

NASA Langley Advanced Materials and Processing Branch: Overview

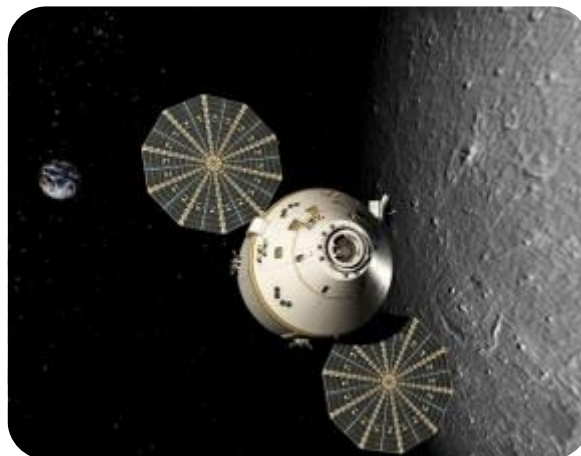
Dr. Robert G. Bryant – Branch Head

Dr. Catharine C. Fay – Assistant Branch Head

Dr. Terryl A. Wallace – Assistant Branch Head

Advanced Materials & Processing

NASA Langley Research Center, Hampton, VA 23681



NASA Vision and Mission



REACH
—NEW—
HEIGHTS

NASA Mission

Drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth.

BENEFIT
—ALL—
HUMANKIND

NASA Vision

We reach for new heights and reveal the unknown for the benefit of humankind..

REVEAL
—THE—
UNKNOWN



NASA Langley Research Center



NASA Langley Research Center Hampton, Virginia

Founded in 1917 (NACA): first civil aeronautical research laboratory converted to NASA in 1958

Facilities: \$3.6 billion replacement value

People: 1840 Civil Servants ; 1630 Contractors

NASA Langley at a Glance (2016)



As of 11/1/15

Langley's Economic Impact (2015)

- National economic output of ~\$2.3b and generates over 17,400 high-tech jobs
- Virginia economic output of ~\$1.1b and generates over 8,800 high-tech jobs



PY2016 Budget Estimate ~\$925m

NASA Langley Budget..... ~\$902m

External Business..... ~\$23m

Workforce..... ~3,470

Civil Servants..... ~1,840

Contractors (on/near-site)..... ~1,630

Infrastructure/Facilities

156 Buildings..... 764 acres

Replacement Value..... ~\$3.6b

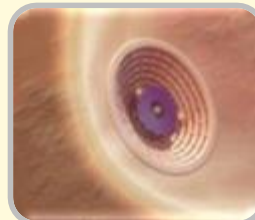
AERONAUTICS
\$191m



SCIENCE
\$232m



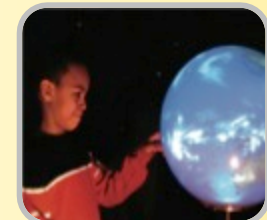
SPACE TECH
\$33m



**HUMAN
EXPLORATION**
\$41m



EDUCATION
\$1m



SAFETY, SECURITY & MISSION SERVICES & CONSTRUCTION/ENVIRONMENTAL COMPLIANCE & RESTORATION

Center Management & Operations

(Facilities, IT, Engineering, Tech Authority, B&P, IRAD, Safety/Mission Assurance, Legal, Finance, Procurement, Human Resources)

Agency Management & Operations

(NASA Engineering & Safety Center, Office of Chief Engineer, Agency IT)

Construction Environmental Compliance & Restoration

(Revitalization Plan)

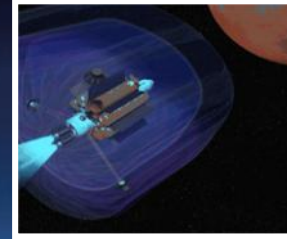
NASA Langley Core Competencies

Aerosciences

Research for Flight in All Atmospheres

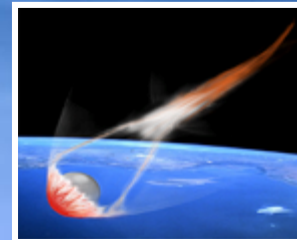


Aerospace Systems Analysis

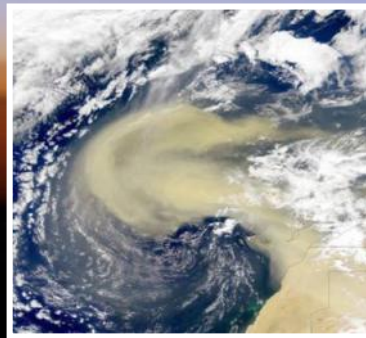


Space Exploration

Entry, Descent & Landing



Characterization of all Atmospheres (Lasers & LIDAR)



Aerospace Structures & Materials



Langley Senior Technologists for Product Lines

Tony Washburn, Aerosciences
VACANT, Intelligent Flight Systems
Steve Scotti, Advanced Materials and Structures

Chief Engineers (CE)

Eric Walker, CE for Test Operations Excellence
Steve Bauer, CE for Aerosciences
Jonathan Ransom, CE for Materials & Structures
Brenton Weathered, CE for Intelligent Flight Systems
William Winfree, CE for Measurement Sciences

Safety, Metrology & Facility Leads

Roger Wagner, Sr. Safety Eng.
Charles Zeitman, Safety Eng.
Shawn R. Britton, Metrology & Calibration SPE
Stacy Sigmon, Metrology Quality Assurance
David Shinn, Senior Projects Portfolio Manager
Dave Cordner, IT Manager
John R. Micol, Business Partnerships Lead

RESEARCH DIRECTORATE (D3)

Jill Marlowe, Director
H. Kevin Rivers, Deputy Director
Steven Reznick, Deputy Director for Workforce Development
Allen Kilgore, Deputy Director for Facility & Laboratory Ops.

Ken Wright, Associate Director for Project Implementation
Joe Morrison, Associate Director for Modeling & Simulation Integration
Bert Senter, Associate Director for Facility Operations

Business Management (OCFO)

Deneace Hines, Bus. Mgr.
Yvonne Beyer, Bus. Mgr.
Jennifer Schuetz, Prg. Analyst
Sandra Palko, Prg. Analyst

Administrative (OHCM)

Tracy Fuller, Lead Administrative
Mgmt. Specialist
VACANT, Mgmt. Specialist
Jennifer Frost, Mgmt. Specialist
Maria Dee, Mgmt. Specialist
Tracy Hunter, Mgmt. Support Asst

**Contracting Officer's
Representatives (COR),
Agreements & Technical Leads**

Marisol Garcia, BAART COR
Rick Ross, NIA COR
Dexter Blackstock, TEAMS2 COR
Pete Kjeldsen, CMOE DCOR-Ops

Edward R. Generazio, Agency
NDE Specialist
Bill Hollingsworth, Agreements
Coordinator
Donner Grigsby, Agreements
Coordinator

**D301 Configuration
Aerodynamics Branch**

Zachary Applin, Head
Sally Viken, Asst. Head

**D302 Computational Aero-
Sciences Branch**

Bil Kleb, Head
Beth Lee-Rausch, Asst. Head

D303 Flow Physics and Control Br

Catherine McGinley, Head
Luther Jenkins, Asst. Head

**D304 Advanced Measurements &
Data Systems Branch**

Tom Jones, Head
Tony Humphreys, Asst. Head
Pete Parker, Team Lead

D305 Aerothermodynamics Br

William Wood, Head
Kelly Murphy, Asst. Head

**D307 Advanced Materials &
Processing Branch**

Robert Bryant, Head
Catharine Fay, Asst. Head
Terryll Wallace, Asst. Head

D306 Hypersonic Airbreathing

Gaffney, Head
VACANT, AsPropulsion Branch
Richard st. Head

D308 Aeroelasticity Branch

Stanley Cole, Head
Russ Rausch, Asst. Head

**D309 Durability, Damage
Tolerance, & Reliability Branch**

Steve Smith, Head
Gretchen Murri, Asst. Head

**D312 Structural Mechanics &
Concepts Branch**

Ted Johnson, Head
Kevin Roscoe, Asst. Head (Acting)

**D313 Nondestructive Evaluation
Sciences Branch**

K. Elliott Cramer, Head
D. Michele Heath, Asst. Head

D314 Aeroacoustics Branch

Mike Doty, Head

**D316 Dynamic Systems & Control
Branch**

Carey S. Buttrill, Head
VACANT, Asst. Head

D317 Flight Dynamics Branch

C. Mike Fremaux, Head
VACANT, Asst. Head

**D318 Crew Systems & Aviation
Operations Branch**

Lisa Rippy, Head
Steven Velotas, Asst. Head

**D319 Electromagnetics & Sensors
Branch**

Charmaine Franck, Head
Jay Ely, Asst. Head

**D320 Safety-Critical Avionics
Systems Branch**

Eric Cooper, Head
Roger Bailey, Asst. Head

D321 Structural Acoustics Branch

Kevin Shepherd, Head
Ran Cabell, Asst. Head

D322 Structural Dynamics Branch

W. Keats Wilkie, Head

**D325 Materials & Structures
Experiments Br**

Kelly Tarkenton, Head

**D327 Subsonic/Transonic Testing
Branch**

Roman Paryz, Head
D327A Richard White, Asst. Hd.

**D328 Supersonic/Hypersonic
Testing Branch**

Michael Difulvio, Head
D328A David Aliff, Asst. Head
D328B Lynn Curtis, Asst. Head

D329 Structures Testing Branch

Lisa Jones, Head
D329A George Palko, Asst. Hd.

**D331 Revolutionary Aviation
Technologies Branch**

Scott Holland, Head

Advanced Materials and Processing Branch

5+ Facilities : Offices and Laboratories



The Future of Materials for NASA AMPB



Mission Statement : *"To Develop Advanced Materials and Processes that Expand the Engineering Design Space to Enable NASA Missions."*

- **Reduction in areal densities of load bearing structures requires the combination of all three material classes: Polymers, Metals, and Ceramics**
 - Reduce amount and traditional use of mechanical fasteners
 - Make bondlines and welds stronger than the weakest parent material
 - Directly insert the correct material where it is needed
- **The increased efficiency of solid state device technology requires the combination of all three material classes: Polymers, Metals, and Ceramics**
 - Decrease material defects and increase operating temperature ranges
 - Increase control of multifunctional properties
 - Directly insert the correct material where it is needed
- **To achieve this, AMPB needs to continue investing in 4 fundamental core technical areas:**
 - New Materials through **Synthesis** (Composition of Matter)
 - New Materials through **Processing**
 - **Characterization** of Materials
 - **Computational** Modeling and Lifting of Material Interactions

AMPB : New Materials through Synthesis

Physical Science Centric Discipline

“The manipulation of atoms and molecules to produce new materials. Includes the development of new synthetic techniques and methodology, and equipment modification and customization.”

Academic Disciplines include Chemistry, Physics, Ceramics, Metallurgy, and Materials Science.

Technologies are resins (solid and liquid), metal alloys, ceramic solid solutions, coatings, adhesives, nanomaterials, molecularly engineered materials, elastomers, “active/smart” materials.

Products are powders, pellets, ingots, solutions, wafers and other stock forms of materials ready to be processed into test specimens.



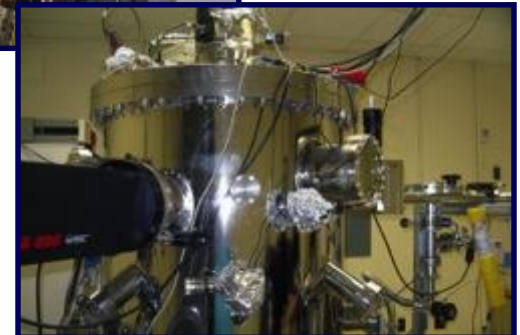
Chemical
Synthesis

Sputtering



Electric Arc
Furnace

Epitaxial
Growth
Chamber



AMPB : New Materials through Process

Engineering Centric Discipline

“The creation of new materials through the processing or combining of stock materials into new forms. Includes the development of new fabrication techniques and technology.”

Academic Disciplines include Chemical, Ceramic, Polymer, Mechanical, and Metallurgical Engineering.

