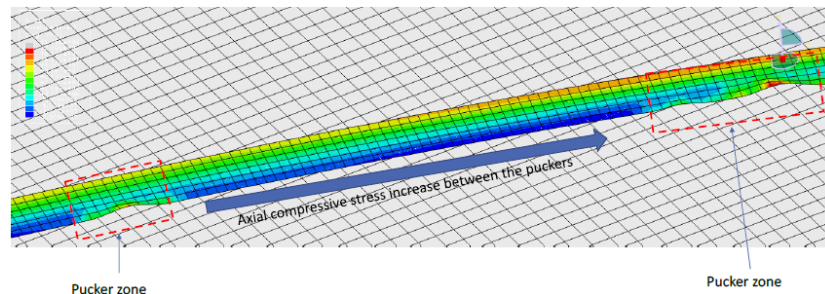
LaRC AFP Head built by Electro-Impact



Tape Buckling Defects



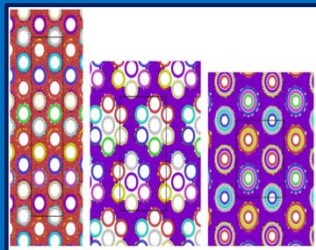
Wrinkle Defect in Cured Laminate



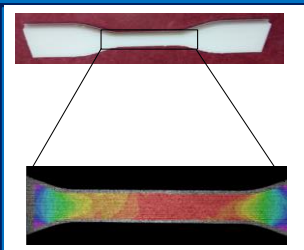
Preliminary AFP process model predictions of "puckers"

- Tape Buckling defects occur due to an excess length of material during AFP over complex-contour tooling.
- During the AFP processing trials at LaRC, Boeing and United Technologies, variation of material temperature, compaction load and tow tension were found to influence the amount and degree of tape-buckling defects.
- Based on these learnings and prepreg material characterization a preliminary physics-based AFP deposition process model has been developed which can predict puckers based on the Tack adhesion force between plies.

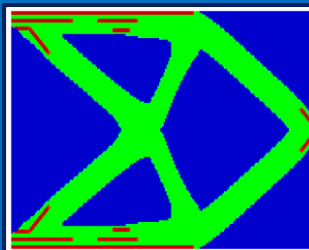
# Additive Manufacturing of Multifunctional Components



Atomistic  
Modeling



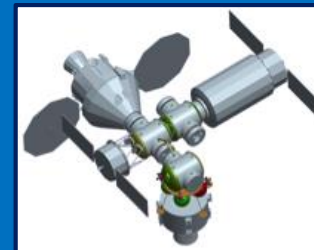
Mechanics of  
Materials Modeling



Topological  
Optimization

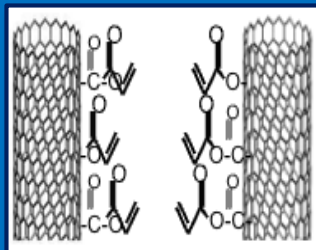
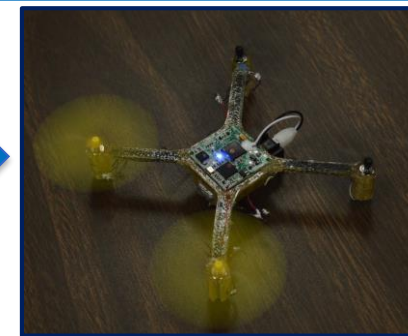


