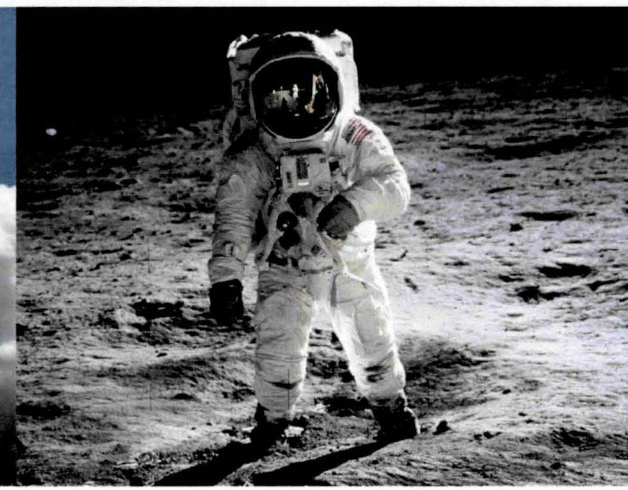
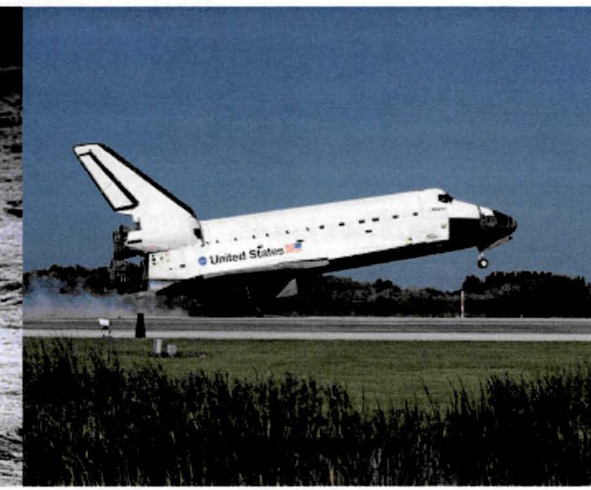
National Aeronautics and
Space Administration

John F. Kennedy Space Center

Advanced Active Materials for the Exploration of Space

Materials Science Division
Engineering and Technology Directorate
Kennedy Space Center, Florida

Luke Roberson, Ph.D.
(Luke.B.Roberson@nasa.gov)
4/10/2012

Materials Science Division Organizational Chart

NE-L
Murray, S. – Chief
Parker, D. – Deputy
Balles, A. – Technical Integration Manager

- NE-L1 Failure Analysis & Material Eval.
- NE-L2 Mat. Testing & Corrosion Control
- NE-L3 Prototype Development
- NE-L4 Materials and Processing
- NE-L5 Applied Physics
- **NE-L6 Chemical Analysis & Polymer Branch Griffin, T.- Chief**
  - Chemical Analysis
  - **Polymer Science & Technology Lab**

Lab Overview

Mission

To develop and apply new technologies in polymer and material chemistry that benefit NASA's programs and mission

Team

5 NASA scientists and 4 contractors

Areas of Expertise

Polymer Nanocomposites
Next Generation Wire Materials
Carbon Nanotube and Nanofiber Materials
Conductive Polymers
Polymer Processing
Fire and Polymers
Foam and Insulation Materials

Numerous Collaborative Efforts

NASA Centers *(JSC, LaRC, MSFC, GSFC, GRC)*
KSC Directorates *(Shuttle, Ares, Orion, Ground support operations)*
Academia *(Alberta, FIT, GT, Harding, Illinois-Urbana Champagne, UCF, UF, USF)*
Industry Space Act Agreements *(Thermax, DeWAL, Sharklet, Crosslink, Sabic, Amalgam)*
Industry Contracts *(ARCnano, Epner, Conductive Composites)*

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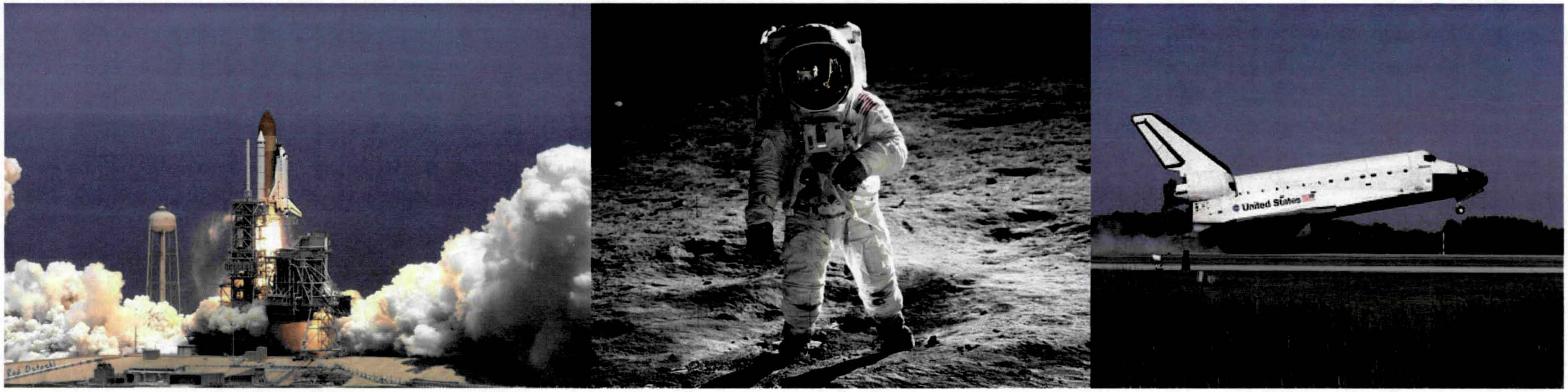
Composite Materials for Space Exploration



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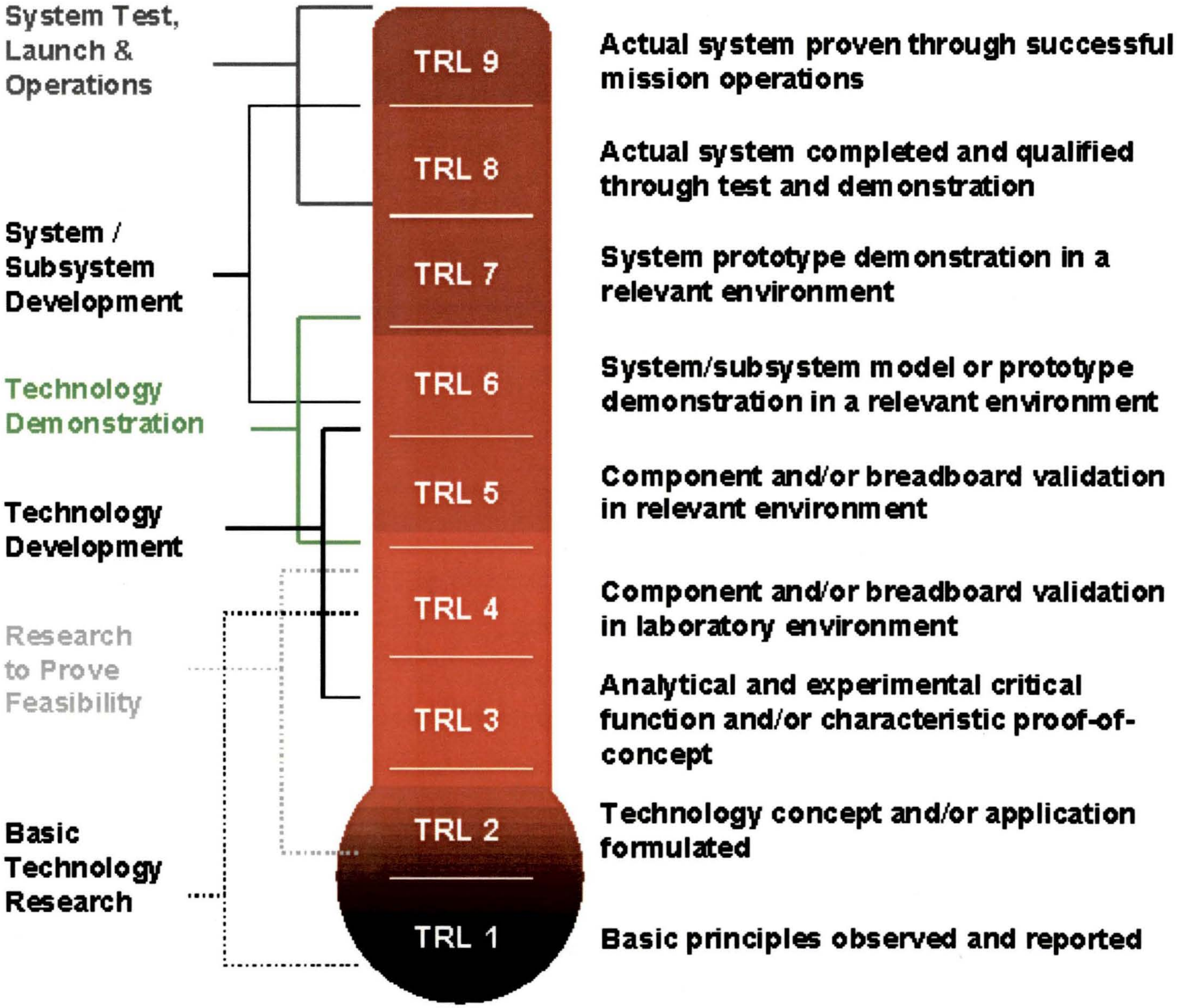
Technology Readiness Levels

TECHNOLOGY READINESS LEVELS (TRL's)



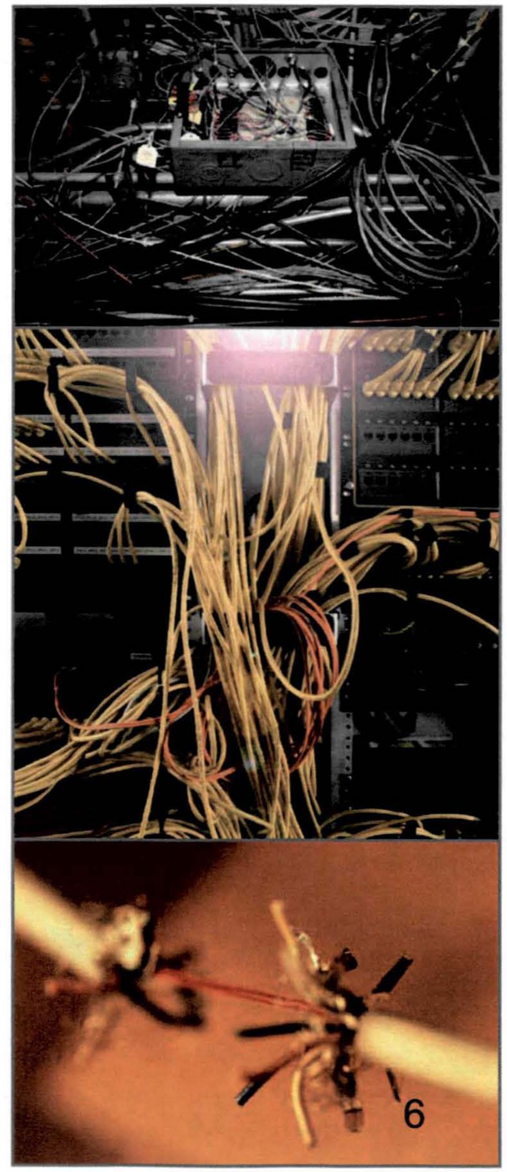
Composites/Materials Development at KSC

- Smart Materials and Detection Systems
- Aerogel composites
- Aerogel for environmental remediation
- Chemochromic hazardous gas detectors
- Antimicrobial polymers
- CNTs and conductive polymer technologies

Why Wiring?