Technologies are processing parameter control, novel fabrication methods, scalable processes, new hybrid materials, bonding and joining technology, extrusion/injection surface engineering and preparation, and equipment design and modification.

Products are particulate, fiber and laminated reinforced composites, films, membranes, engineered surfaces, electrical, optical, and mechanical devices, and prototype structures.

Composites



Ceramics



Plasma Spray



EBF³



AMPB : Characterization



Physics Centric Discipline

“The analysis of material properties at scales from atomic through bulk. Includes instrument design, statistically based data reporting, and new test method development and validation.”

Academic Disciplines include Chemistry, Physics, Microscopy, and Materials Science.

Technologies are customized analytical equipment, unique property test-data sets, streamlining of verification procedures, forensic failure analysis, validation of new test methodologies.

Products are highly accurate and precise data, quality specimen development, unique analytical methods, accurate lifecycle testing, and a fundamental understanding of material properties and composition as tied to synthesis and processing.

Microscopy



Spectroscopy



Thermal Analysis



Mechanical Testing

AMPB : Computation



Numerical Methods Centric Discipline

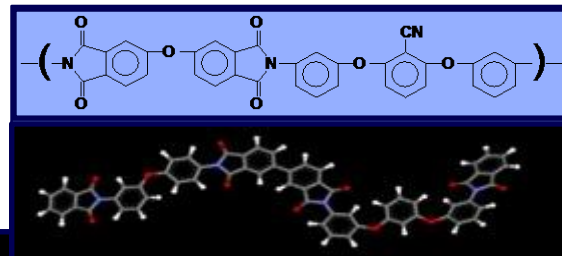
“The use of computation to simulate and predict the behavior and interactions of materials from synthesis and processing through lifing. Includes the input of experimental data and the development of computational and process control algorithms.”

Academic Disciplines include Computer Science, Physics, Mathematics, and Computer Engineering.

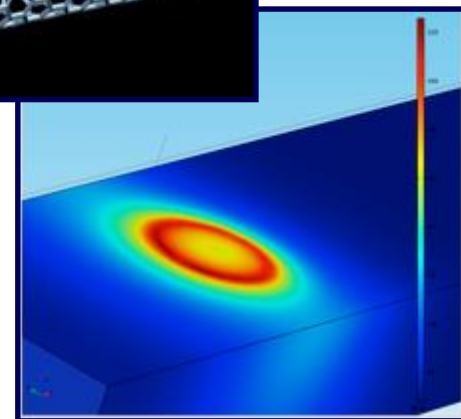
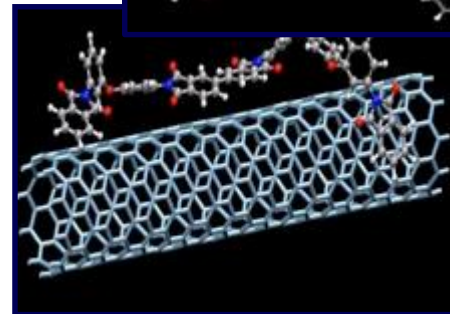
Technologies are Interactive machine codes, database of experimental inputs and material properties, reduction in the amount of experiments to develop a new material or validate a result.

Products are faster development of new materials, process control algorithms, faster computational methods, increased predicative lifing capabilities, and the development of a Virtual lab.

Molecular Simulation



Molecular Interaction



Process Simulation and Control

General Technical Capabilities and Instrumentation



- **Materials Synthesis**

- Chemical (small molecule)
- Polymer (macromolecule)
- Metallic Alloys

- **Materials Processing**

- Prepreg and Composite (any resin/fiber)
- Solution film casting/melt extrusion
- Vac Press, VARTM, Autoclave, ATP
- Plasma Spray
- EBF3
- Bonding/Joining
- Heat treatment Vac. Furnaces
- Sputtering/PVD

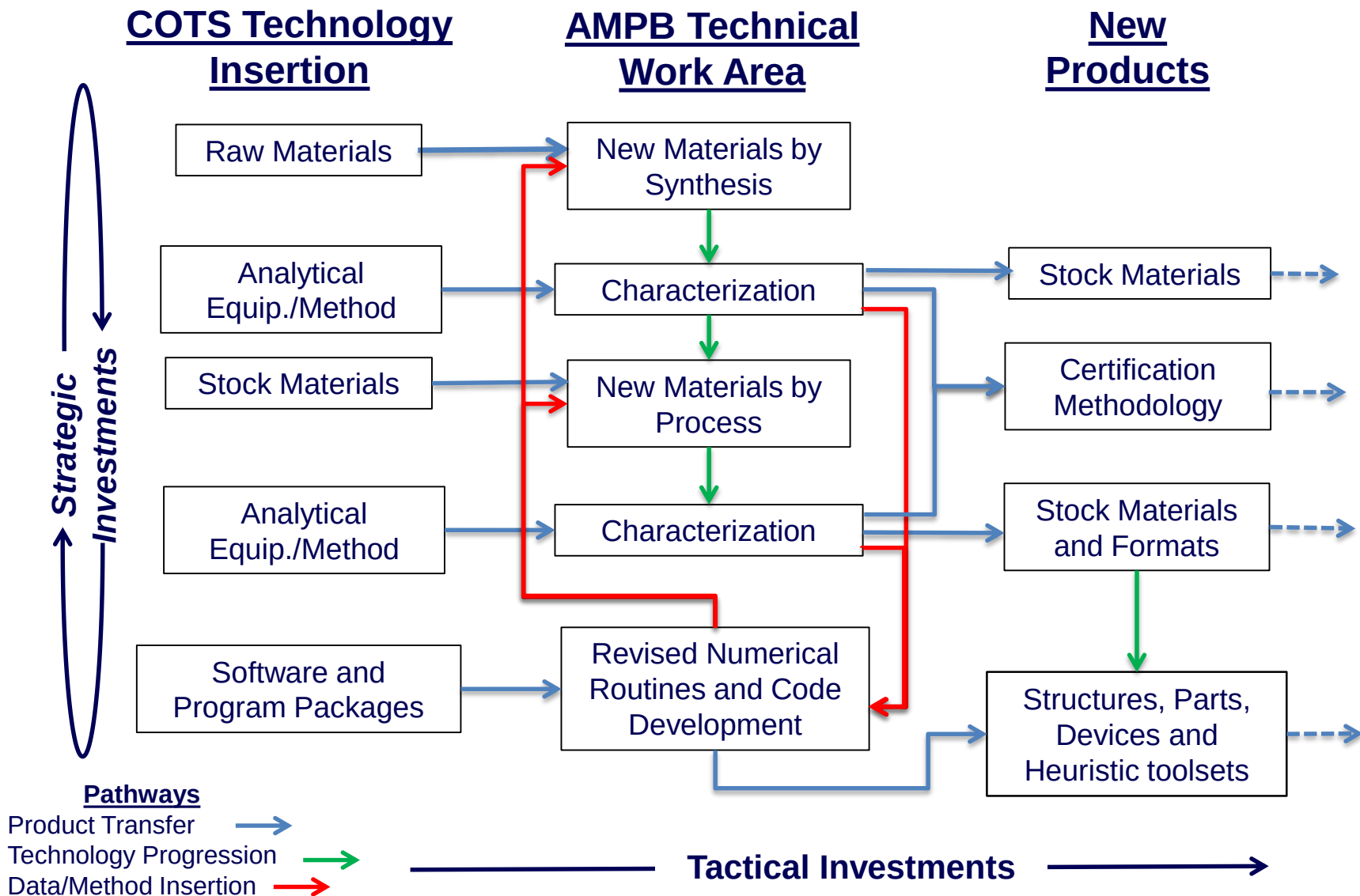
- **Mechanical**

- Electromagnetic/servo-hydraulic load-frames (Liq. He to 3000F to 10-7T)
- Small Ball-screw frames w/ E-Chambers
- Pin-on-disk Tribometer w/ furnace
- Tabor Abrader

- **Analytical**

- Microscopy: SEM/TEM/HR-SEM Xe⁺-PFIB: SEMs – Variable Pressure Lg chamber (w/ EDX, WDS, μ -probe, load frame, EBSD/AFM tips, EELS, SIMS)
- Thermal Analysis: DSC, TGA, TGA-MS, DMA, TMA, Laser Flash, Heat Flow, Rheometers
- Spectroscopy: NMR, IR, near-IR, UV-Vis, RAMAN, /XRD, Elipseometer, XPS, Auger
- Chromatography: GPC, GC-MS
- Surface Analysis: Droplet and Insertion instruments for surface tension, Optical profilometer, SPM, Nitrogen Absorption
- Optical Microscopy: Confocal, Fluorescence, Metallograph, X-Polarized

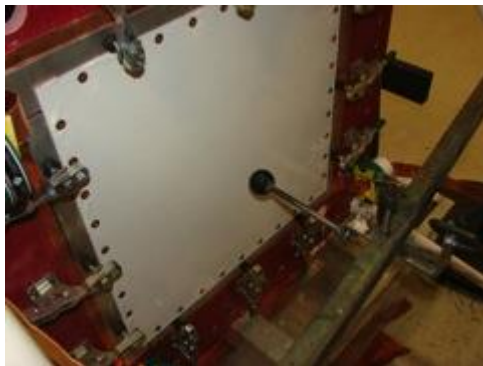
AMPB : Interaction of Technical Areas



VARTM PMC Metal Hybrid Panels for Lightning Strike Protection: Initial Testing



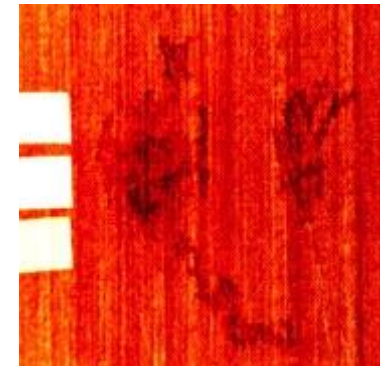
Before Strike



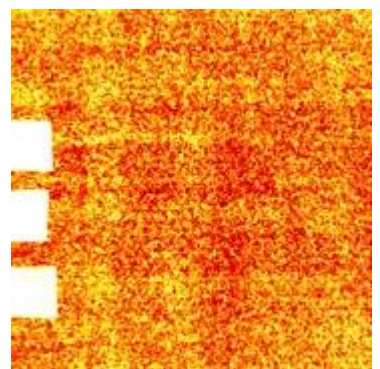
After Strike



X-Ray



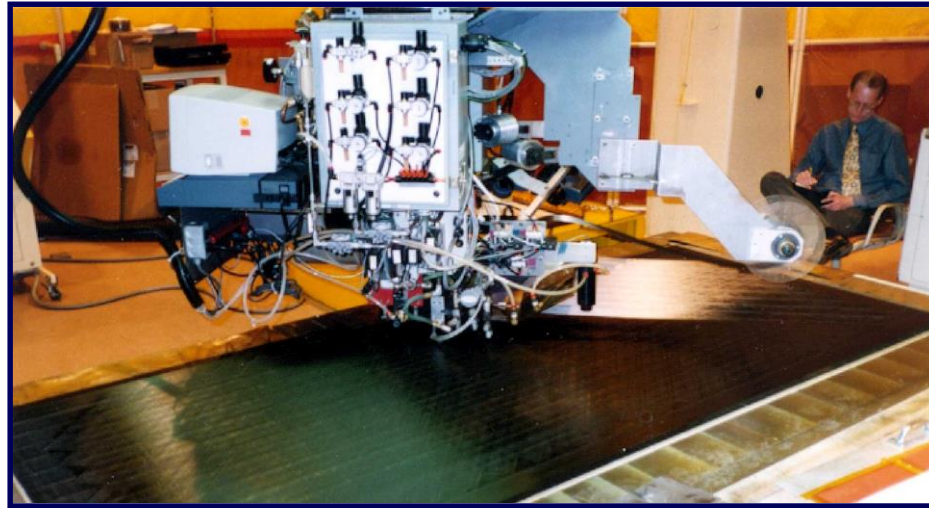
SOA DEXMET –
Cu Mesh over
PMC



PMC-Metal Hybrid
fabricated at LaRC

- In trial testing of a glass fabric plasma coated layer secondarily bonded to an IM7/8552 PMC:
 - The strike of the PMC-Metal Hybrid was very dispersive and spread the currents thru multiple paths.
 - Plasma coated PMC exhibited similar displacement and damping characteristics as the SOA DEXMET panel (3mm to 0 in 350ms)
 - Unlike the SOA DEXMET, the plasma coated Hybrid lost no conductivity during the test

HH-ATP of High Performance Thermoplastics



- Heated Head Automated Tape Placement is a PMC fabrication technology which offers the potential to fabricate high performance thermoplastic matrix composites out-of-autoclave
 - Engineering Thermoplastics such as PEEK, PEKK, and PPS have significant advantages over Thermoset matrices such as epoxy and BMI
 - Higher Toughness, reducing knockdown associated with CAI.
 - Comparable Use Temperatures.
 - No out-life or shelf-life issues
 - Potential for recycling
- Since the adoption of toughened epoxy PMCs in the 1990's by the major airframers, thermoplastic PMCs have found limited use as primary structure on 777 or 787. This is due in large part to the increased manufacturing cost associated with fabrication using these materials. The HH-ATP fabrication process addresses this issue
 - In 2010, M&P engineers at BOEING, ATK, and LHM commented that their companies had ongoing research projects to lower the cost of fabricating thermoplastic matrix PMCs for both primary and secondary structure on future aircraft
 - Airbus is using thermoplastic PMC on the leading edge of the A380

Advanced Composites Project: AFP Defects Process Model Development



Problem:

Inability to predict and quantify the effects of random and shape induced in-process defects during automated fiber placement (AFP) on complex contour resulting in expensive rework or performance degradation of final component.