Process Modeling

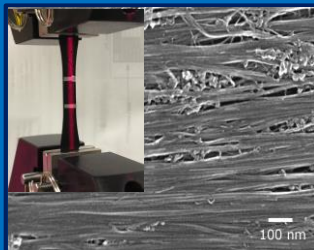


Systems Analysis

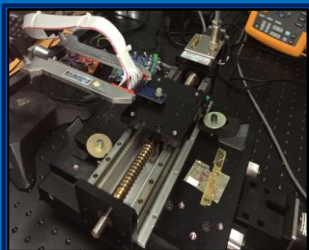
Multifunctional Component



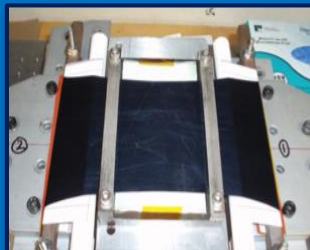
Chemistry



Materials  
Characterization



Sensor Fab and  
Characterization

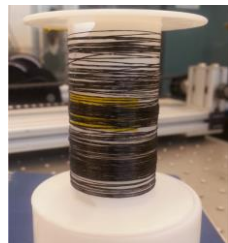


Composite  
Processing



3d Printing

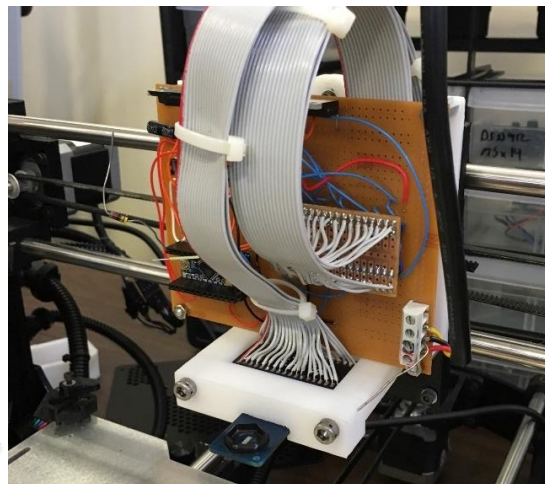
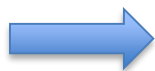
# 3D Printing Carbon Nanomaterials in Multifunctional Parts



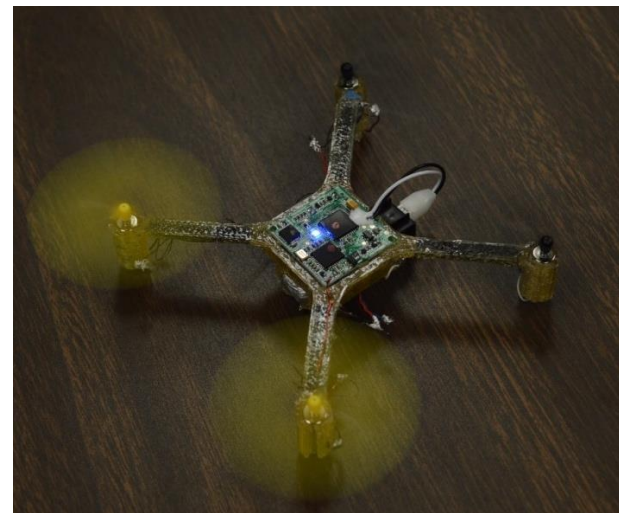
CNT Yarn



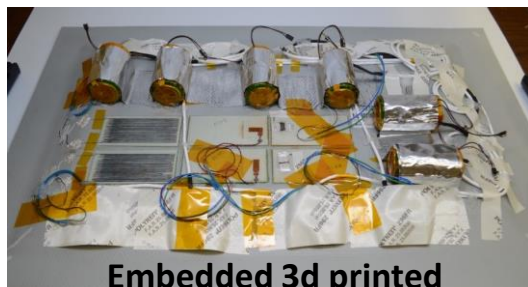
Graphene



NASA developed 3D printer



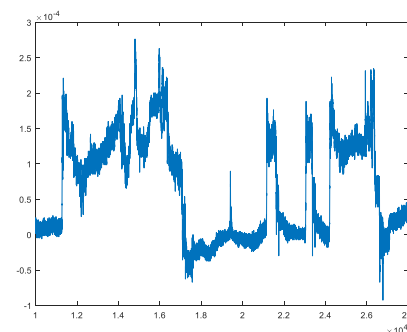
3D printed multifunctional quadcopter



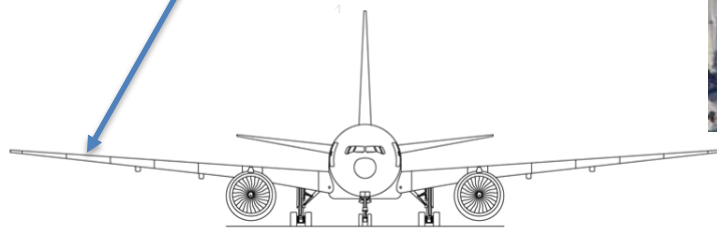
Embedded 3d printed nanosensors on flight article