- **Aged Wire**
  - Cracks and frays over time
  - Hard to detect damage
  - Extensive maintenance related damage during ground processing work

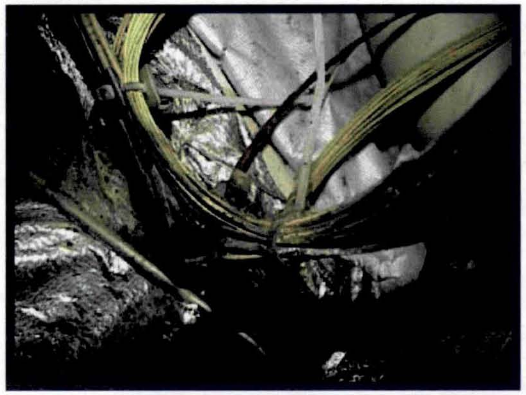
- **Space Shuttle Orbiter**
  - 183 miles of wiring buried deep within structure of vehicle
  - Difficult to manually inspect

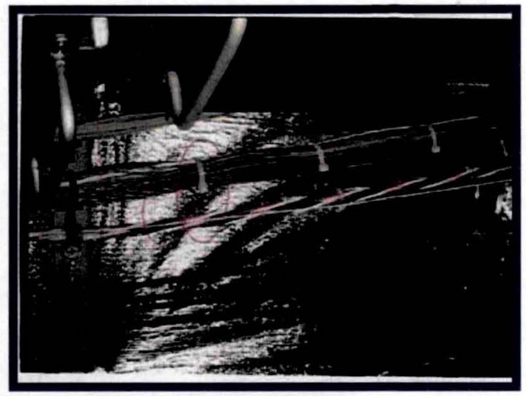


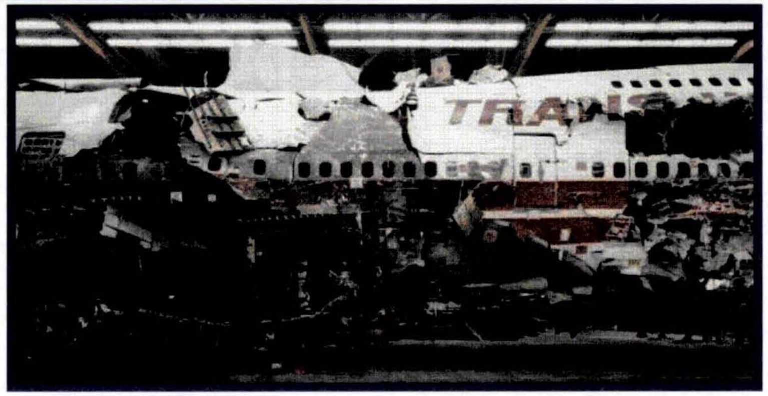
Next Generation Wiring Materials

Wire System Failures

- STS-93 (July 1999)
  - Short circuit in 14 AWG polyimide, Kapton® type insulated wire
- TWA 800 (July 1996)
  - Frayed Kapton® wire in center tank area
- Swiss Air 111 (September 1998)
  - Damaged wire in plane's entertainment system







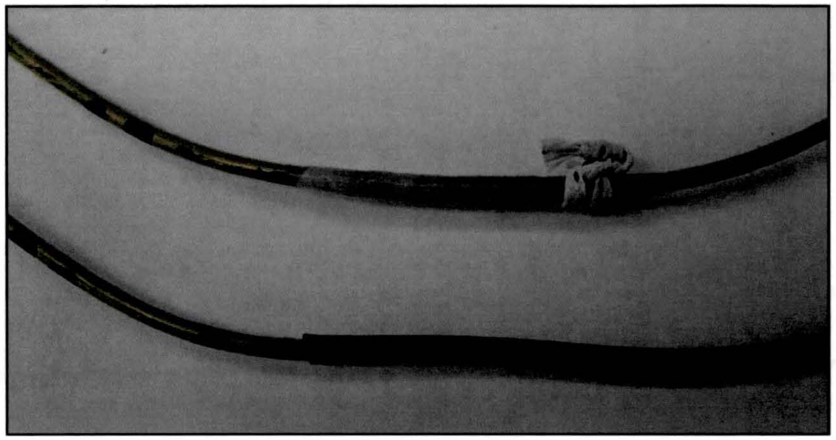
Wiring Technology Solutions

- Manual Repair Technologies for polyimide and fluorinated wires
- In-Situ Damage Detection Systems for Vehicle Health Monitoring
- Self-healing or self-repair insulation

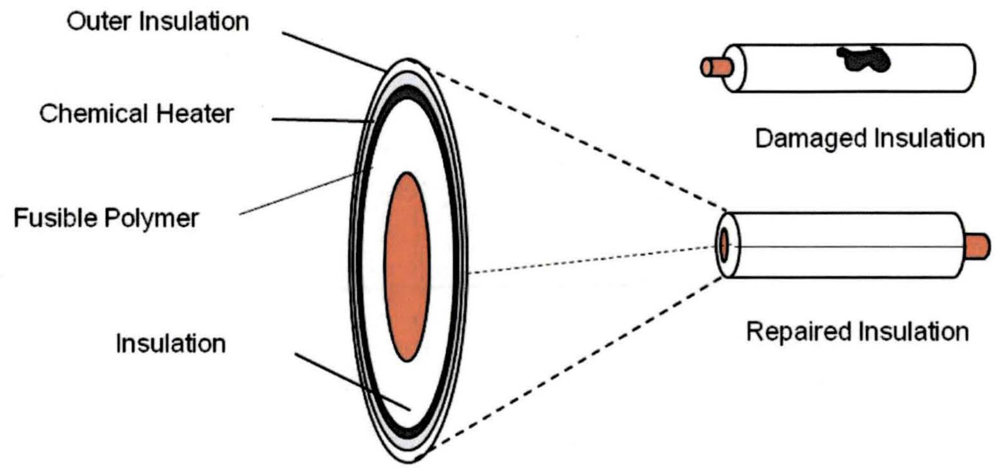
Wire System Materials

Insulation and Repair Materials

Present Wiring Repairs

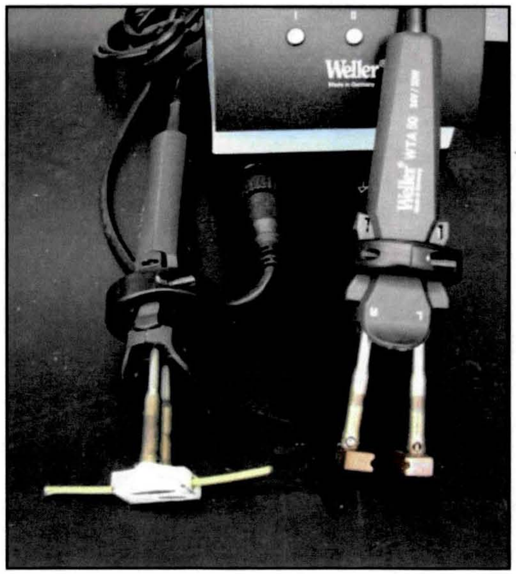


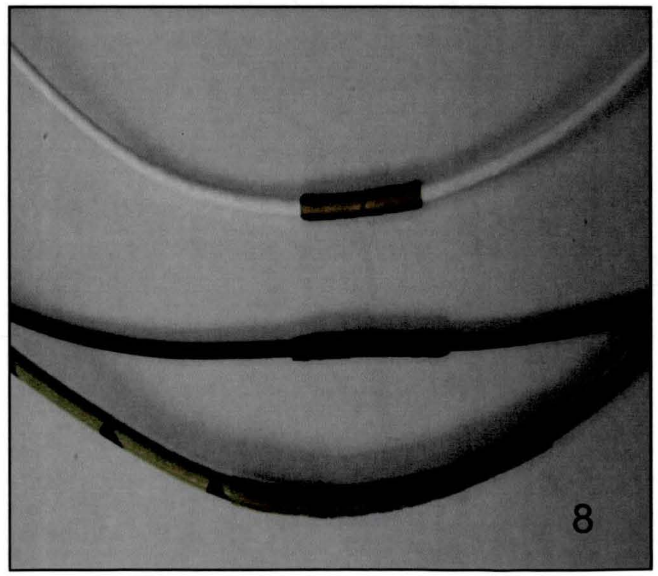
Manual Repair Concept



Casting of Wire Repair Films

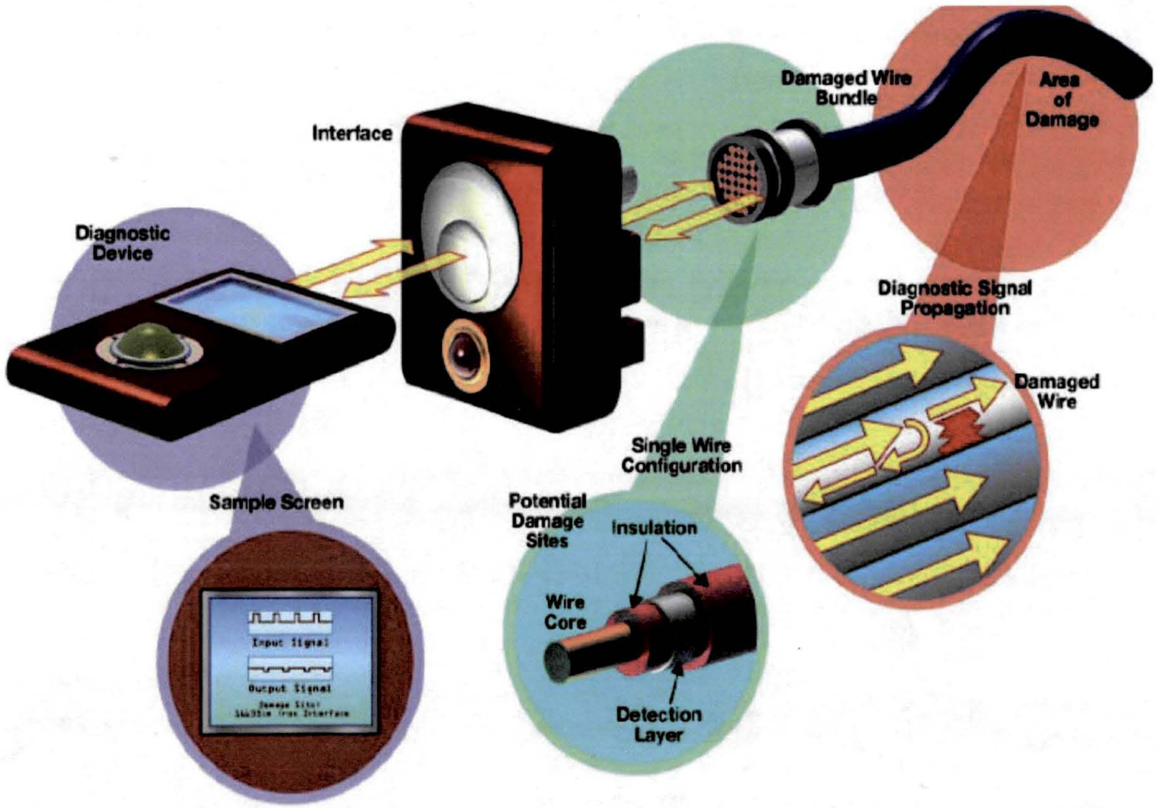
Laboratory Repair Process

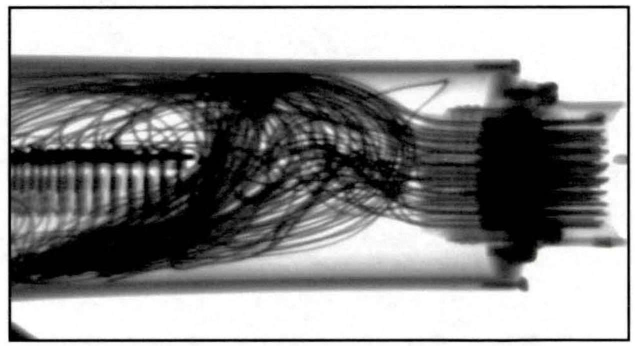




Wire Detection Systems & Integration

- In-situ wire damage detection system
  - Capable of wire damage detection "on-the-fly"
- Smart Connectors
  - Small, lightweight, ultra reliable
- Integrated vehicle health monitoring (IVHM)
  - System-of-systems level, providing high level of reliability