Objective:

Develop a physics-based AFP process model based on a deep understanding of the AFP process and the effects of AFP defects on laminate quality and performance.

Approach:

- Rank the common AFP process induced laminate defects (laps, gaps, and wrinkles) by fabricating flat CFRP panels containing defects and obtain ASTM coupon data to determine the knock-down in mechanical performance.
- Conduct AFP process characterization experiments to develop the depth of understanding necessary to simulate the AFP processing parameters leading to defects which significantly effect laminate performance.

Results:

- Three flat quasi –isotropic IM7/8552-1 panels were fabricated at LaRC utilizing the recently installed AFP equipment (Figure 1) to place 0.25" wide IM7/8552-1 slit-tape in courses containing six tows.
- Two 59" x 27", $[+45/90/-45/0]_{3S}$ panels containing intentional tow gaps in the ply #9 (+45) and ply #11 (-45). Two Gap widths are being investigated based on input from the Boeing Co., including 0.05" and 0.10" (Figure 2).
- One 44"x25", $[+45/90/-45/0]_{3S}$ pristine (no intentional defects) was fabricated utilizing identical materials batch and AFP processing parameters to obtain ASTM test coupons for the purpose of laminate strength comparisons in notched and un-notched tension, compression and in-plane shear.



Figure 1. NASA LaRC AFP equipment during fabrication of ACP defect panels

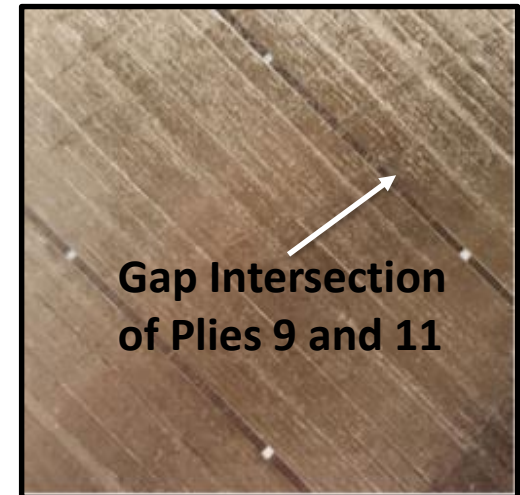


Figure 2. Max gap trial lay-up of plies 9 & 11 containing 0.10" gap between 6 tow courses

Traditional Cryotank Manufacturing Approach

Problem

- Machined/welded construction of launch vehicle cryotanks is expensive, heavy, and risky



Integrally Machined

- 90% Scrap Rate
- Approx. 540,000 lbs. Chips/Tank
- \$8M Chips/Tank
- Environmentally Unfriendly



Welded Structure

- Material Property Knockdown
- Potential Weld Defects
- Weld Lands Concentrate Load
- Approx. 0.5 Miles of Welds

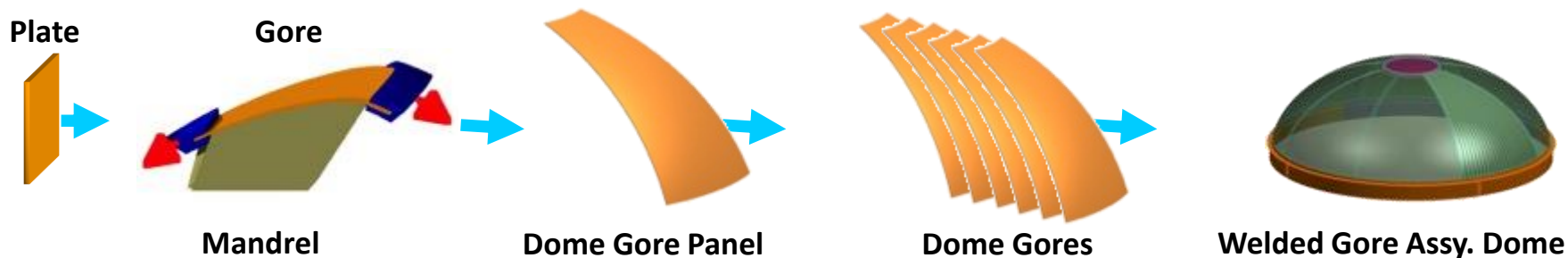
Solution

- Use innovative metals forming techniques to manufacture cryotanks which are cheaper, lighter, with less welds

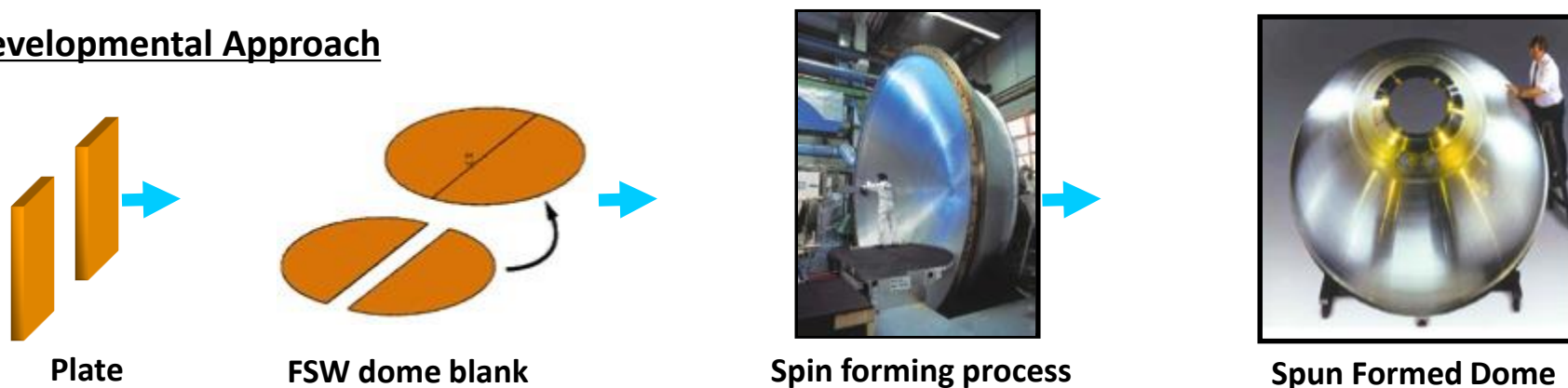
Technology Maturation and Insertion: Cryogenic Tank Dome Manufacturing



Traditional Approach



Developmental Approach



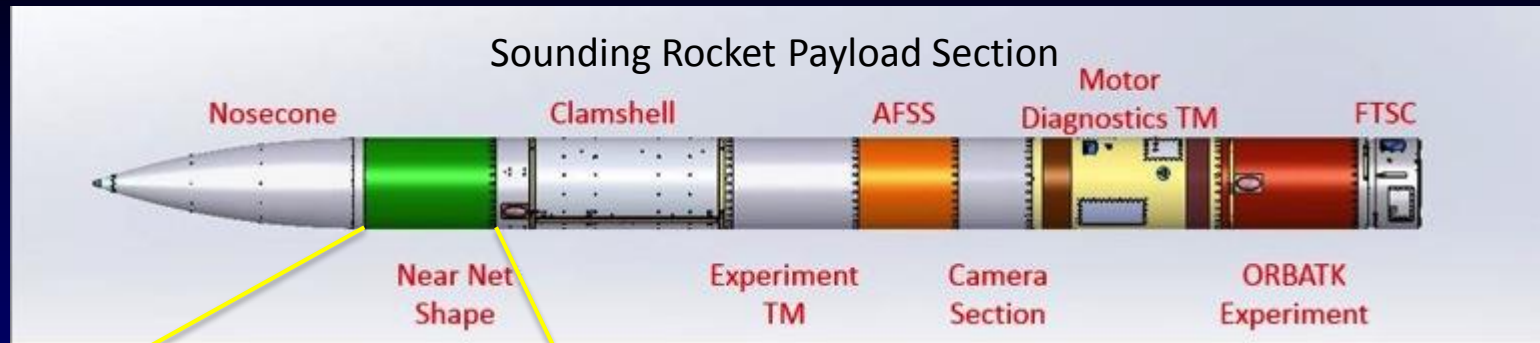
Status:

Joint ETDP / ARES I Task
Assessment of friction stir welded blanks in progress
1 m sub-scale spun dome – July 08
5 m full-scale demonstration spun dome - Feb 09

Benefits:

Improved reliability / safety
Eliminates up to 9 major welds and associated weld lands
Reduced part count and touch labor
Reduced inspection costs

Sounding Rocket Flight Demonstration of Near Net Shape Structure



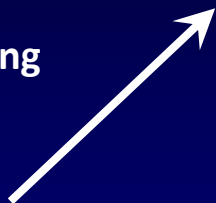
17" (0.4m) diameter
20" (0.5m) length

- Fabricated the forward-most cylinder in the payload section using the scaled-up ISC process
- Launched October 2015

Technology Maturation of Integrally Stiffened Cylinder Process for Launch Vehicles



Al-Li
Forming



Commercially produced
steel clutch housing



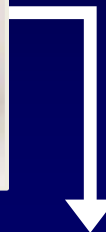
As-formed, No machining,
~ 8" (0.2m) dia.

Successful Forming of
Al-Li 2195

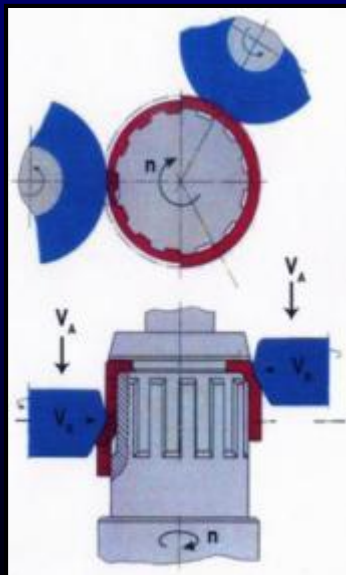


As-formed, No machining,
~ 8" (0.2m) dia.