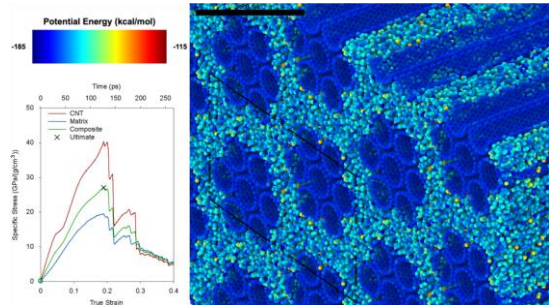
Boeing 2018 EcoDemonstrator



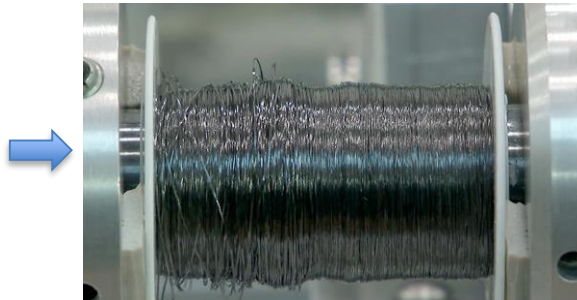
Strain sensor data from flight test



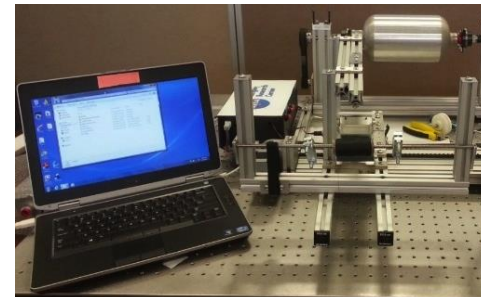
# Computationally Guided High Strength Carbon Nanotube Composite Development



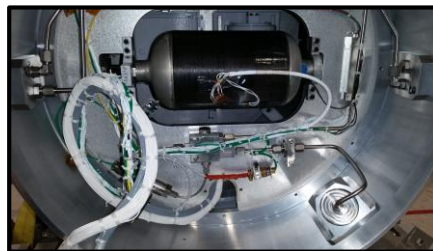
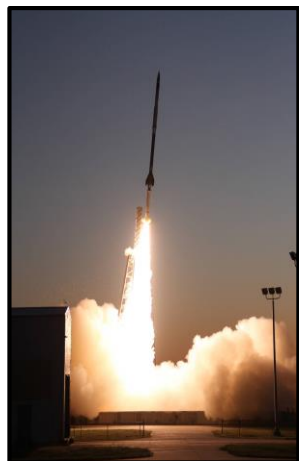
Computational modeling of CNT composite



Collaborate with industry to scale up high strength CNT



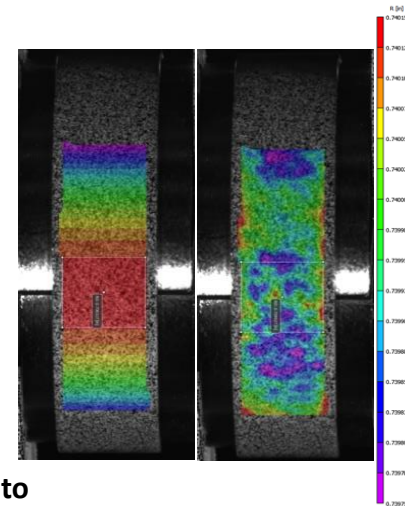
CNT composite process development



Integrate flight test article



Transfer of CNT processing method to commercial winder at MSFC to manufacture flight test article