X-ray image of miniaturized TDR connector

Aerogel Technology

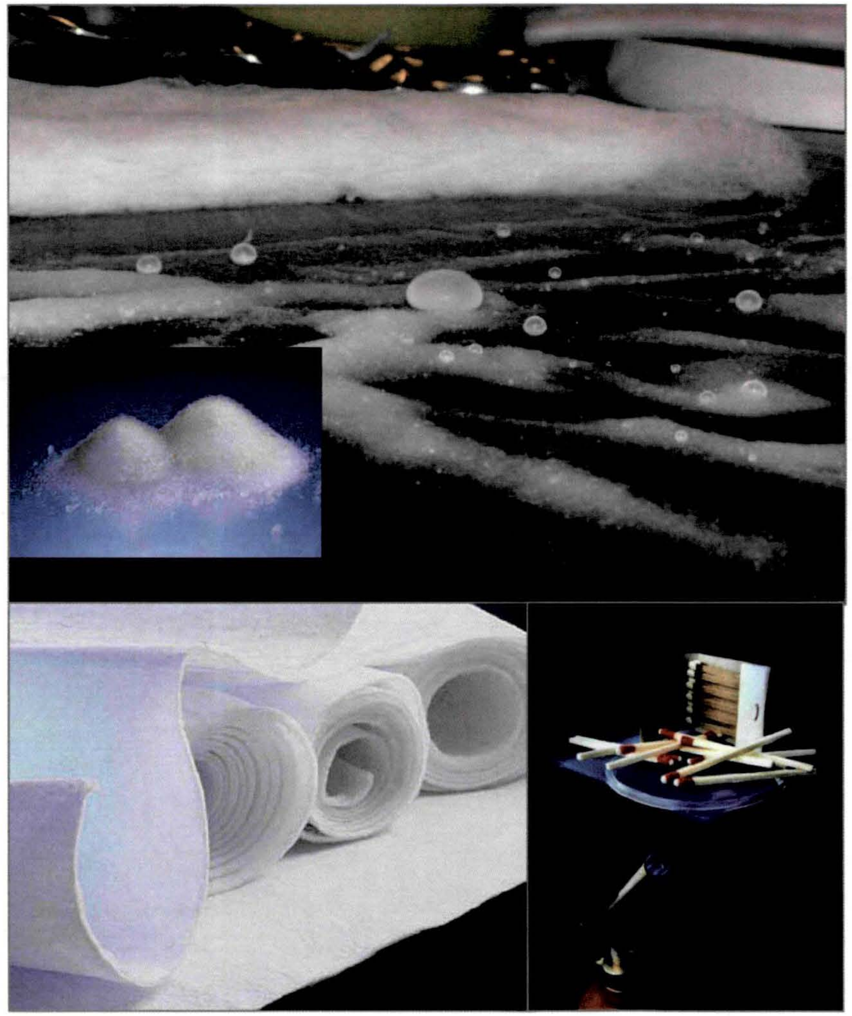
- Aerogel materials are generally silica based, light weight materials, fully breathable, and treated to be super-hydrophobic.

- Aerogel granules are free flowing, fills small cavities, does not compact, no preconditioning required, and can be molded or formed using binders.

- Aerogel granules (Nanogel®) by Cabot Corp.:
  - 90% porous with a mean pore diameter of 20 nm.
  - Bead bulk density ≈ 80 kg/m^3 (5 lbs/ft^3).
  - Individual beads are fragile; but have high elastic compression of over 50% with no damage.
  - k-value ≈ 18 mW/m-K @ 25 C and 760 torr.

- Aerogel Spaceloft® blanket manufactured by Aspen Aerogels:
  - Bulk density 6 to 8 lbs/ft^3.
  - k-value ≈ 12 mW/m-K @ 38 C and 760 torr.

- Aerogel Pyrogel® blanket manufactured by Aspen Aerogels:
  - Flexible aerogel composite blanket designed for high-temperature applications (up to 650°C/1200°F).



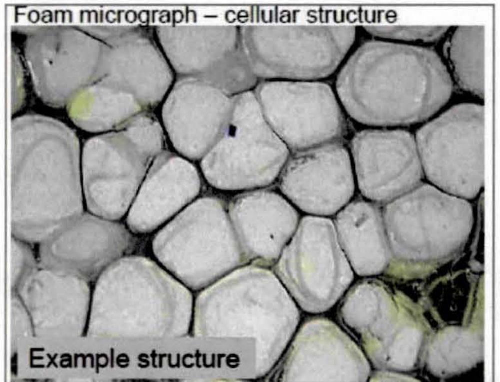
Aerogel Composites

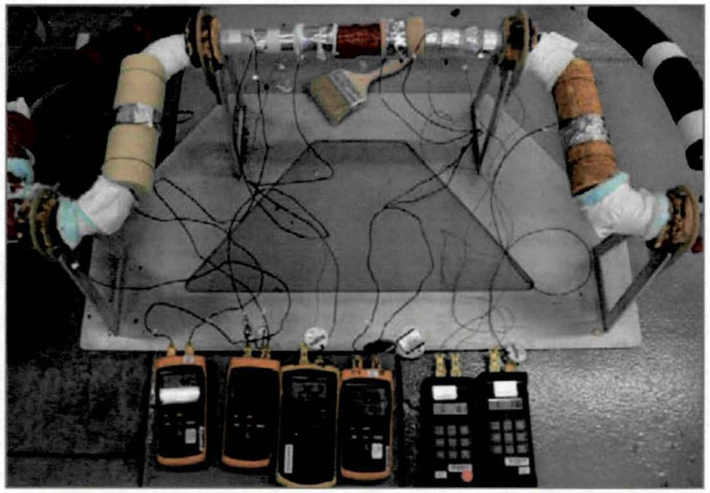
AeroFoam™ = polyimide foam + aerogel

Enhanced thermal and vibration damping performance. Structural integrity to the aerogel and cryogen storage capabilities.

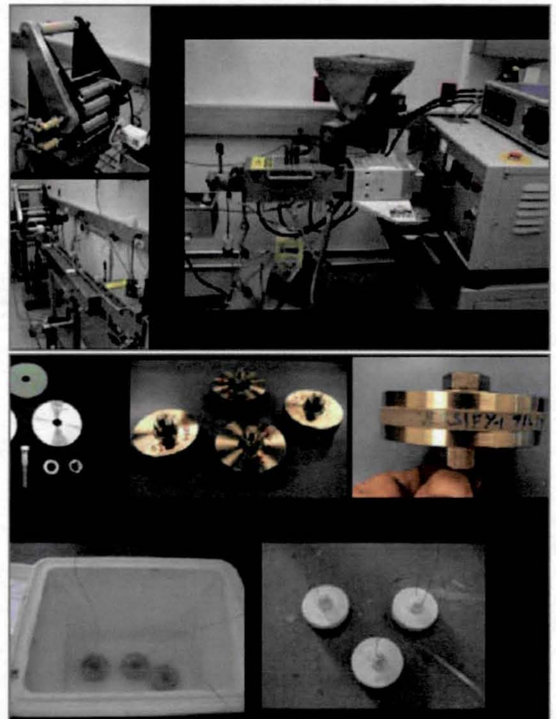
AeroPlastic™ = thermoplastic + aerogel

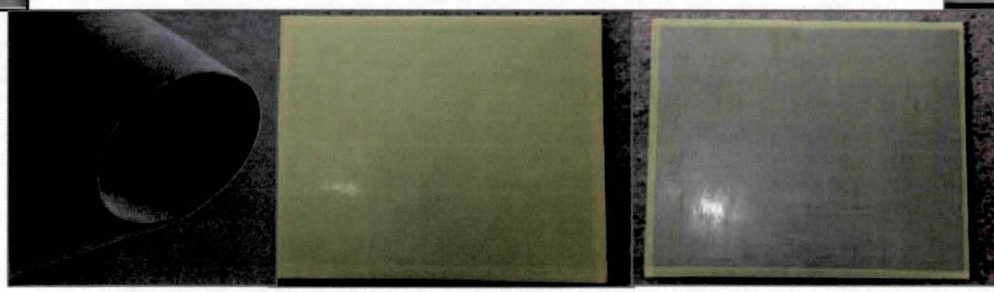
Extruded process, composite reducing heat transfer by 40-60%. Cryogen storage and transfer applications such as piping and seal.





AeroPlastic demo testing on cryo-piping system





Fiber/Textile + aerogel structural composites

Aerogel for Oil Remediation

Lightest solid known (80 kg/m^3) – floats on water

High oil absorbency – 250 $gallons/m^3$

Super-hydrophobic material (repels water)

Environmentally friendly – inert amorphous silica

Stable – long consistent service life, no UV degradation

Commercially manufactured in bulk quantities

Aerogel incorporated into mesh bag, blanket, or filled boon for easy deployment

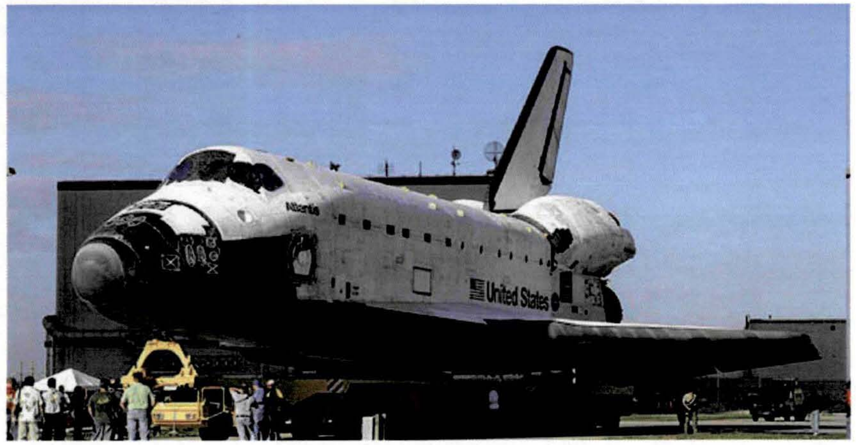
Aerogels for Oil Remediation

KSC's Solution

- Aerogel booms are 20% more effective than commercial PP/PE booms
- Reusable booms – Oil recovered through distillation
- $2800 per m^3 = 250 gallons oil
- Increase effectiveness through catalyst or bacterial infusion
- Cabot Nanogel and EnviroUSA: Commercial small business collaborations through existing SAA with NASA KSC

Domestic inventory	Europe inventory	Sustainable capacity per month
100 m^3	2000 m^3	600 m^3
25,000 gallons equivalency	500,000 gallons equivalency	150,000 gallons equivalency

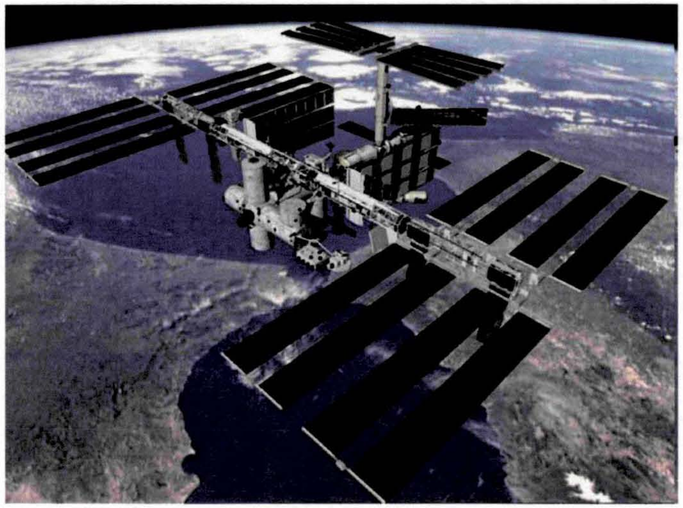
Antimicrobial Countermeasures



Shuttle Potable Water

Water generated on-orbit by fuel cells and stored in four 170-lb Inconel bellows tanks

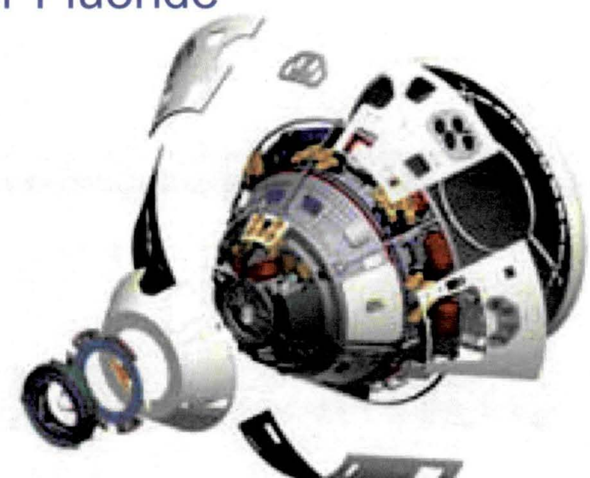
Iodine (3-4 mg/L)



ISS Potable Water

Ground-supplied potable water (Shuttle, Progress, ATV, HTV, or commercial cargo) and reuse water recovered from humidity condensate and/or urine (SRV-K and WRS)