Scale-up to 17" (0.4m)
dia.
for Sounding Rocket



Spin/flow forming process
for fabrication of integrally
stiffened cylinders

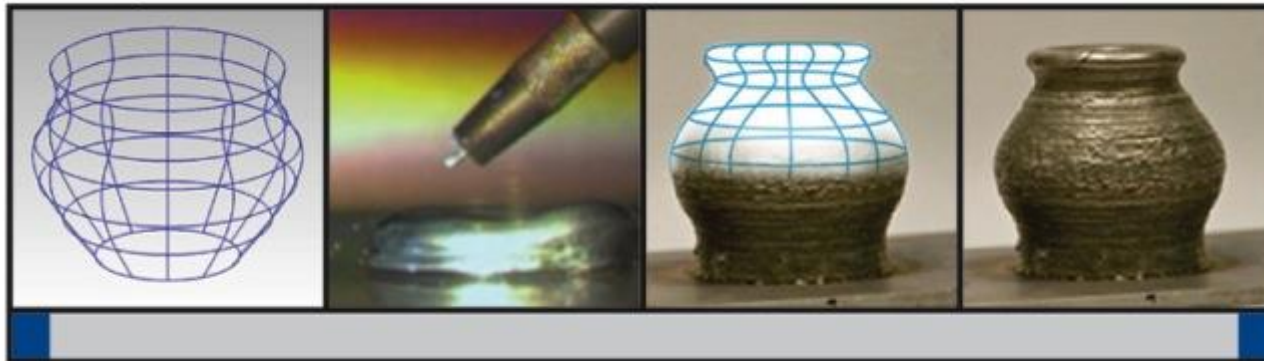


ISC Forward Cylinder Launched
October 2015 on Sounding Rocket

EBF³ Build Process

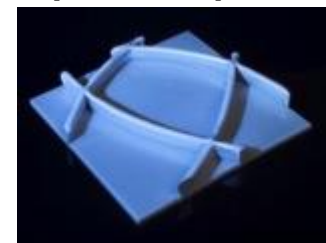


EBF³ System in ISPR

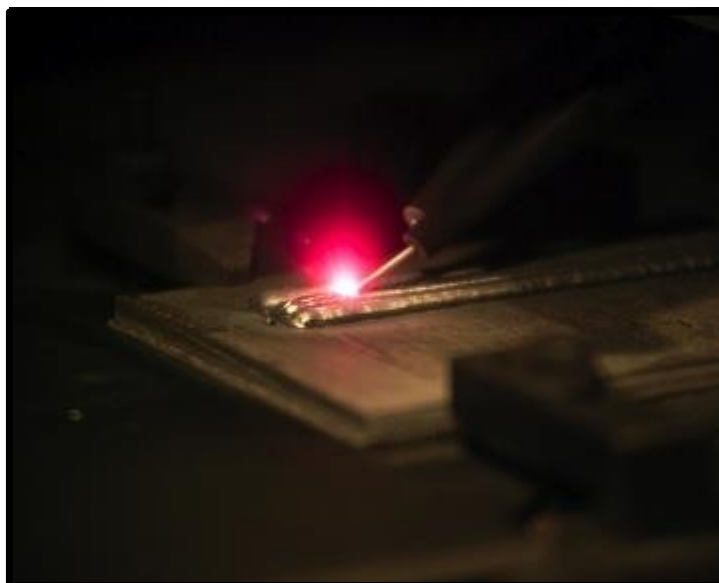
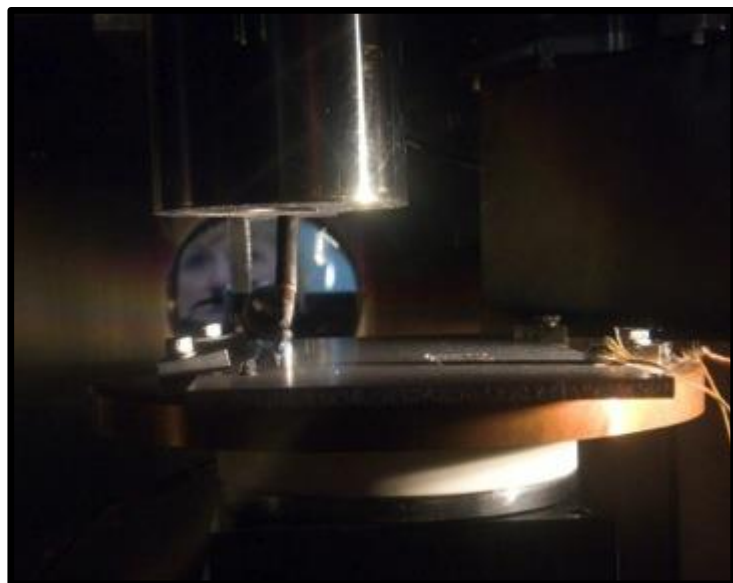


Initialize → Build → Control → As-Built

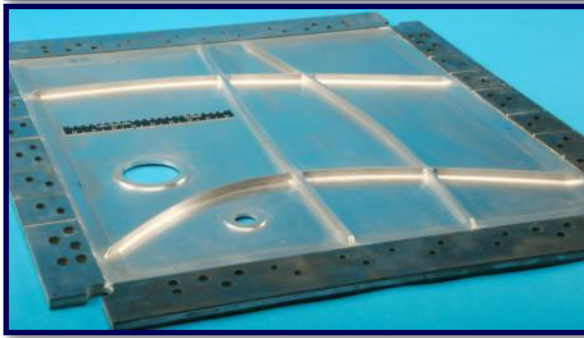
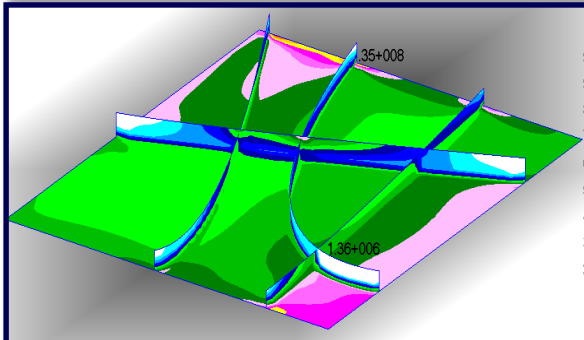
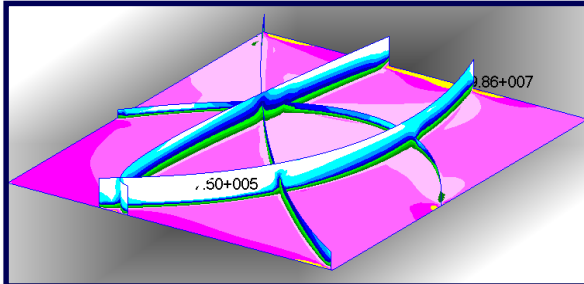
Structurally optimized panel



Microgravity testing



Optimized Structural Design



Structurally optimized panel designs & machined test panel

Funder

NASA Aeronautics – Fixed Wing & Supersonics Projects

Challenge

Optimize aircraft structural efficiency through structural design and analysis tools (development at VA Tech funded by NASA)

Current Work

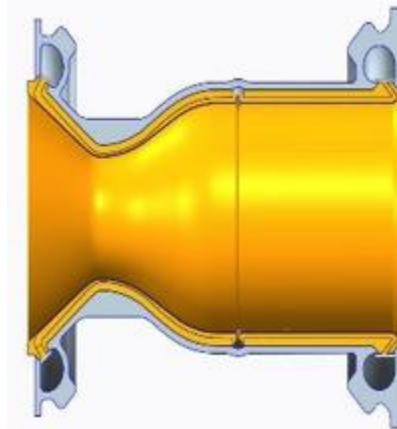
- Design and optimization tool development:
 - Contoured stiffeners that follow load paths
 - Acoustically-tailored fuselage structures
 - Aeroelastically-tailored wing structures
 - Functionally graded stiffeners for material properties tailored to structural needs
 - Selectively reinforced structures for improved stiffness and damage tolerance
- Build and test panels for code validation

Electron Beam Freeform Fabrication (EBF³) Functionally Graded Rocket Nozzle

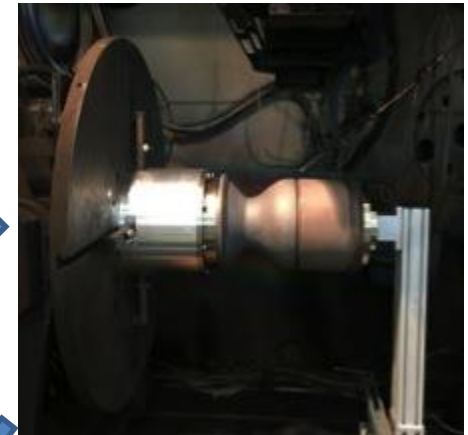


Basics:

- **Additive manufacturing being investigated 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 (EBF³)**
- Additive Manufacturing refers to a process by which digital 3D design data is used to build up a component in layers by depositing material. The term "3D printing" is increasingly used as a synonym for Additive Manufacturing



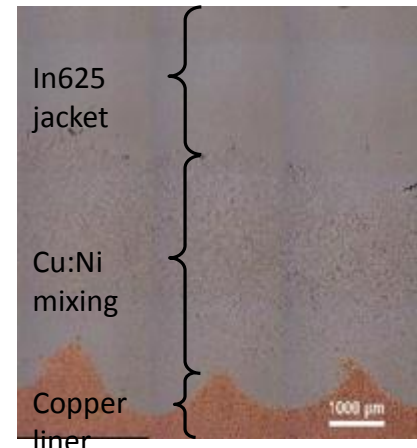
Schematic of Cu-Ni graded rocket nozzle



EB weld SLM Cu liner in LaRC EBF³ chamber



Structural Inconel 625 jacket EBF³ deposited onto SLM Cu liner



Microstructure of graded interface

Benefits:

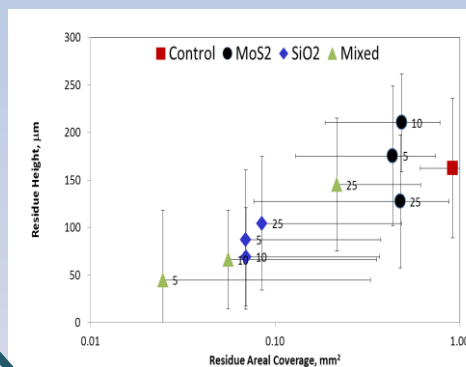
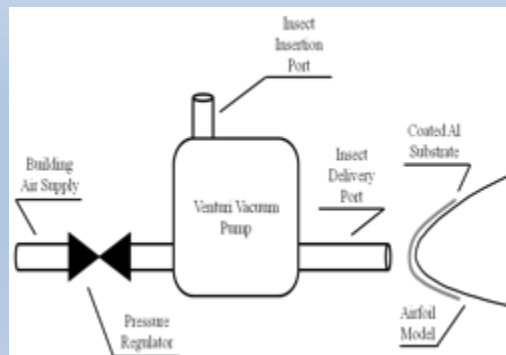
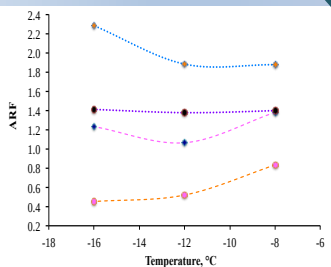
- **Reduce injector manufacture time** from months to weeks
- **Increased performance** through improved cooling with conformal passages enabled by additive manufacturing
- Potential to **reduce full scale injector cost** by nearly an order of magnitude (~90% reduction)

Laboratory for Adhesion Mitigation Projects

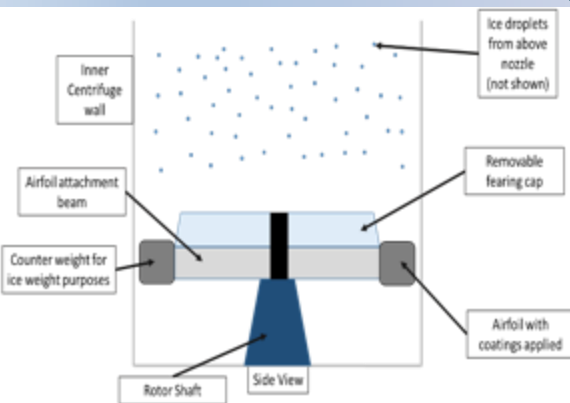
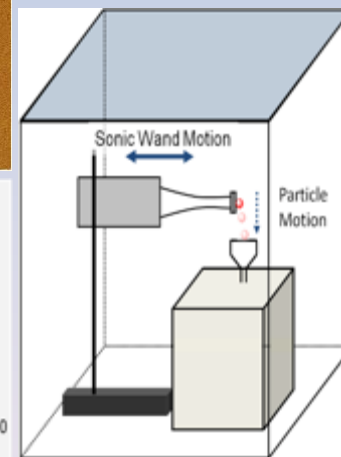
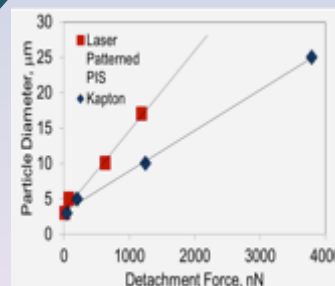
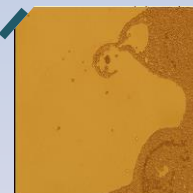