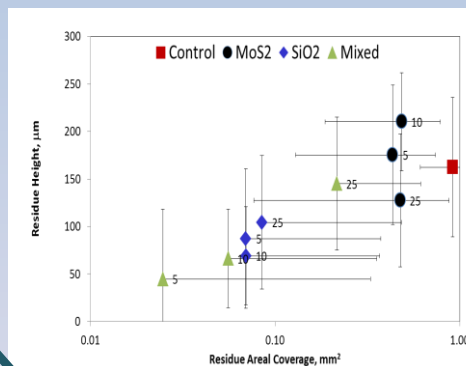
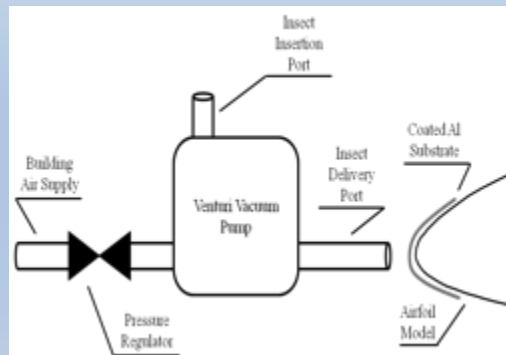
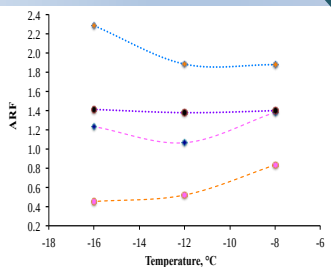


# Laboratory for Adhesion Mitigation Projects

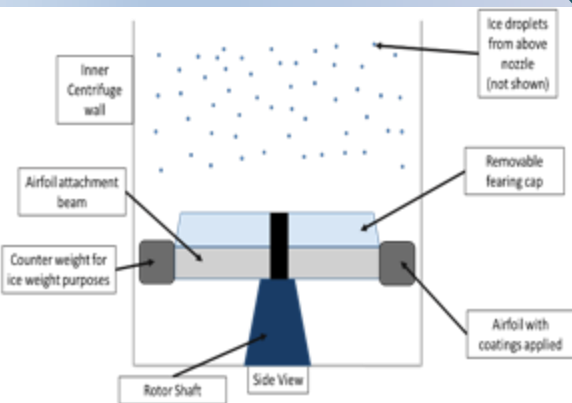
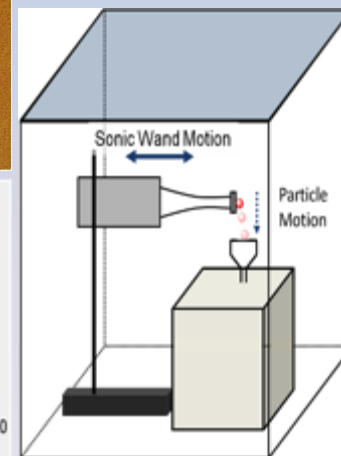
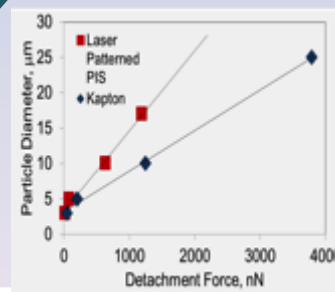
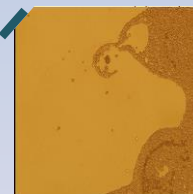


## Insect Residue Adhesion Mitigation

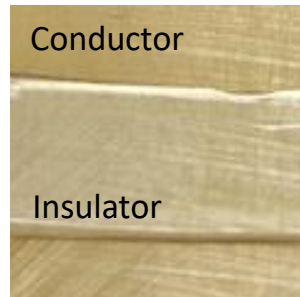
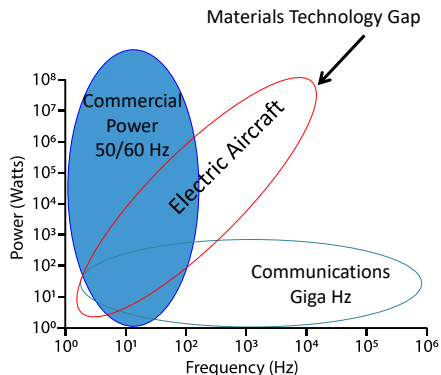
### Ice Adhesion Mitigation