Iodine, Silver Nitrate, Silver Fluoride



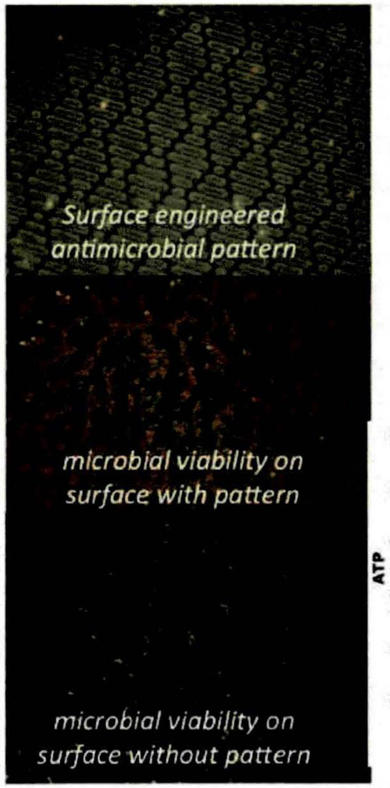
Orion Potable Water

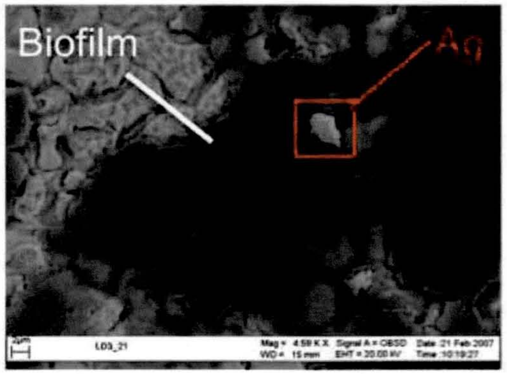
Ground-supplied potable water stored in
Five Inconel 718 Tanks (14.3 gal)
Miles of Titanium water lines
Silver Fluoride (0.4 mg/L)

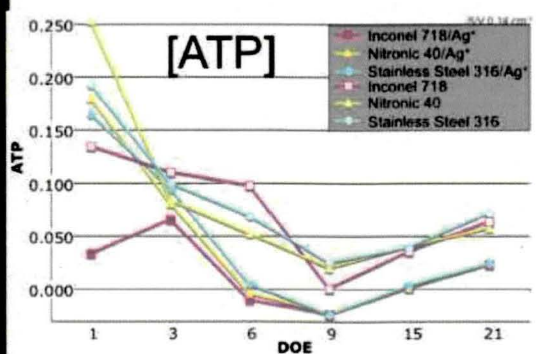
Antimicrobial Countermeasures

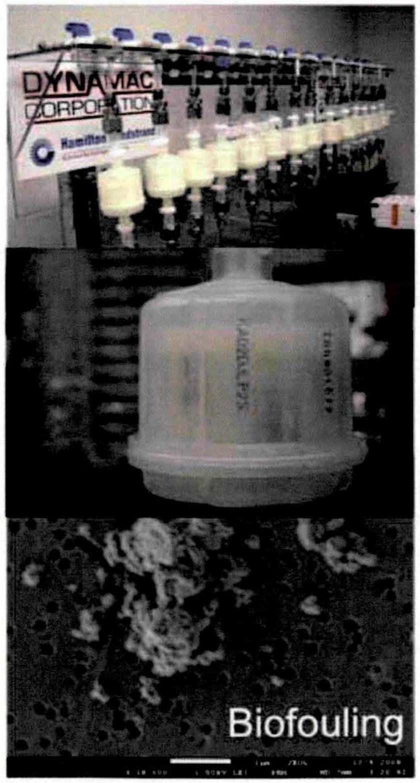
Multiple technologies are required for persistent microbial control in potable water systems

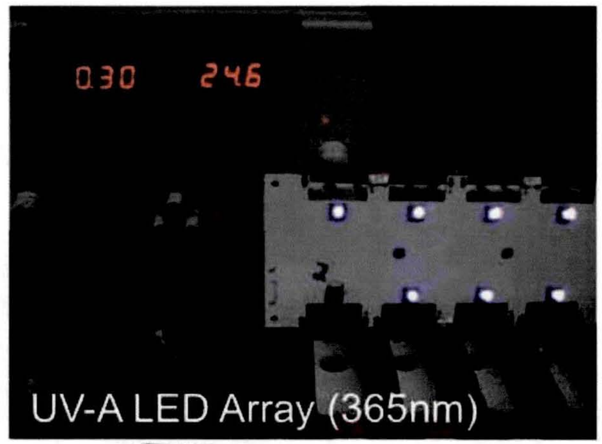
Antimicrobial materials
Biocide delivery systems (ionic silver)
Point-of-use sterilizing-grade filtration
Solid state lighting systems (UV-A and UV-C LEDs)

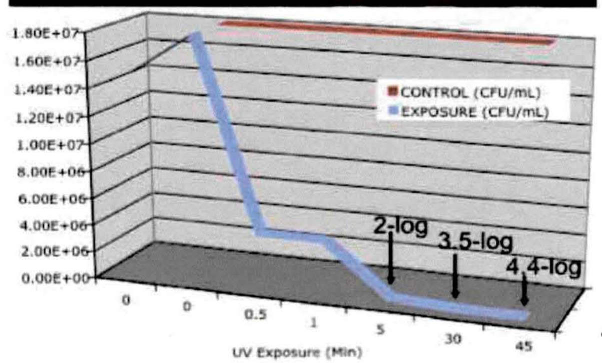








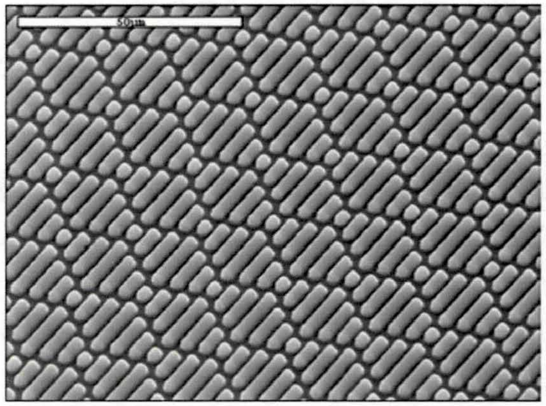


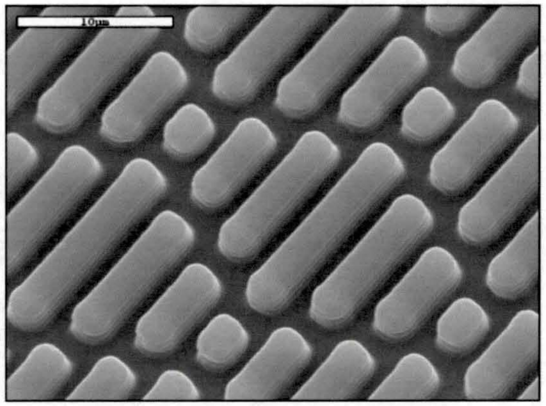


Antimicrobial Polymers

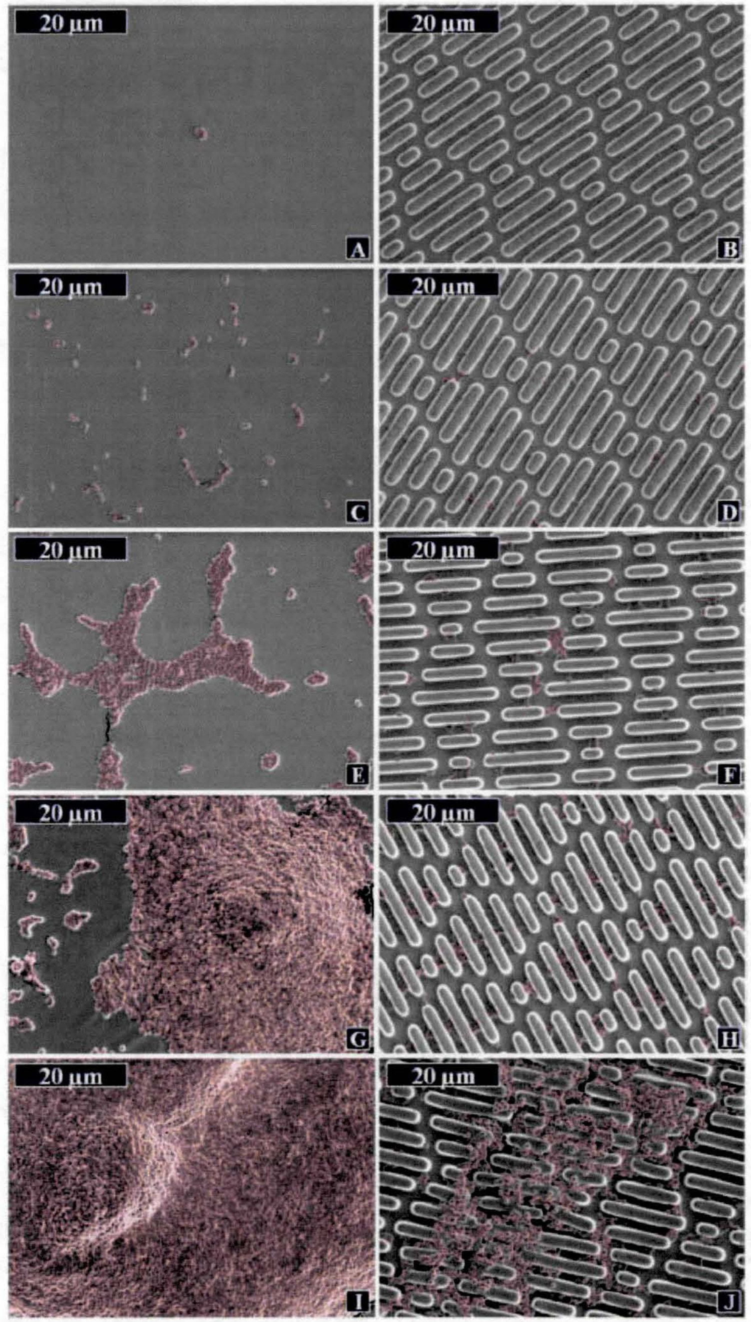
In collaboration with Sharklet Technologies and UF

Surface Morphology and Surface Chemistry





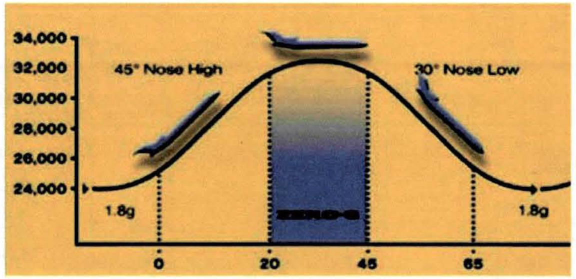
- Efficacy studies after 21 days decreases biofilm formation
- Easy to imprint during manufacture of polymer articles through a coining process
- Can be used in conjunction with antimicrobial polymers

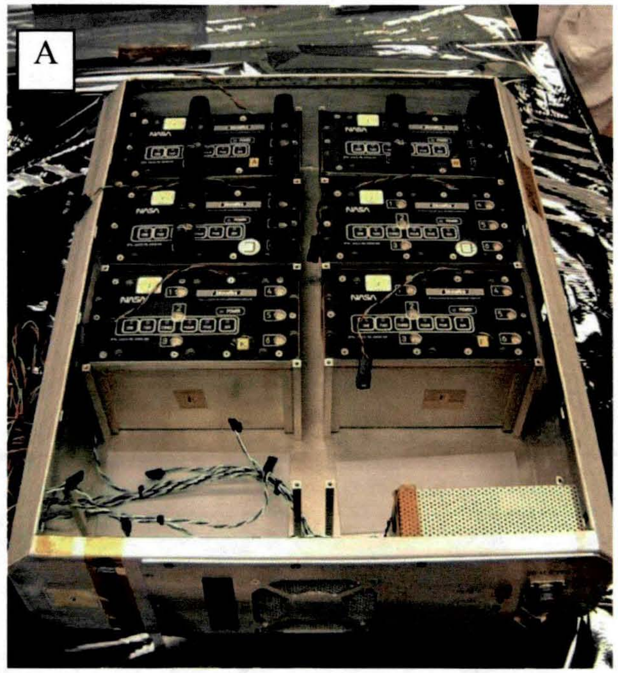


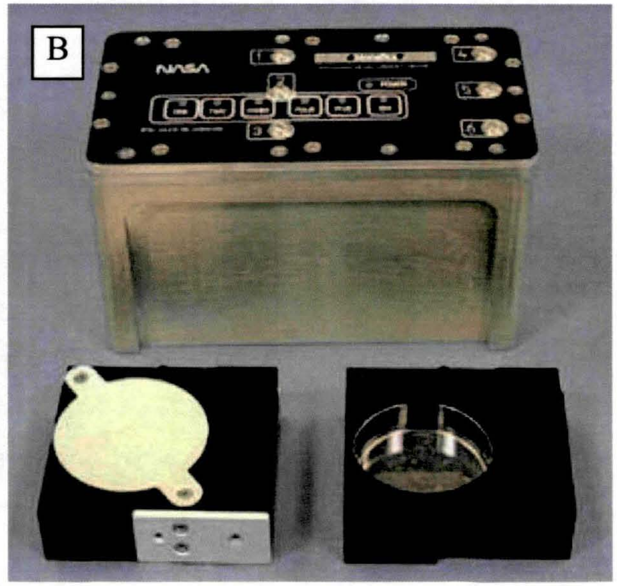
Antimicrobial Materials

Microgravity Flight Experiments

Measure ability of Sharklet® patterned coupons in combination with chemical surface treatments to inhibit biofilm formation by bacteria in reduced gravity