Insect Residue Adhesion Mitigation

Ice Adhesion Mitigation



Particulate Adhesion Mitigation

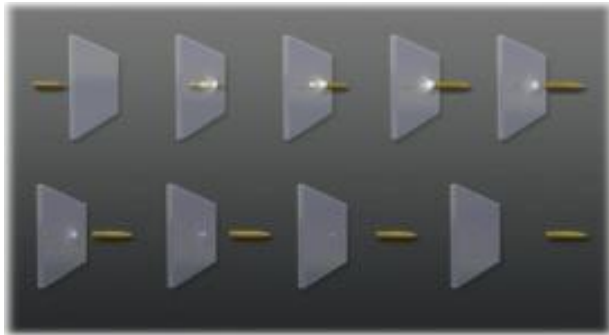


Self-healing Materials

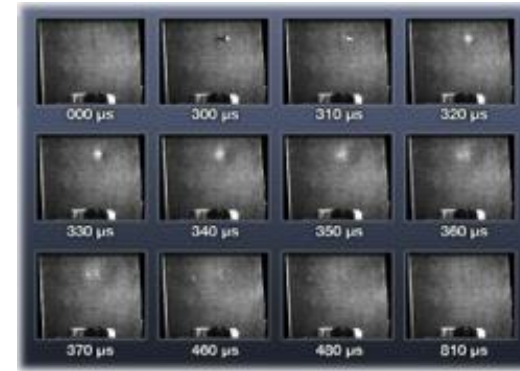


Overview: Self-healing materials development based on inherent healability due to molecular design

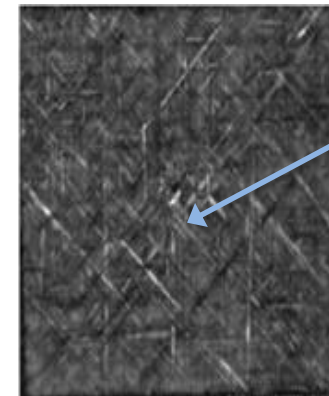
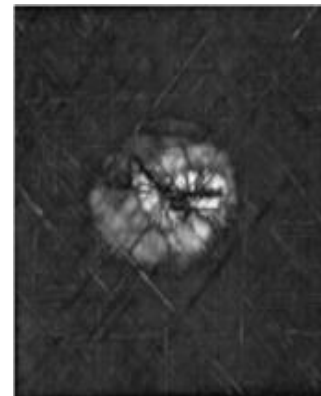
- ✧ Healing induced by energy imparted by damage event
- ✧ Material design not based on monomer encapsulation



Puncture healing concept



Rate of puncture healing from high velocity projectile penetration



Except for broken fiber, NDE shows no evidence of damage

Improved damage tolerance of composites with self-healing matrix

Positioning Ourselves for the Future

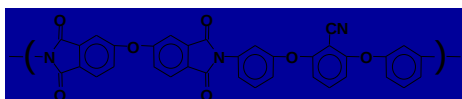
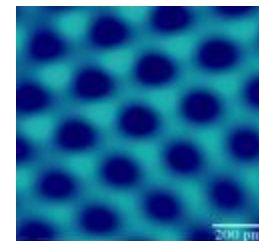
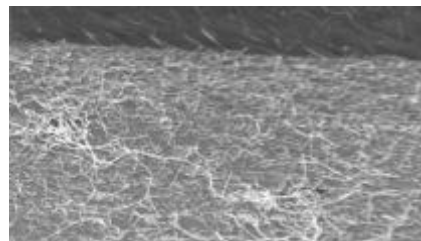
Emerging Technologies – NanoTech to Aerospace Materials



Material Synthesis



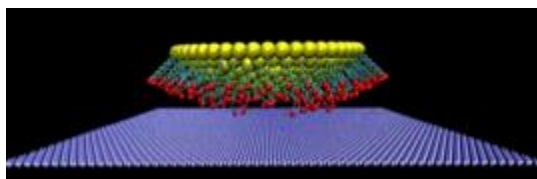
Cutting Edge Characterization Tools



Custom Processing Capability for Emerging Materials



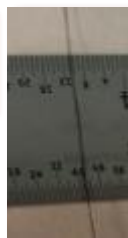
Computational Modeling



Test Articles for Materials Evaluation



**Extruded CNT
Nanocomposite**



**Injection Molded
Tensile Test Specimen**



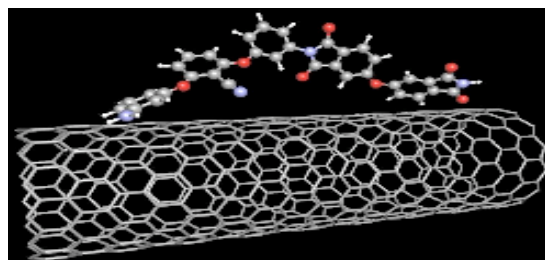
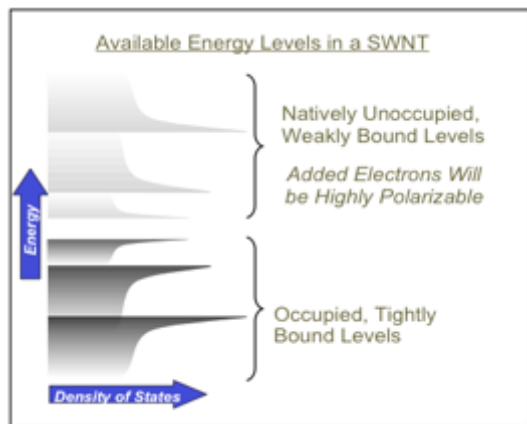
Coupling Modeling with Experiments to Guide Materials Design



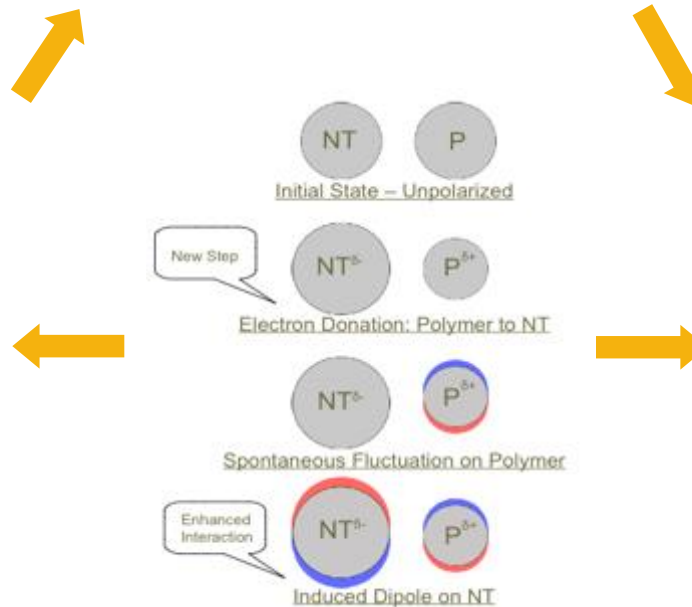
Observed Differences in Nanocomposite Solution Stability



Schematic of Proposed Donor-Acceptor Interactions

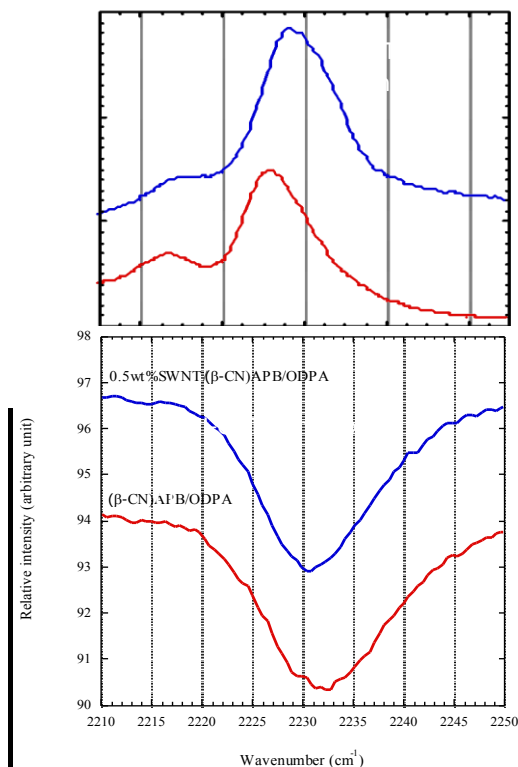


Quantum Chemical Modeling



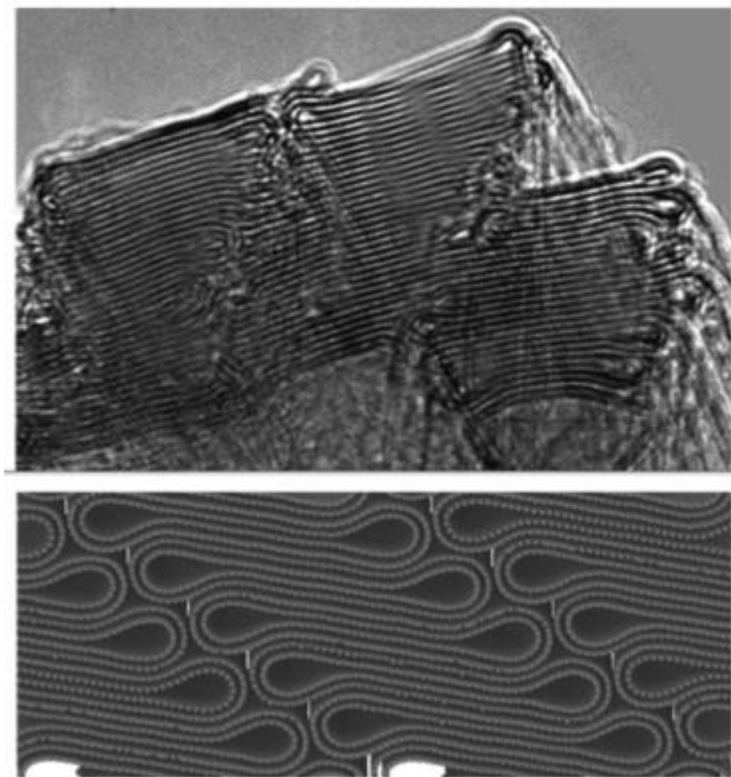
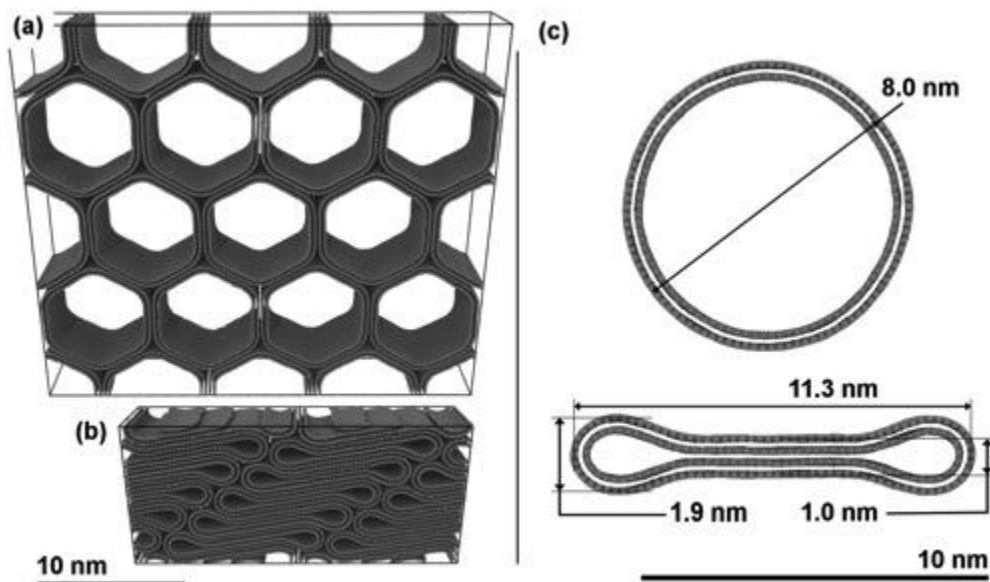
Experimental Evidence of Donor-Acceptor Interactions