### Particulate Adhesion Mitigation



# Self-Healing Materials for High Voltage High Frequency Insulators



Synthesis of insulating materials



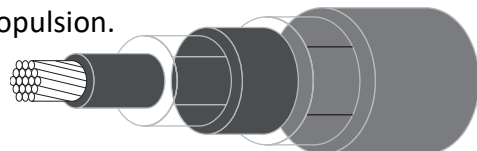
Custom test apparatus to assess real-time scratch healing under simulated use conditions.



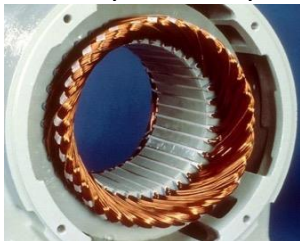
After heating, the insulator has healed and the damage is no longer present.



Prototype testing of self-healing insulation

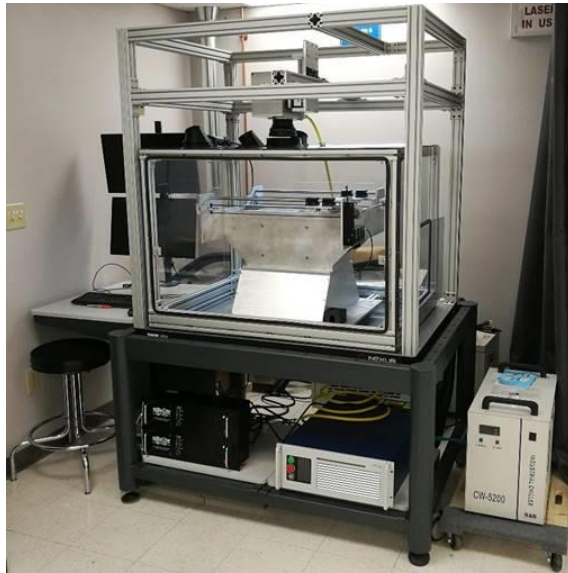


Thick film insulator for integration into multilayer cable system



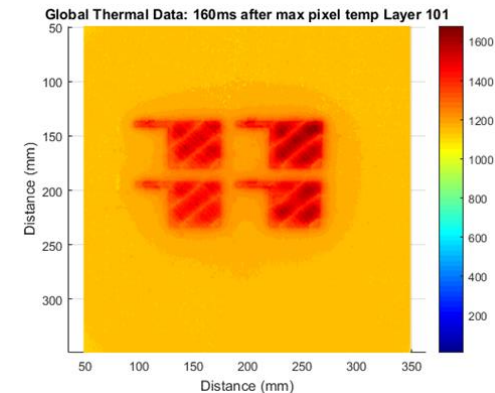
Wire coatings for electric motors

Development of a set of *validated* tools for optimization, certification and sustainment of new designs that are enabled by advanced manufacturing methods.

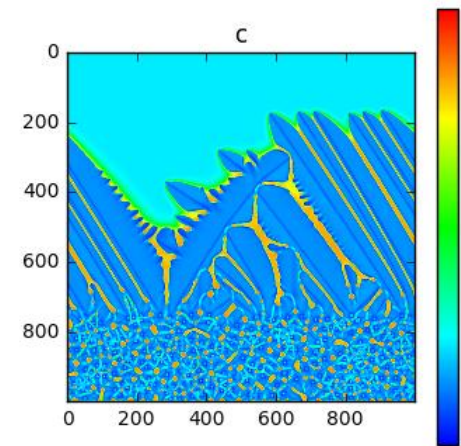


## OPENSIM test-bed

- Video and Thermal camera
  - plume emissivity monitoring
  - in-situ strain gauges
  - in-situ thermal couples
- 
- Post-build: material & defect identification, microstructure and chemical characterization.
  - Develop efficient and standardized data analysis tools
  - Utilize thermal process and phase field modeling tools for the material systems and experiments of interest under TTT.