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Chemochromic Hydrogen Sensors

In collaboration with FSEC/UCF

Irreversible Sensor

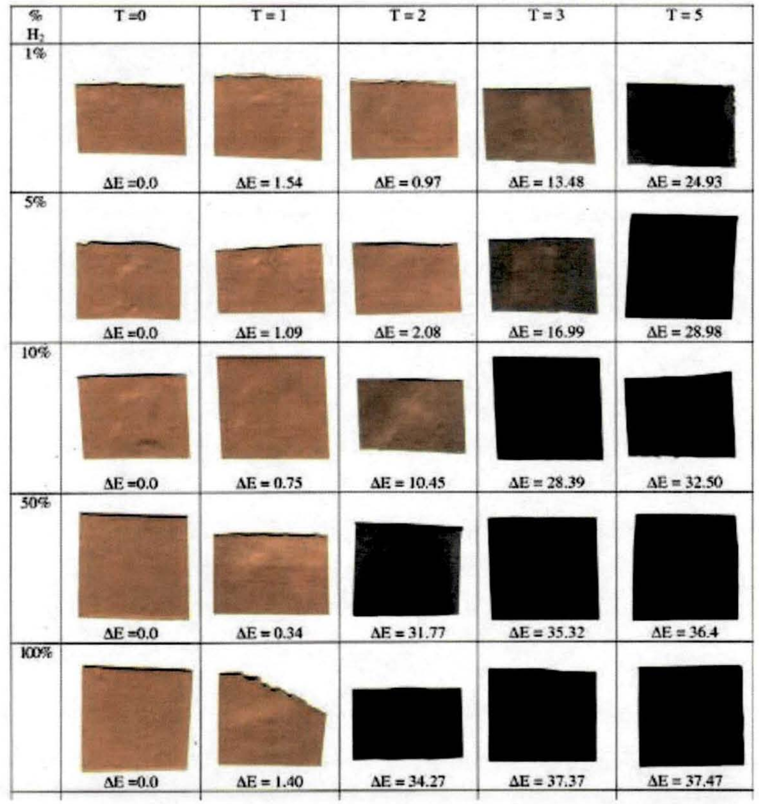
A patent-pending irreversible color changing H_2 gas sensor was developed at KSC in partnership with UCF and ASRC.

Changes color from a light tan to black in the presence of H_2.

Can be manufactured into any polymer part, tape, fiber, or fabric material for unlimited potential uses.

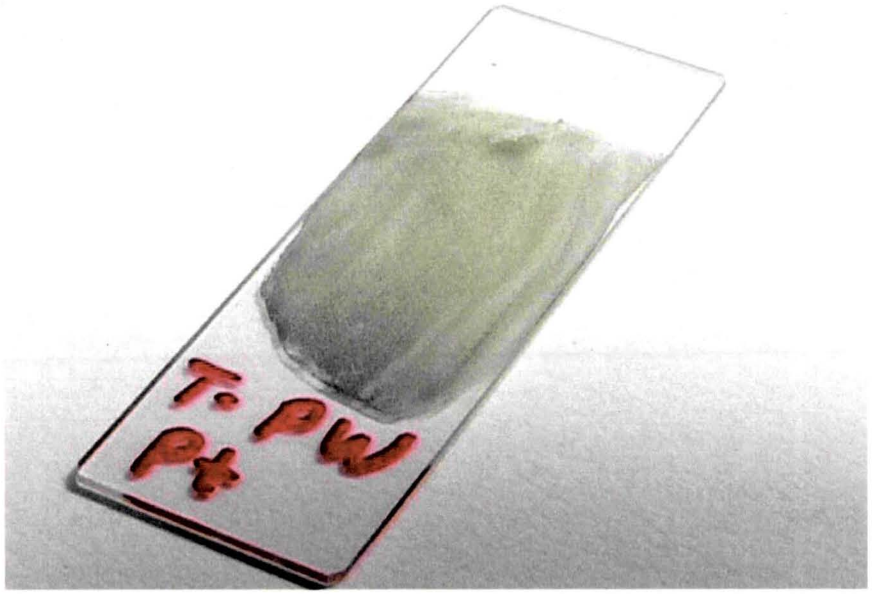
- Paint, Gloves, Coveralls, PPE

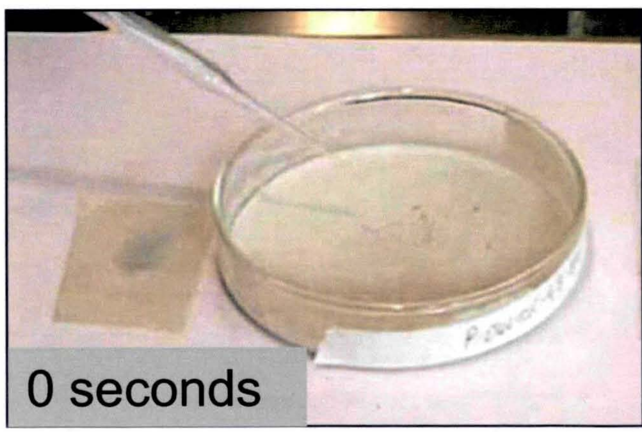
Operates under ambient and cryogenic temperatures.

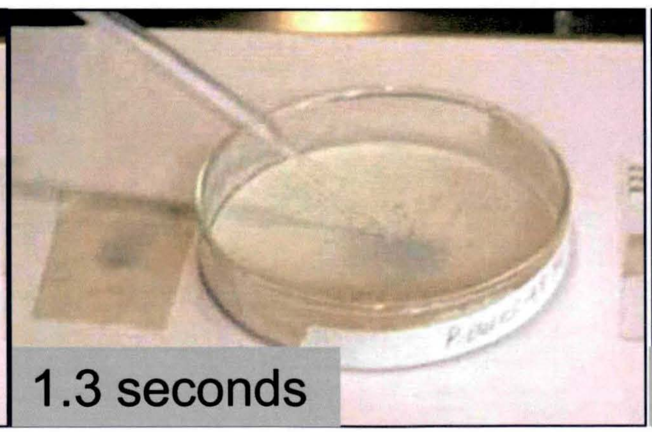


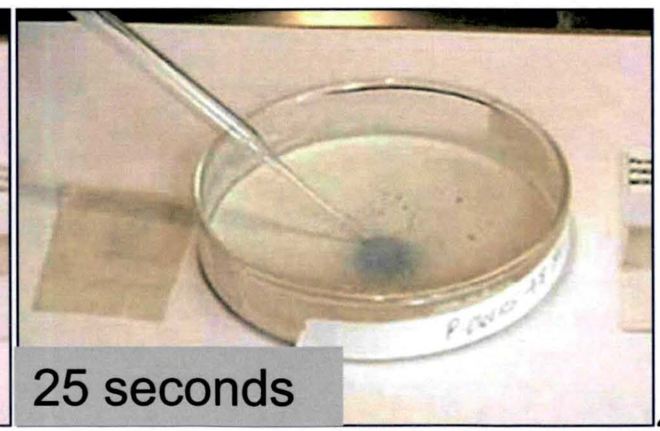
Reversible Hydrogen Sensor

In collaboration with FSEC/UCF









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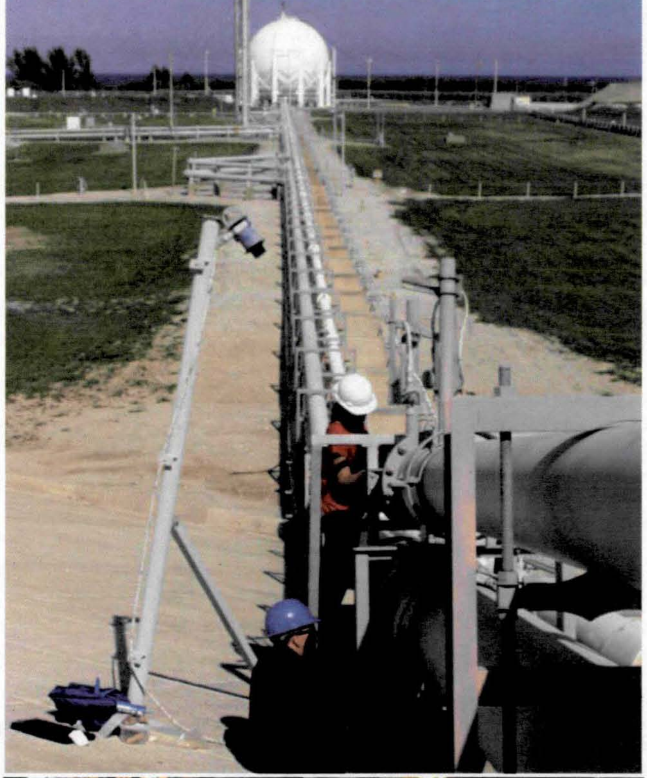
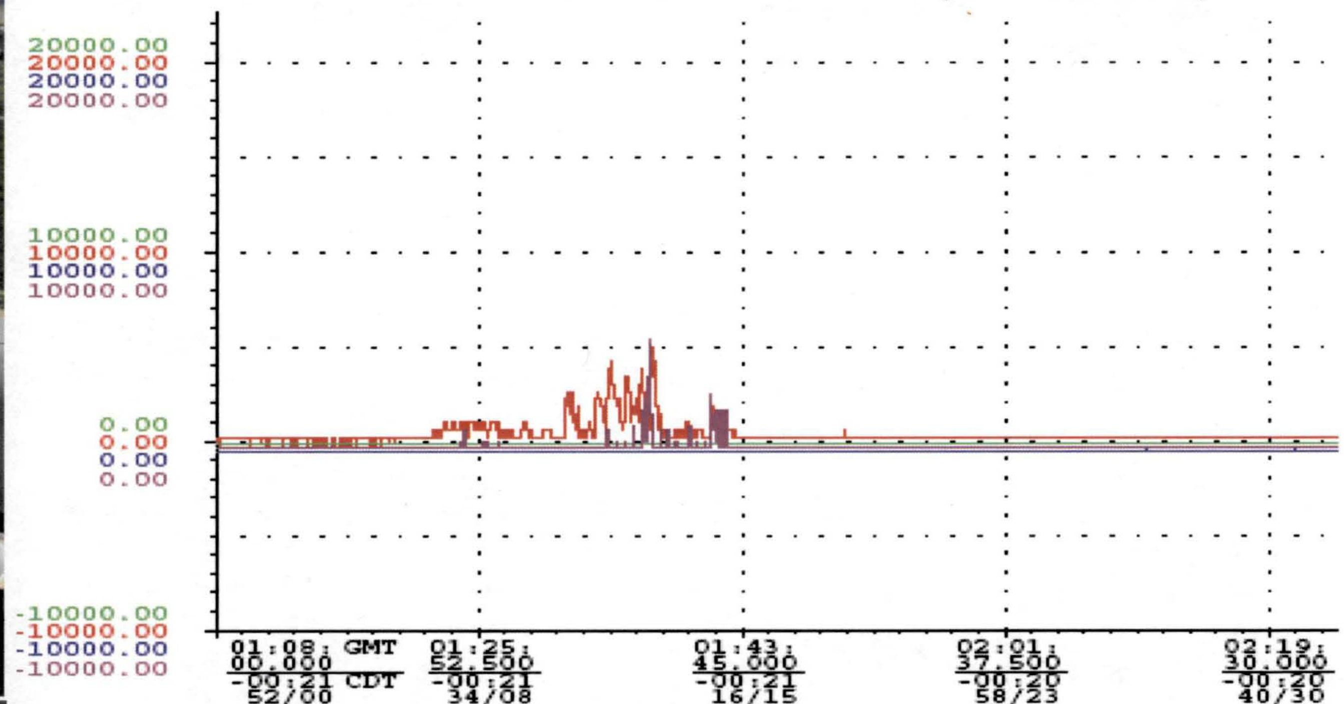
Chemochromic Hydrogen Sensors