Raman Spectra



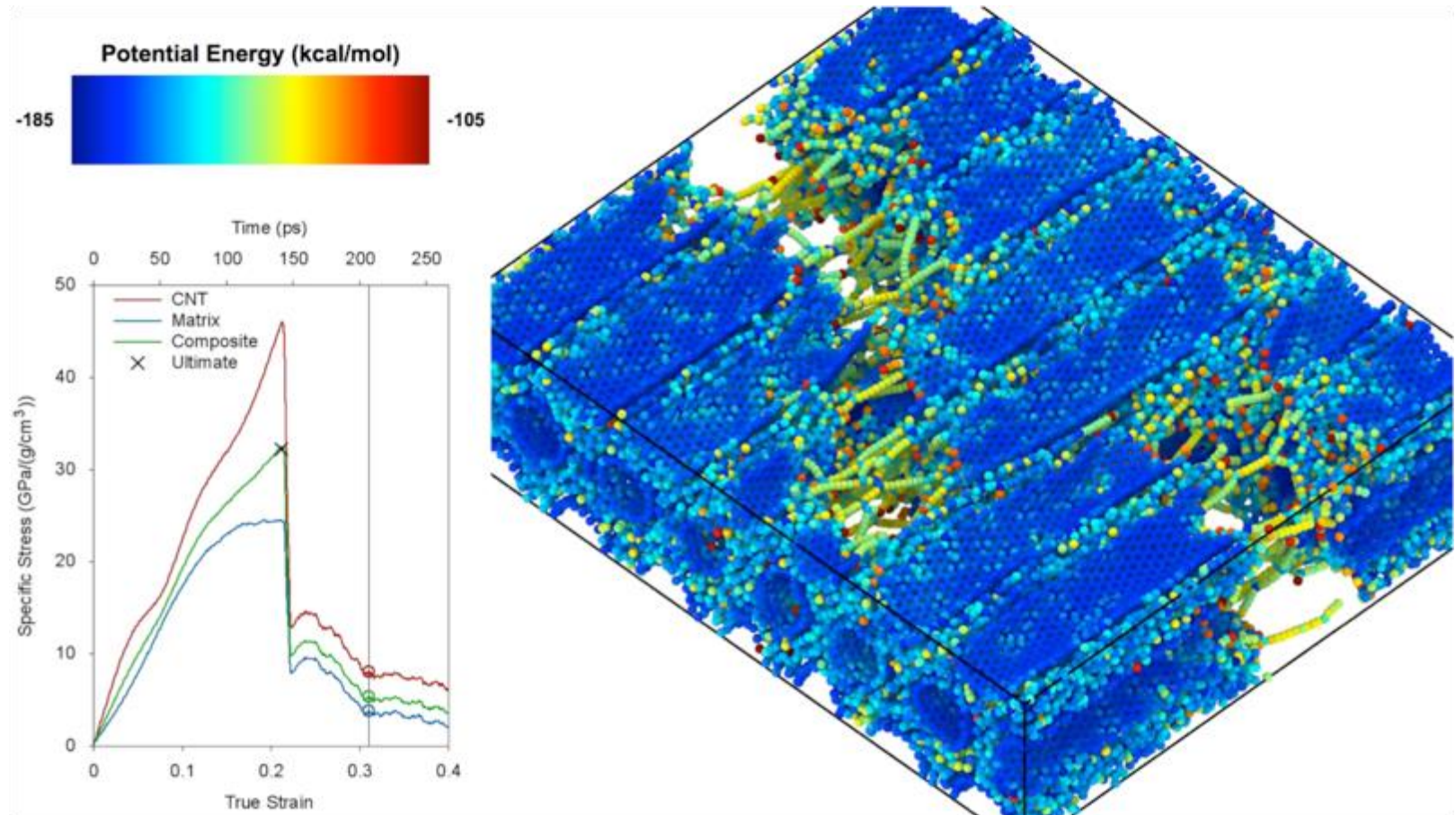
Used classical molecular dynamics simulations to:

- Interpret TEM images showing collapsed CNTs
- Predict maximum stable CNT diameter
- Compare mechanical properties of round & collapsed CNTs



Used reactive molecular dynamics simulations to:

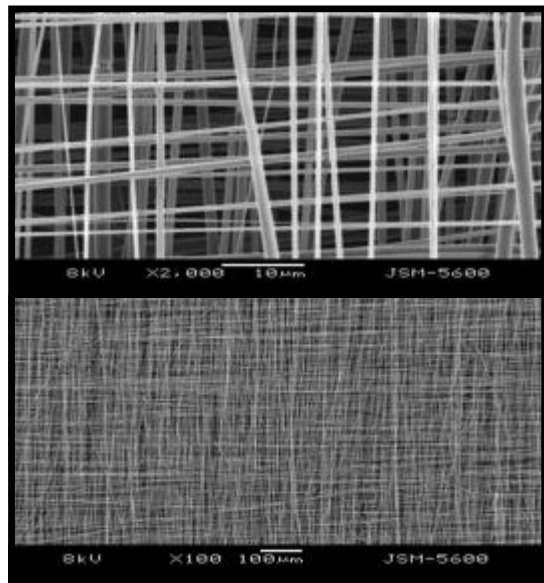
- Predict mechanical properties of CNT composites
- Simulate & visualize fracture behavior of CNT arrays and bundles



Positioning Ourselves for the Future

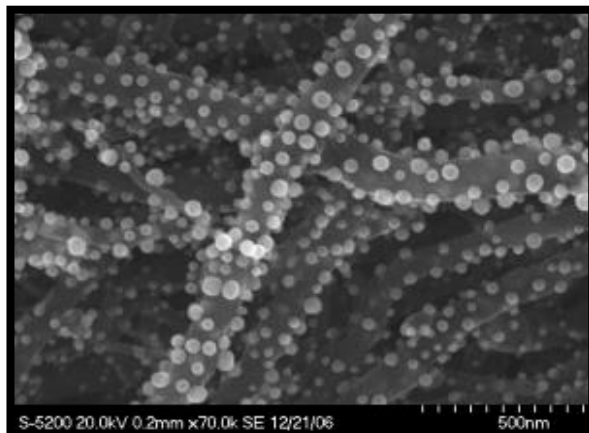
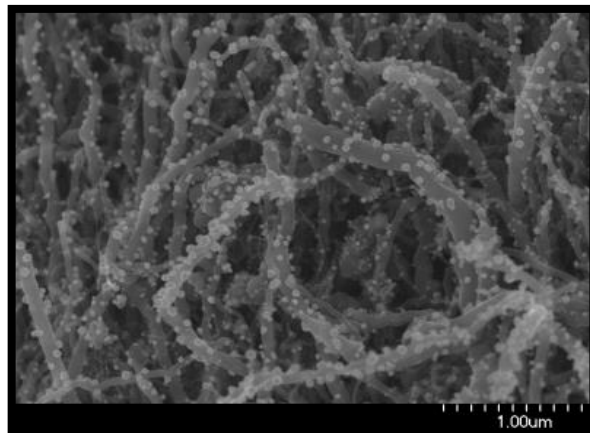
Emerging Technologies – Beyond Carbon Nanotubes

Aligned Electrospun Fabric

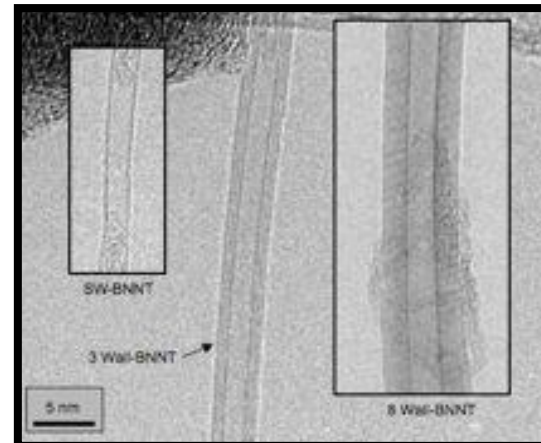
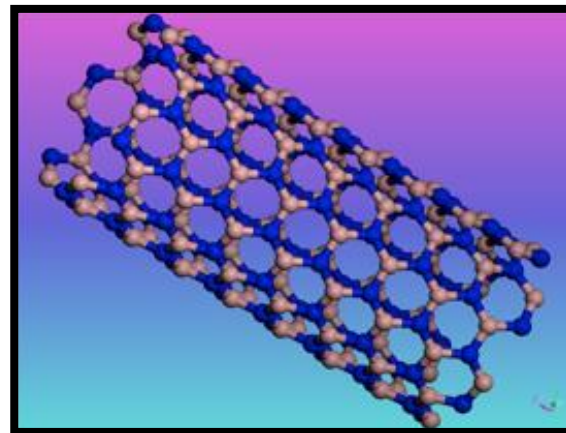


PGA 30 Layer mat: top image at 2000x; bottom image at 25x

Metal Decorated Nanotubes



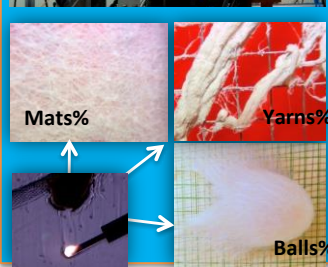
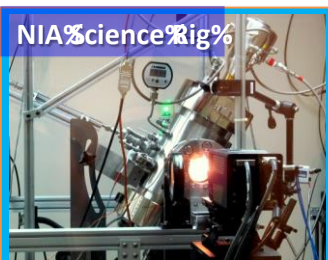
Boron Nitride Nanotubes



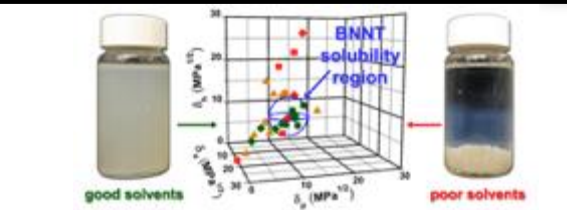


Boron Nitride Nanotube and BNNT Composites

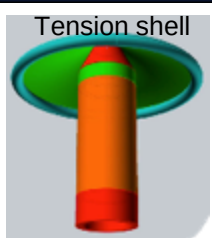
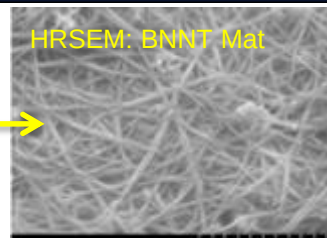
BNNT Synthesis



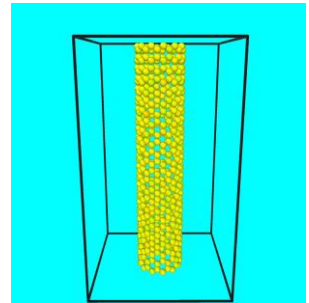
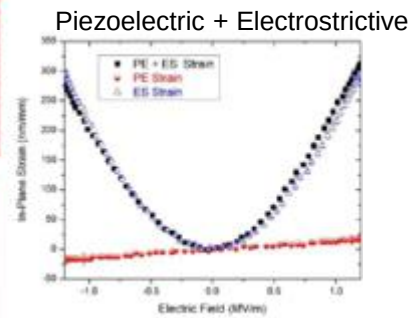
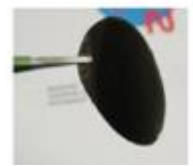
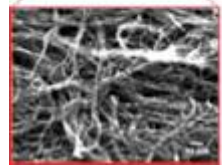
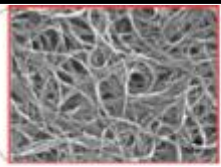
Dispersion Processing



Flexible Structural TPS



Sensor/Actuator/Energy



Holey Graphene Materials for Energy Storage



Objective

- To fully exploit the potential of holey graphene materials and their derivatives for high performance energy storage and conversion applications that meet future NASA and national needs.