Example In-situ thermal measurement  
(image credit: UTC, J. Middendorf)

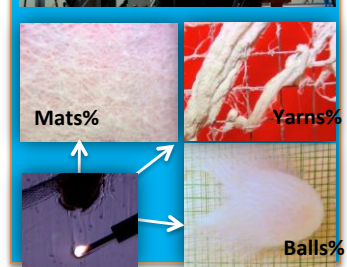
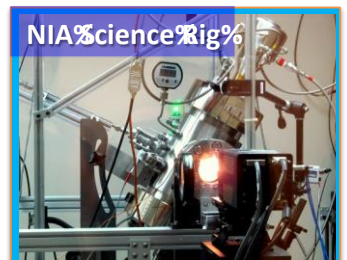


Example phase field result  
(image credit: RPI, D. Lewis)

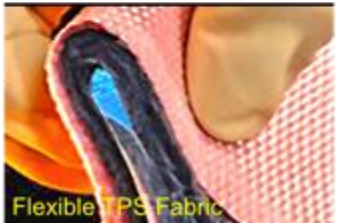
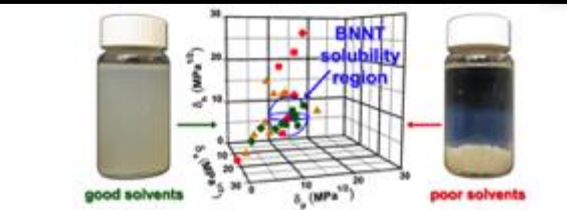


# Boron Nitride Nanotube and BNNT Composites

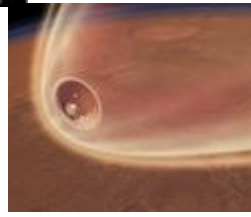
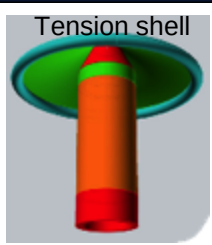
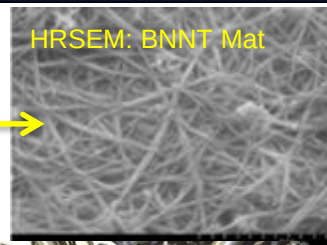
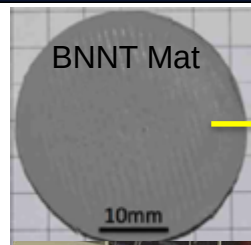
## BNNT Synthesis



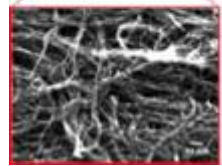
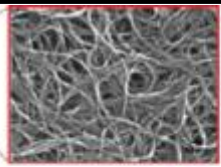
## Dispersion Processing



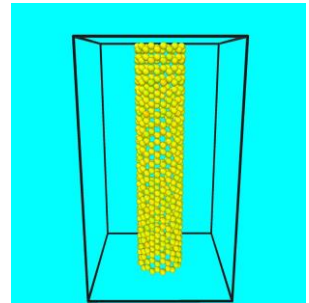
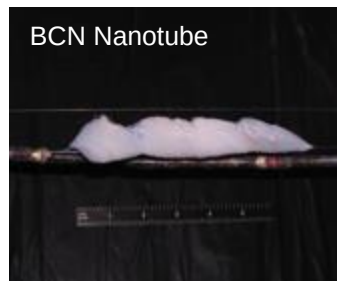
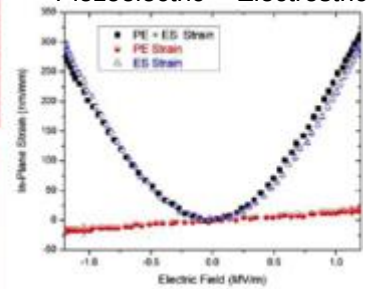
## Flexible Structural TPS



## Sensor/Actuator/Energy



Piezoelectric + Electrostrictive



# Langley Research Center ----

---- from the beginning!



*2017 was NASA  
Langley Research  
Center's 100<sup>th</sup>  
Anniversary!*