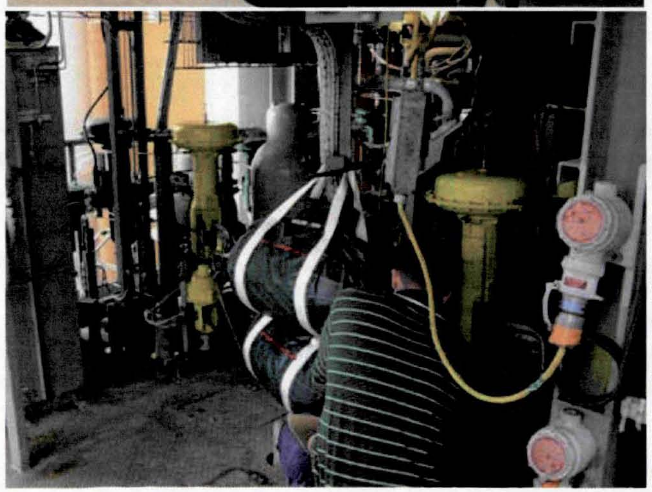
STS-129 Transfer Line



LPA OMBUU Deployment for STS 117, 118, 120, 122, 123

STS-118 LOAD-1 HP SKID (H2CONC-B)





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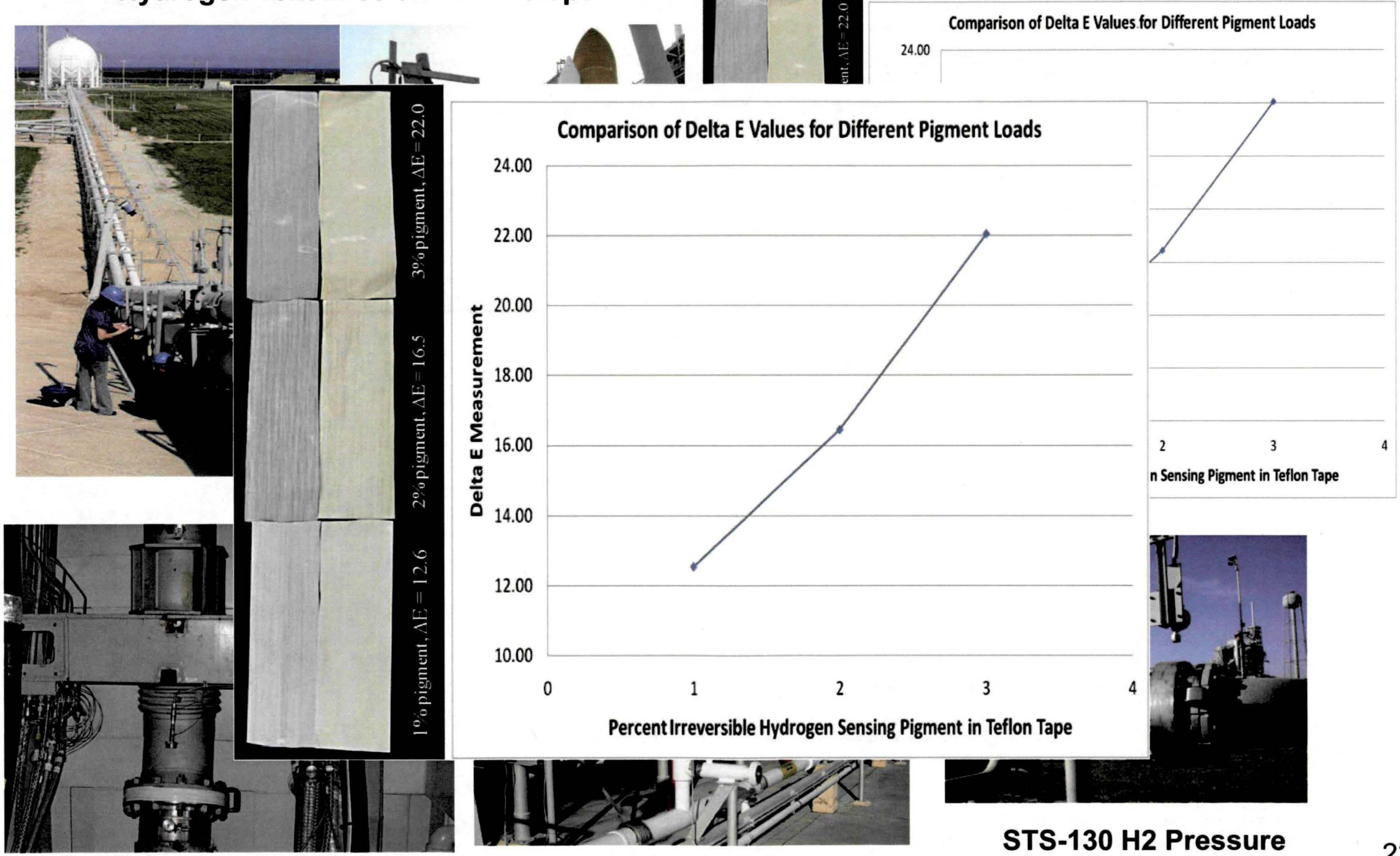
STS-130 and 131 Operations

Hydrogen vent lines on Pad A slope



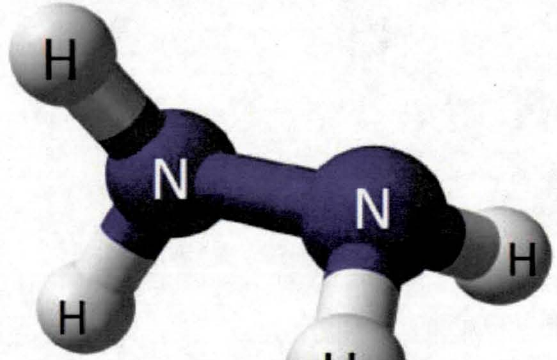
TSM for STS-131

STS-130 H2 Pressure Flange A3362

Hypergolic Fuels

Direct Applications

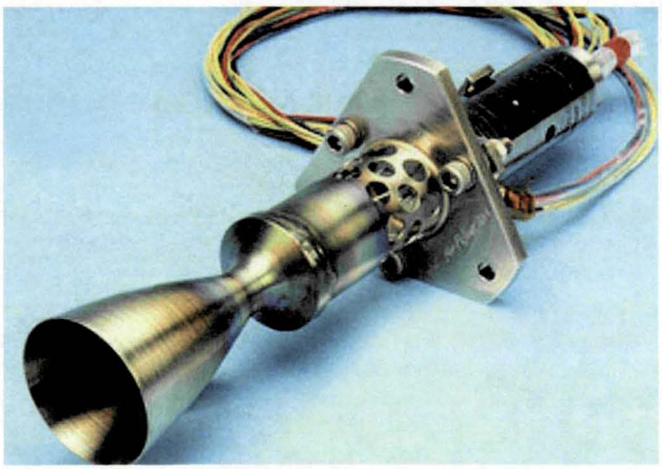
- Boiler Feed Water Treatment
- Monopropellant
- Bipropellant
- Fuel Cells
- Polymers
- Metallurgical

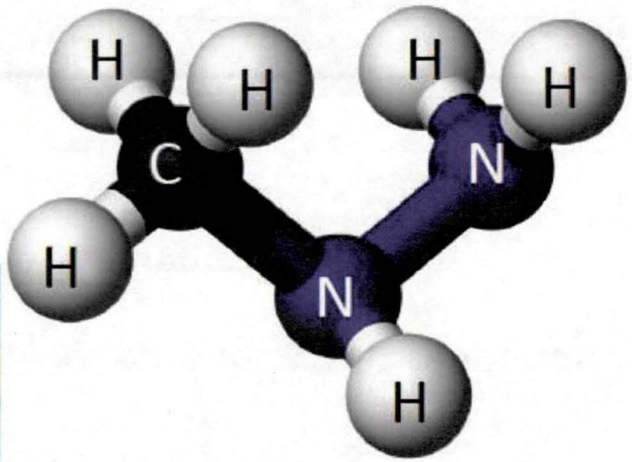


hydrazine

Derivative Applications

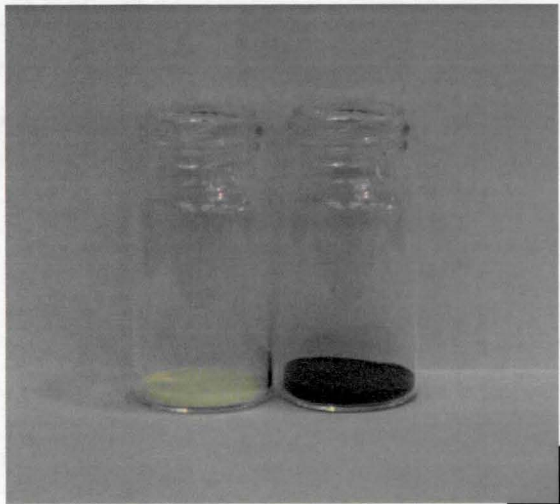
- Solid Propellant
- Gun Propellant
- Explosives
- Pesticides
- Pharmaceutical