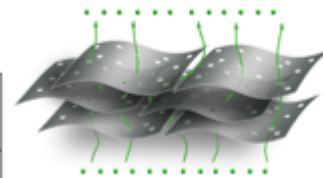
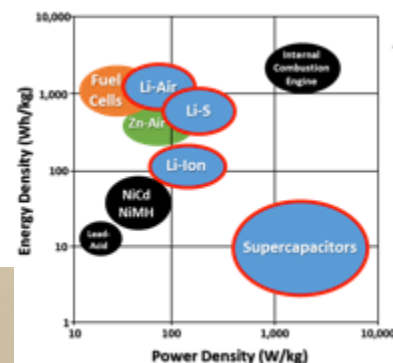
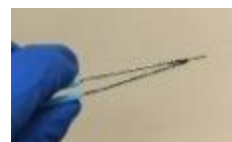
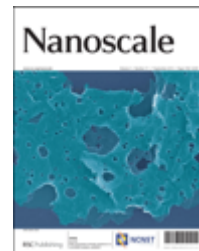
Why It Matters

- Holey graphene has unique combination of properties (such as conductivity, porosity, surface area, chemistry, processibility) that make it a top electrode platform choice for a variety of next-generation energy applications.

Recent Accomplishments

- Demonstrated scalable preparation of holey graphene and structure-property relationship in electrochemical energy storage [1-5].
- Demonstrated the potentials of holey graphene electrodes in supercapacitors [4,5] and lithium ion batteries that are lightweight and of ultrahigh volumetric performance [6].

(1) U.S. Patent 9,224,286; (2) Patent filed; (3) *Nanoscale* **2012**, 4, 6908; (4) *ACS Nano* **2014**, 8, 8255; (5) *Adv. Func. Mater.* **2015**, 25, 2920; (6) *Small* **2015**, 11, 6179.



Holey graphene can be made into ultra-lightweight and highly compact electrodes that have high accessible active surface area with effective through-electrode molecular storage and transport, thus enabling superior performance in various types of electrochemical energy storage mechanisms.

Clients

- NASA Langley
- NASA-ARMD

Participants

- NIA – Yi Lin, Jae-Woo Kim
- NASA LaRC – John Connell
- U. Maryland – Liangbing Hu
- Case Western Reserve U. – Liming Dai

Multifunctional Sensors and Actuators



Thin Layer Composite Unimorph Ferroelectric Driver and Sensor (THUNDER™)



R. F. Hellbaum, R. Bryant and L. Fox, US "Thin layer composite unimorph ferroelectric driver and sensor," U.S. patent # 5,632,841.

Face® International Corporation

<http://www.thunderandlightningpiezos.com/>

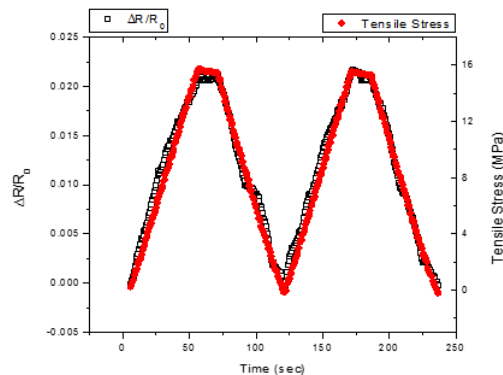
Piezoelectric-Macro Fiber Composite (MFC)



W. Keats Wilkie, Robert G. Bryant, et al, "Method of Fabricating a Piezoelectric composite apparatus," U.S. patent 6,629,341 B2, 2003, and U.S. patent 7,197,798 B2, 2007.

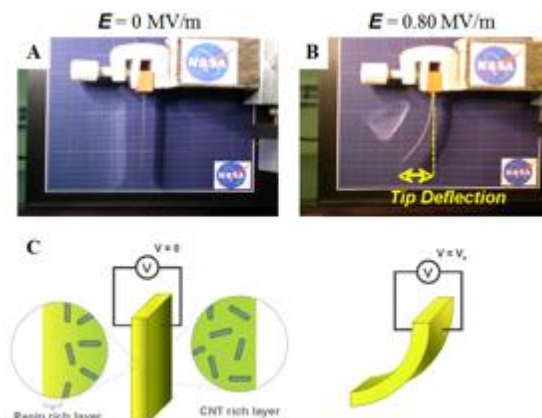
Smart Materials Inc.: <http://www.smart-material.com/MFC-product-main.html#>

Carbon Nanotube Based Strain/Stress Sensor



J. H. Kang, C. Park et al., "Piezoresistive Characterization of Single Wall Carbon Nanotube/Polyimide Nanocomposite", J. Polymer Sci. B:Polym. Phys. 47, 994 (2009)

Carbon Nanotube Based Actuator

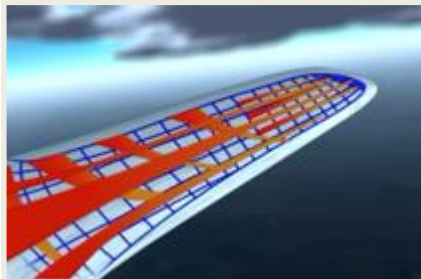


C. Park, J. H. Kang et al., "Actuating Single wall Carbon Nanotube-Polymer Composites: Intrinsic Unimorphs", Adv. Mater. 20, 2074 (2008)

Multifunctional Sensors and Actuators for Future Aerovehicles



Lightweight Airframe Structures

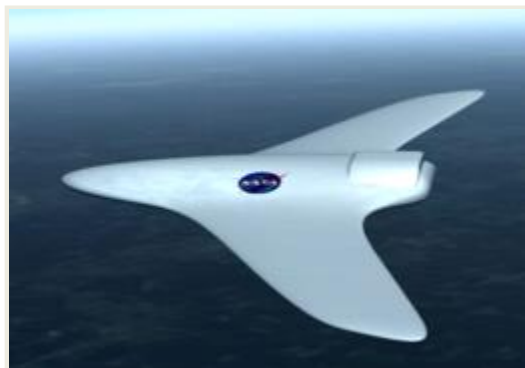


CNT-polymer composites have shown:

50% ↑ tensile modulus
30% ↑ ultimate strength
40% ↓ mass reduction relative to aluminum

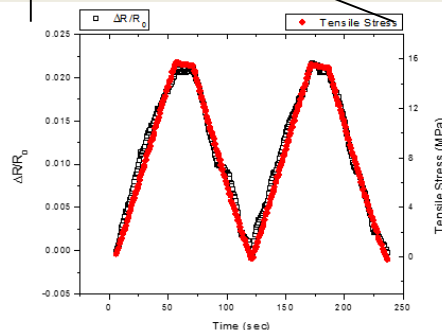
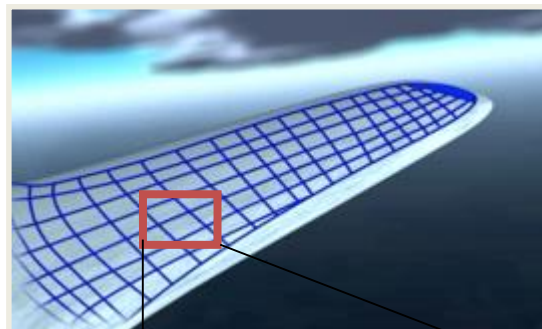


Research results demonstrate a piezoresistive response to pressure and strain



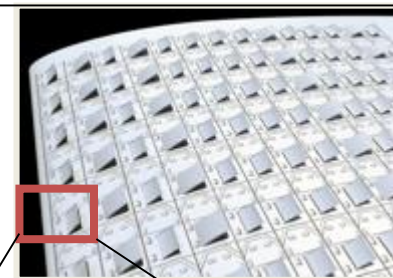
NASA LaRC

Self-sensing Structures for IVHM



Smart Actuator Arrays

CNT-polymer composites have exhibited large strains ~3% for low drive voltages ~ 1MV/m



Thin Layer Composite Unimorph Ferroelectric Driver and Sensor (THUNDER)



Piezoelectric Macrofiber Composite (MFC)

Contamination and Control

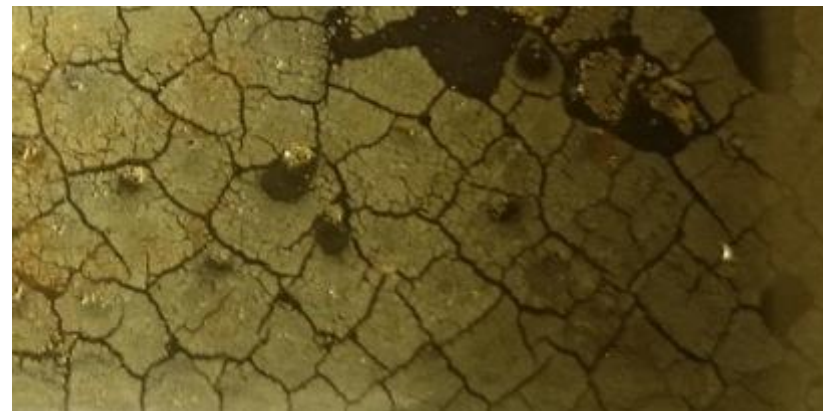


Overview:

Contamination/Non-volatile Residue NVR Analysis Testing is performed on a wide range of materials, using advanced analytical techniques with rapid turnaround times. Nonvolatile residue is isolated and analyzed by the following methods (by AMPB): Mass Determination, Fourier Transform - Infrared Spectroscopy (FTIR), and Gas Chromatography - Mass Spectrometry.

Goals and Objectives:

The objective of this work is to provide contamination/NVR testing, detection, analysis, troubleshooting and resolution expertise to minimize downtime, maintain confidence, for quality & safety. Also, this NVR analysis capability will help pave the way for Langley's ability to certify flight hardware outgassing requirements in support of flight projects such as SAGE III, CERES, MISSE-X, and DAWN.



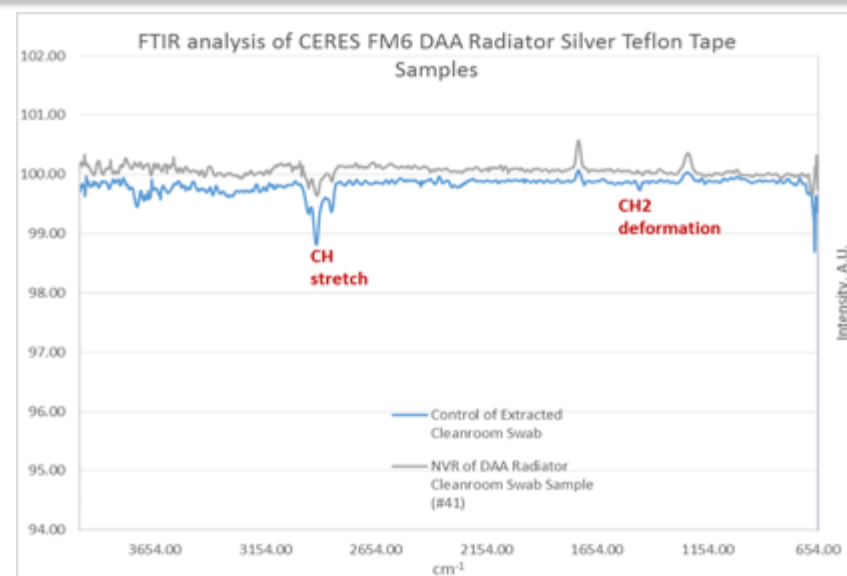
Molecular Contaminant Film from Thermal Vacuum Scavenger Plate

Contamination/NVR analysis capability:

- NVR/Contamination analysis techniques generate a molecular fingerprint and a mass determination method to quantitatively determine the amount of residue using key techniques including: Thermoelectron Nexus 670 Fourier transform infrared (FTIR) spectrophotometer and Shimadzu GCMS-QP2010 Series Gas Chromatograph and Mass (GCMS).
- Final reports are generated and provided upon completion of analysis.