monomethylhydrazine

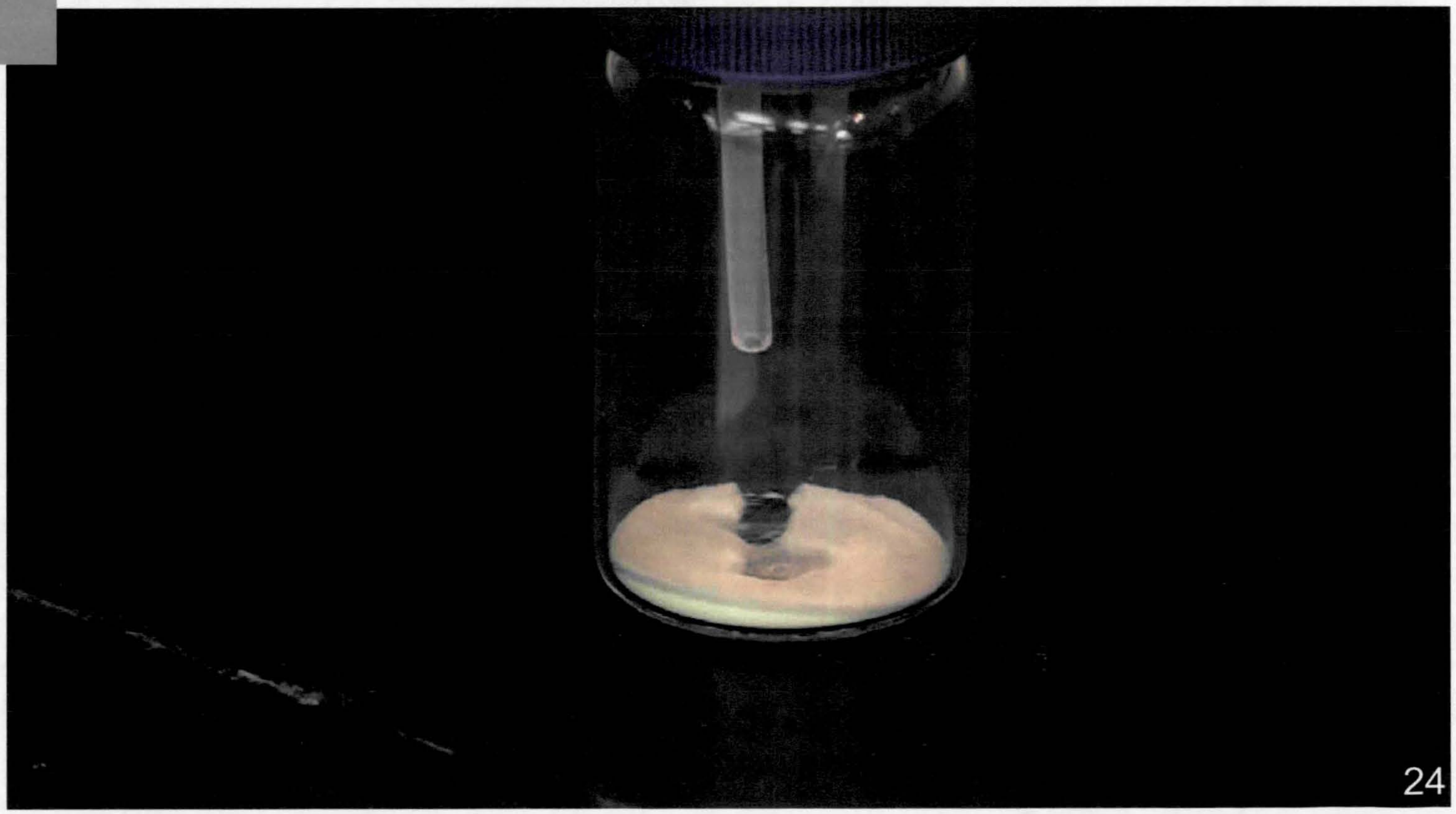
HyperPigment



Pigment shown is 1% by weight $KAuCl_4$ on silica

Concentrations were tested up to 5% to increase color response

Pigment can be incorporated into most polymer materials
- SCAPE suits



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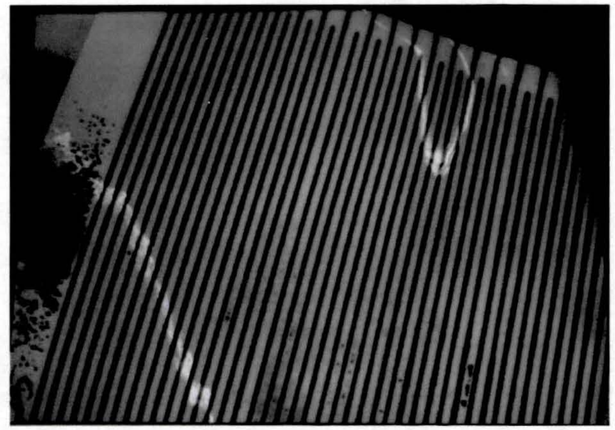
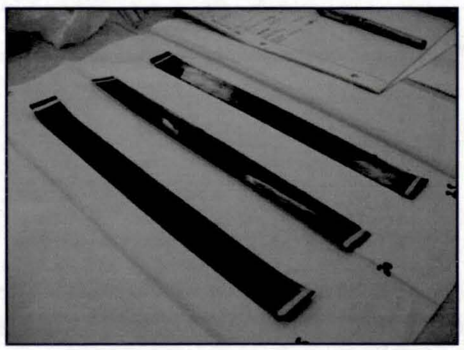
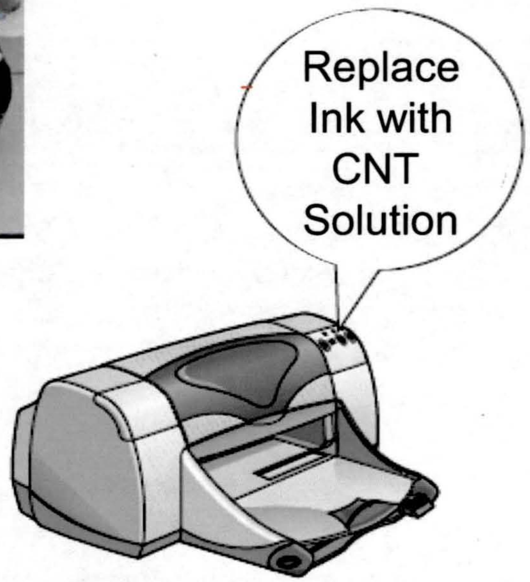
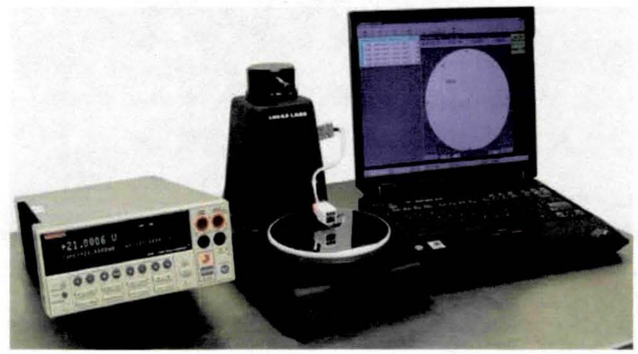
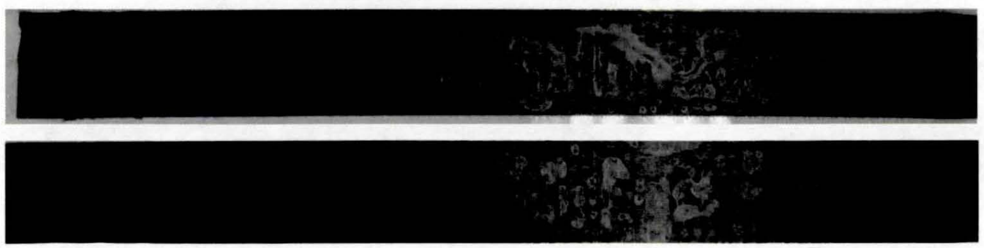
Conductive Inks Formulations for Multiple Applications











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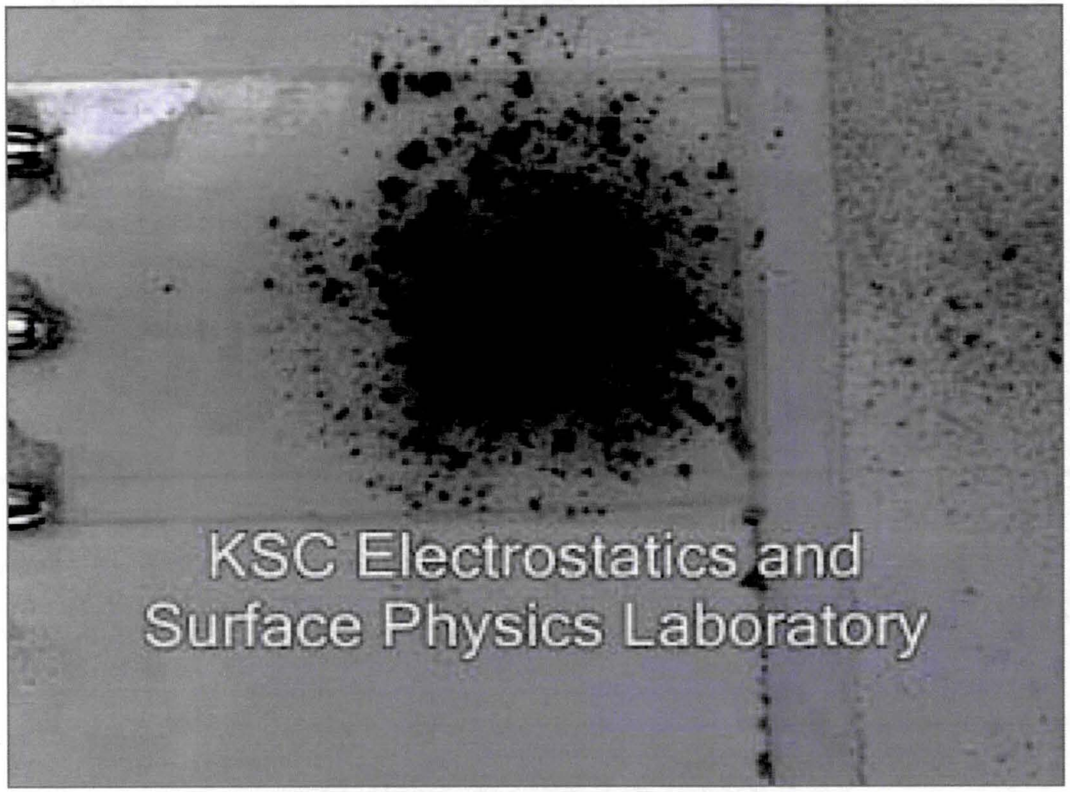
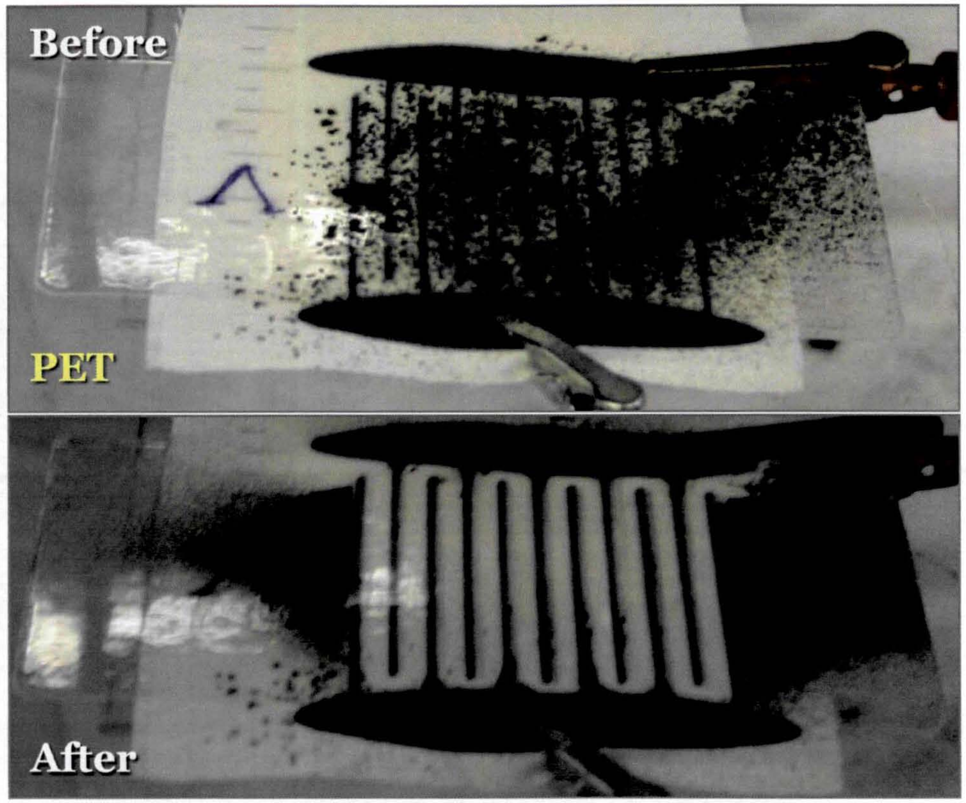
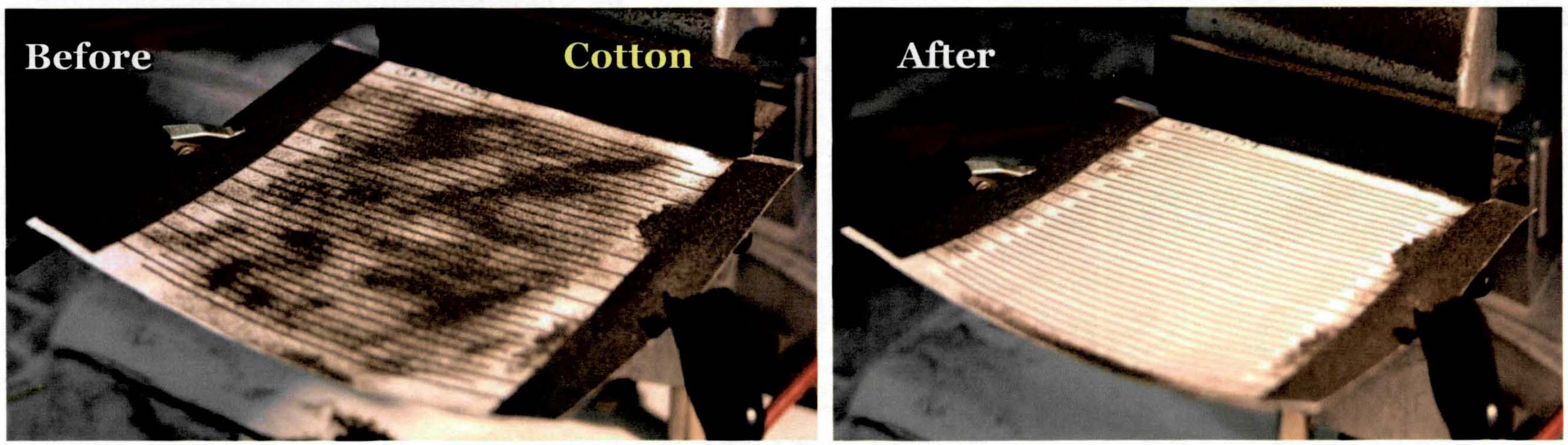
CNT Ink Dust Screens