Current Collaborations/Partners:

- Collaboration initiated between the Advanced Materials and Processing Branch AMPB (LaRC) and the Systems Integration and Test Branch SITB D210 (LaRC) for Thermal Vacuum Chamber – Nonvolatile Residue Analysis (TVAC-NVR). Scavenger plates and QCM heat sinks from 8 x 15 Thermal Vacuum Chamber located in SITB are isolated and analyzed by AMPB.



Materials International Space Station Experiment – Flight Facility (MISSE-FF)

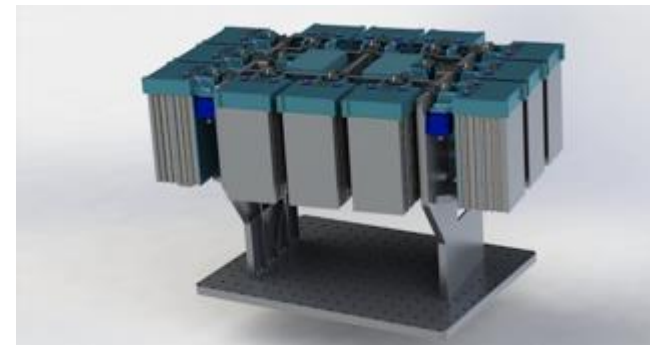


HISTORY

- NASA Langley's MISSE & MISSE-X Programs directly led to MISSE-FF

FEATURES

- To be launched in 2017
- Permanent facility on outside of International Space Station (ISS)
- For testing materials and devices in the space environment
- Passive and active experiments
- Power and communications from ISS for active experiments
- Ram, wake, zenith, and nadir orientations
- On-orbit photographs
- Modular experiment containers to be robotically deployed/retrieved
- Temperature and contamination monitoring
- Long-duration space exposures
- Affordable, easy access to space
- 40% allocation for NASA
- 60% allocation for non-NASA
- <http://www.alphaspace.com/>



Materials International Space Station Experiment – Flight Facility (MISSE-FF), in open and closed positions. *Images with permission from Alpha Space Test & Research Alliance, LLC.*

Aligns with SMD Outer Planet Space Technology Development



Highlights

Space Heritage TRL↑

1. Z-Grade Radiation Shielding
2. Charge Dissipation Film
3. Electrostatic discharge Clean (ESD) CubeSat Solar Panels
4. IEEE Part Listing
5. Recent Beam Testing Experience

Relevance to the Europa Mission

Extends typical CubeSat missions from 3 months to years with an atomic number (Z)-grade vault.

Demonstrates a Charge Dissipation Film designed for extreme charging environments.

Develops and demonstrates a one-piece (Z)-grade radiation protection for electron radiation environments.

Matures innovative μ dosimeters.

Reduces technology development schedule and associated costs by collective testing in a relevant space environment.

Publications

1. 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.

2. LAR-18586-P, "Additional Methods of Making Z-Grade", Donald L. Thomsen III, Joel A. Alexa, and Sankara N. Sankaran, June 2015.

3. U.S. Patent No. 8,661,653, 4 March 2014, "Methods of Making Z-Shielding." D.L. Thomsen III, R.J. Cano, B.J. Jensen, S.J. Hales, and J.A. Alexa.

Onboard Technologies

LaRC Z-Grade Radiation Shielding

LUNA Charge Dissipation Film

Vanguard Space, ESD Clean Solar Panels

Teledyne μ dosimeters

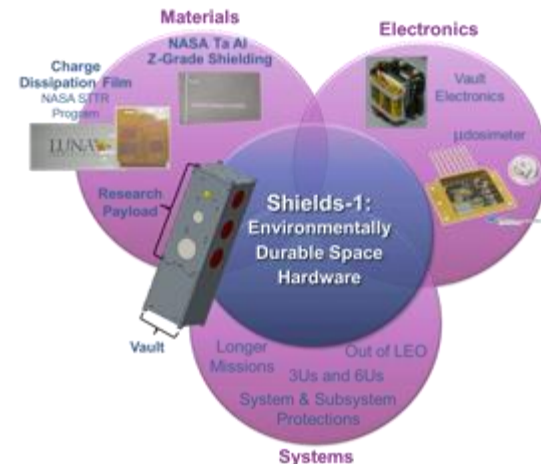
Astrodev Commercial Flight Computer

NDA's

Vanguard Space Technologies

Fabrisonics

Sheridan Solutions



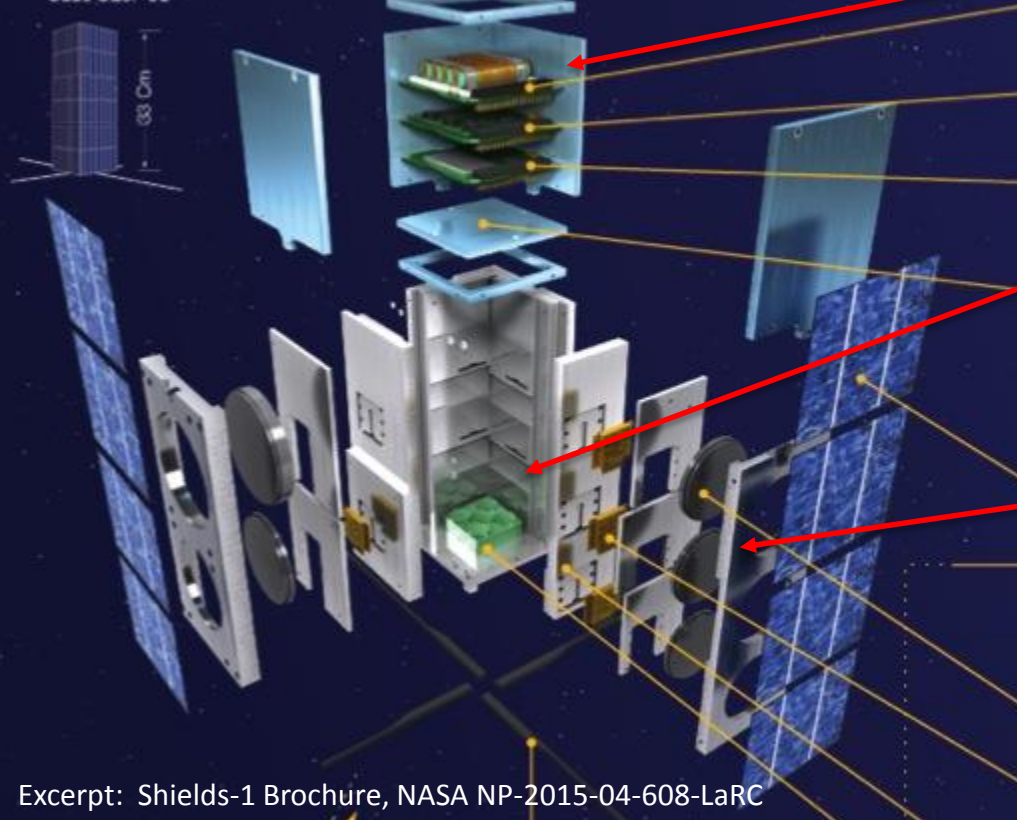
* <http://www.nasa.gov/feature/nasa-announces-seventh-round-of-candidates-for-cubesat-space-missions>

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**

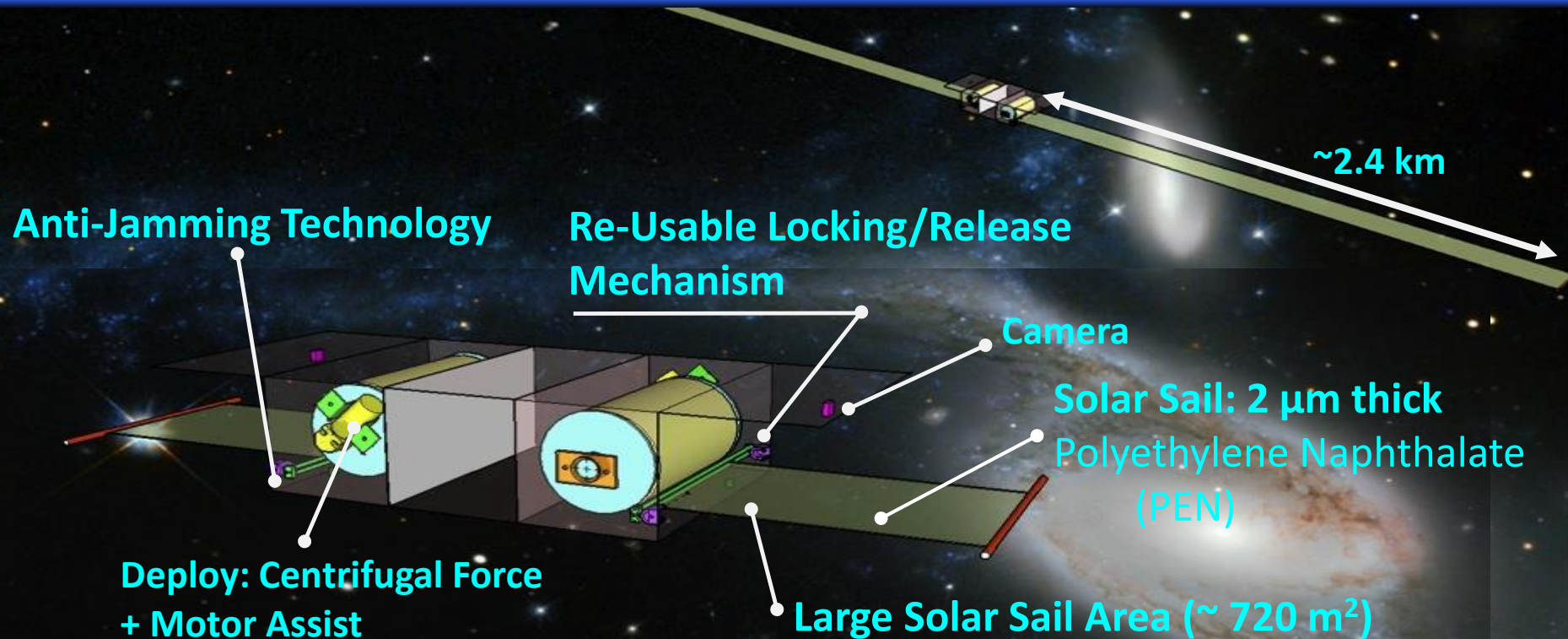
- Measure the resistance over time

- **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.

2-Bladed Heliogyro Orbital Platform in Space Mission (HOPS^{2B})



Heliogyro-Configured: 6U Form Factor

- No fuel
- Mass $\sim 8 \text{ kg}$
- Retractable Solar Sail System: Control CM/CP*, avoid thermal heat flux

CM = center of mass, CP = center of pressure



Benefits

- Future spacecraft can have a heliogyro-configured solar sail installed on board for fuel-less in-Space navigation and propulsion.
- Orbiting CubeSat heliogyro(s) can be sent to assist spacecraft that require additional power to achieve a different orbit.
- Missions: long mission period such as interplanetary travel, multi-missions, station keeping, asteroid field mapping, and interception of micrometeoroids can be performed.
- Perform a precision de-orbit by imposing solar/aerodynamic drag. This has been proven by analysis to be a more cost effective approach to de-orbiting than carrying extra fuel to achieve the same goal.^{1,2}

[1] Vaios Lappas et al., CubeSail: A low cost CubeSat based solar sail demonstration mission, *Advances in Space Research* 48 (2011) 1890–1901

[2] Walker et al., *Update of the ESA Space Debris Mitigation Handbook*, ESA, 14471/00/D/HK

Langley Research Center ----

---- from the beginning!



2017 will be NASA Langley Research Center's 100th Anniversary!