In collaboration with Electrostatics Laboratory







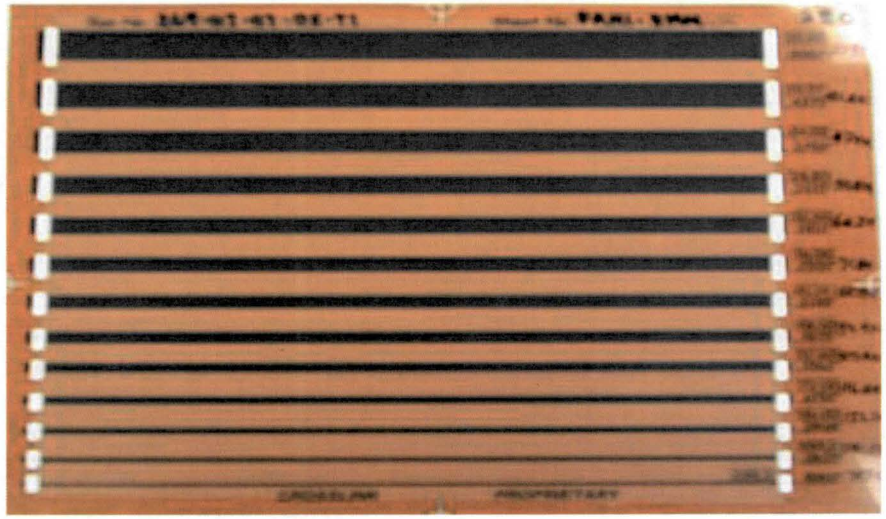
CNT Ink Printed Circuitry

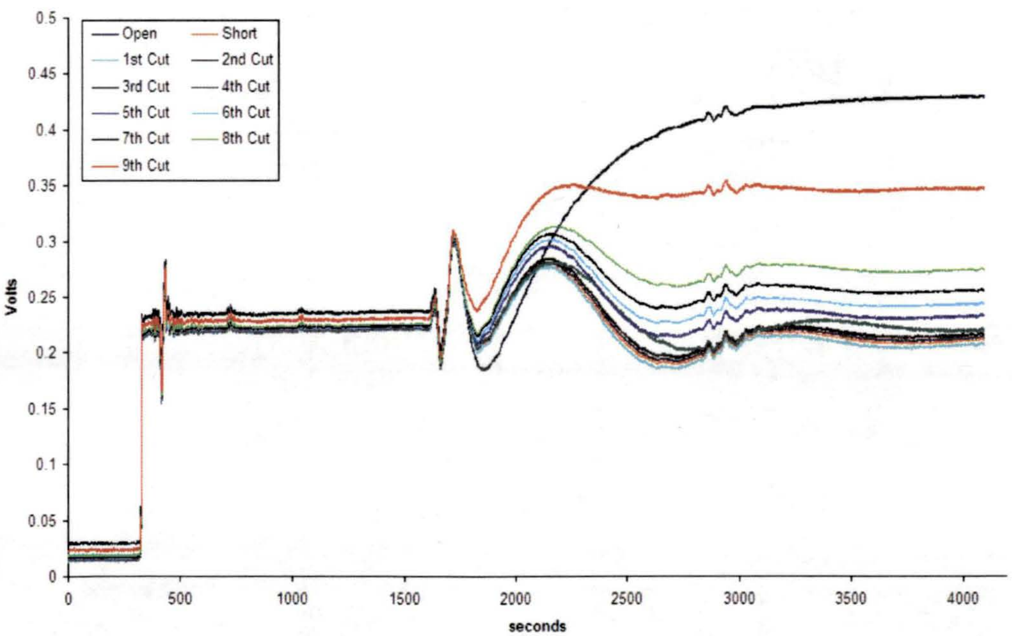
In collaboration with Crosslink

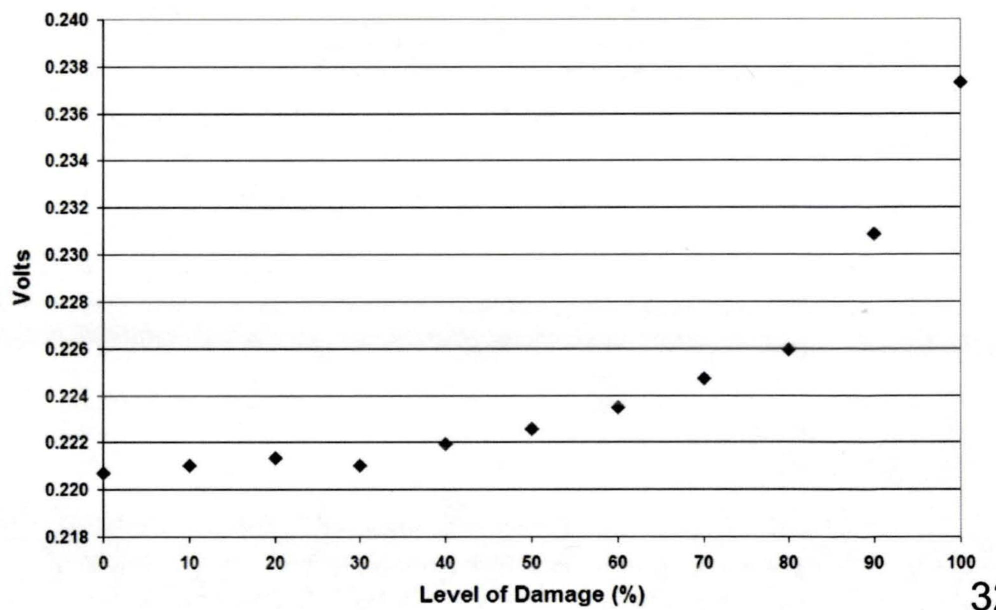
Screen printed polymer-composite material

Line thickness and width increases conductivity

50 Ohm resistance able to measure damage to circuits







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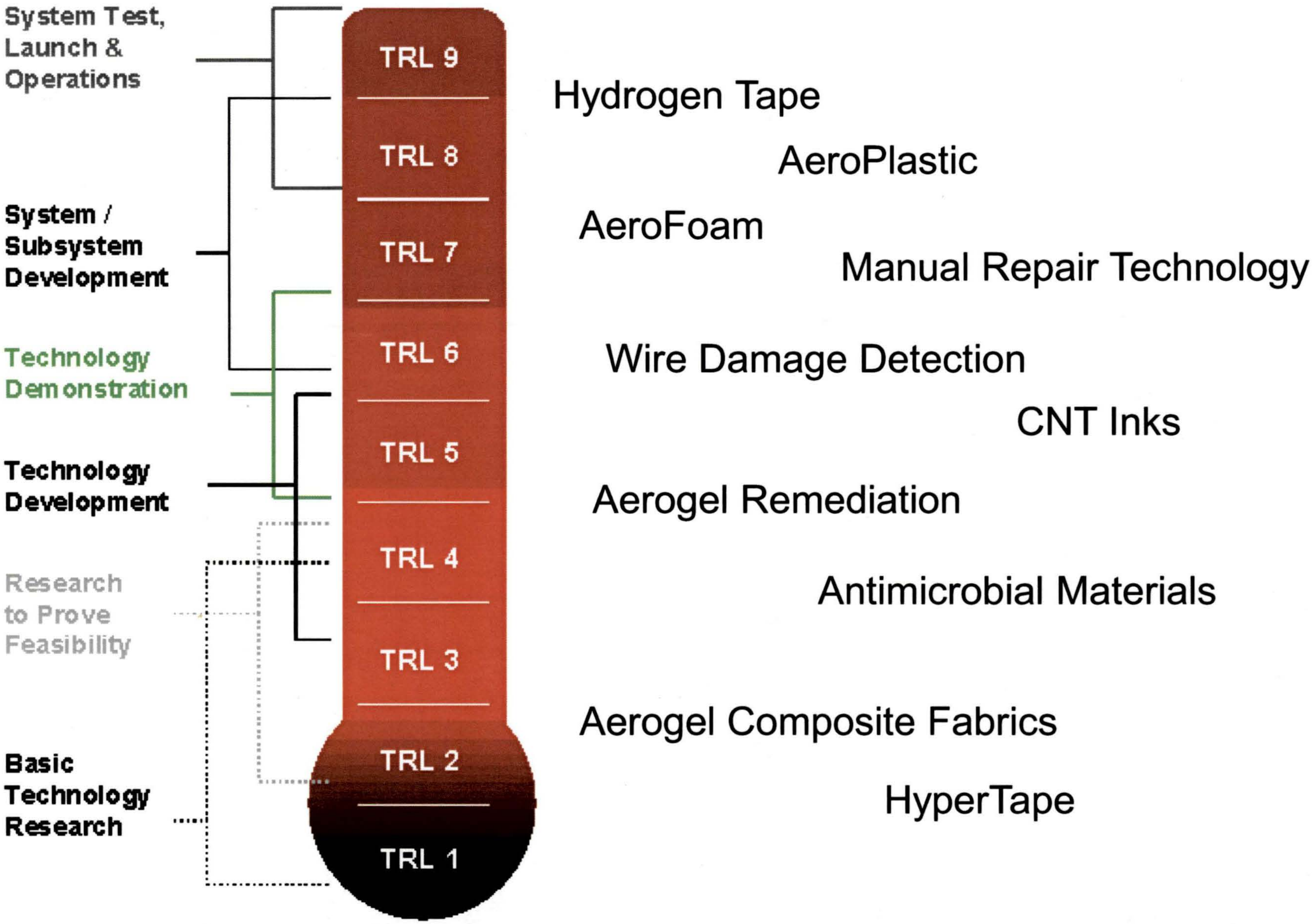
Technology Readiness Levels



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Questions?

Testing and Processing Equipment

- Fire Testing
  - Cone Calorimeter
  - Oxygen Index**
  - UL94 fire test
  - NASA Std 6001 fire test
  - Radiant Panel*
  - NBS Smoke Chamber*
  - Two foot tunnel*
  - Glow wire ignition*
- Cryogenic Materials Testing
  - Cryogenic moisture uptake (CMU)**
  - Brittleness/Impact test **
  - Liquid helium cold finger test**
  - Single Pin-Socket Krytox Contamination Electrical Characterization under Cryogenic Conditions**
- Specialty Test Equipment

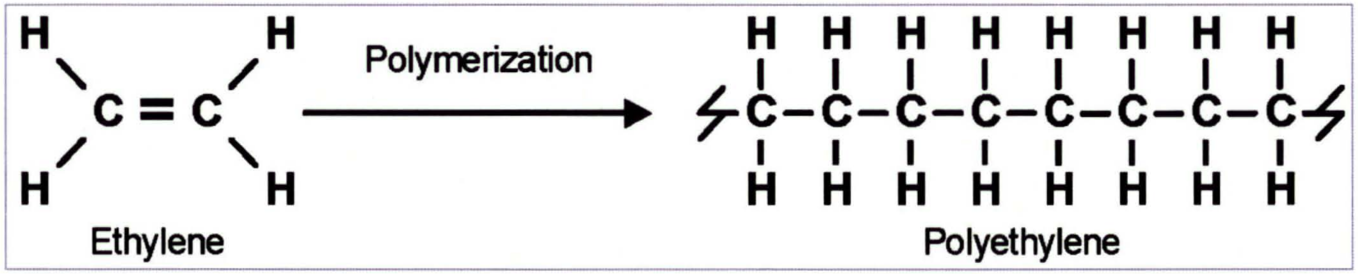
*in collaboration with Cryogenics Test Laboratory
**in collaboration with Florida Tech

- Cellular Solid Analysis
  - Pycnometer (closed/open cell)**
  - Surface area measurement**
- Thermal Analysis
  - Thermogravimetric analysis (TGA)
  - Differential Scanning Calorimetry (DSC)
  - Dynamic Mechanical Analysis (DMA)
- Physical Testing
  - Tensile Test
  - Compressive Test
  - Pull/Peel Test
- Electrical Testing
  - 4-point probe
  - Surface /Volume resistance
- Polymer Processing capabilities
  - Extrusion
  - Injection molder
  - Fiber spinning equipment
  - Melt, ball, and high intensity mixers

What Are Polymers?

POLY MERS** are made of many **MONO MERs

↓ *Many* ↓ *Units* ↓ *One* ↓ *Unit*



Polymers: Derived from the Greek words ***poly*** and ***mers*** meaning **"*many parts*"**.

- Large molecules composed of repeated chemical units
- When you think of *POLYMER* most automatically think → *PLASTIC*. *However*, polymers are a wide range of *natural* and *synthetic* materials with a wide variety of properties.
- **Molecular weight** of the resulting synthesized polymer can range from the very lightest of molecules up to huge gels.