Space Programs & Initiatives Partnership Opportunities

Electron Beam Curing of Composites Workshop

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Agenda

- Structural Composite Materials and Process Programs at AFRL/MLBC
- Non-Autoclave Processing
- Related and Future Technologies and Research
- Summary and Points of Contact

Nonmetallic Structural Materials Team

- **Mission: To Plan and Execute the USAF Program for Structural Nonmetallic Materials and Processes in the Areas of Basic Research, Exploratory Development and Advanced Development**
- **Technology Teams for Integrated Development**
  - **Composite Materials**
    - **Resin: Epoxy, Polyimides,Carbon-Carbon, etc**
    - **Innovative Reinforcements, Sandwich, etc**
  - **Processing Science**
  - **Mechanics**
- **Coordinated Contractual, In-House Program**
- **Customers & Paths to Transition: SPOs, Industry, AFRL Manufacturing and Structures**

Core Technology Area: Organic Composites

CTAL
Scott Theibert

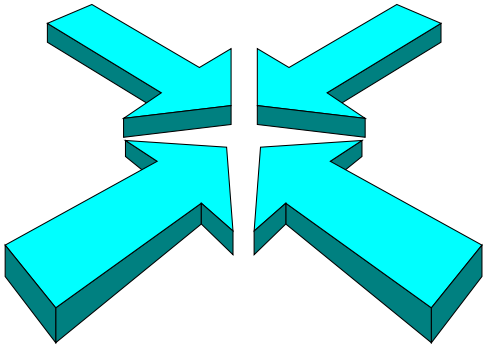
RDL
Dave Curliss

TDL
Tia Benson Tolle

Long Term Durability in Extreme Environments

Innovative Processes

Novel Material Forms



M&P for Space Platforms
Kris Kearns

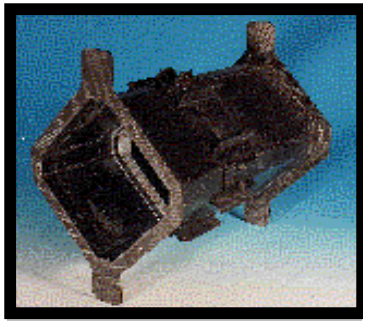
M&P for Air Platforms
John Russell

Processing and Evaluation for Expanding Capabilities
Steve Donaldson

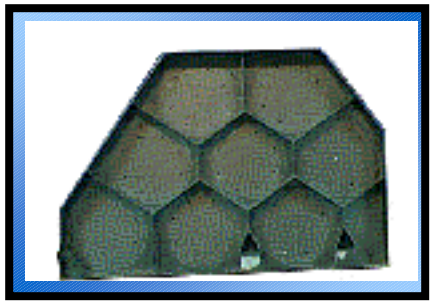
How To Work With Us

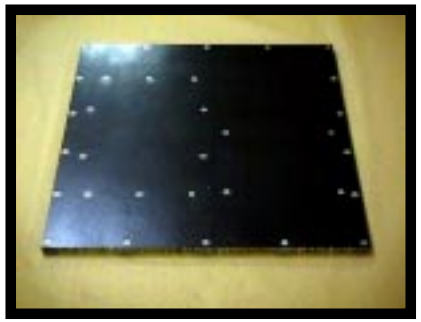
- Contractual Efforts
  - Basic through Advanced Research
  - SBIRs, STTRs, Contracts
  - Other Means - Open to Innovation
- Cooperative Efforts (Government, Industry, Academia)
  - Collaborative Research
  - Individual and Group Level
- In-House Research
  - Independent Research
  - Augment Contracts (Add Value, Testing, etc)
  - Government Engineers & Scientists
  - On-Site Professionals, Technicians

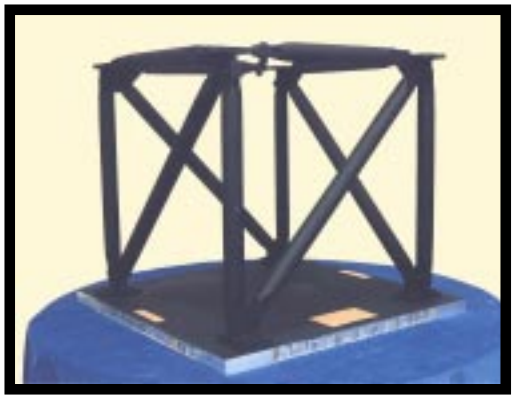
Past Efforts & Focus in Composites for Space: Reduced Weight, Improved Thermal Performance



- **SDIO/BMDO Support**
  - Thermoplastic Materials
  - Cyanate Ester Materials
- **High Modulus Prepreg for Spacecraft Applications**
  - Data
  - Residual Stresses due to Thermal Cycling
- **Thermal-Structural Materials**
- **Thermal Management**
  - C-C Radiators
  - Doublers







Future: Larger Investment in Space

- **Air Force is Moving More towards Space**
- **More Investment in Composites for Space**
  - **Satellites**
  - **Launch**
  - **Other**
- ***Non-Autoclave Processing for Military Reusable Launch Vehicles (SOV)***
  - **Integrated In-house, Contractual, SBIR Programs**
  - **Coordination with SOV, NASA**
- **Thermal Management**
- **Multifunctional Materials**

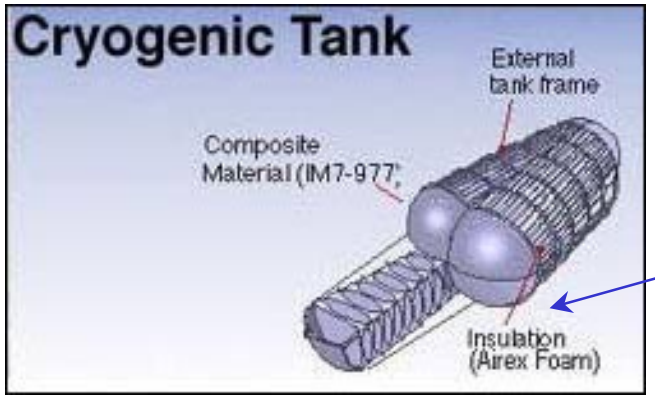
Non-Autoclave Processing Enables Large Composite Structures

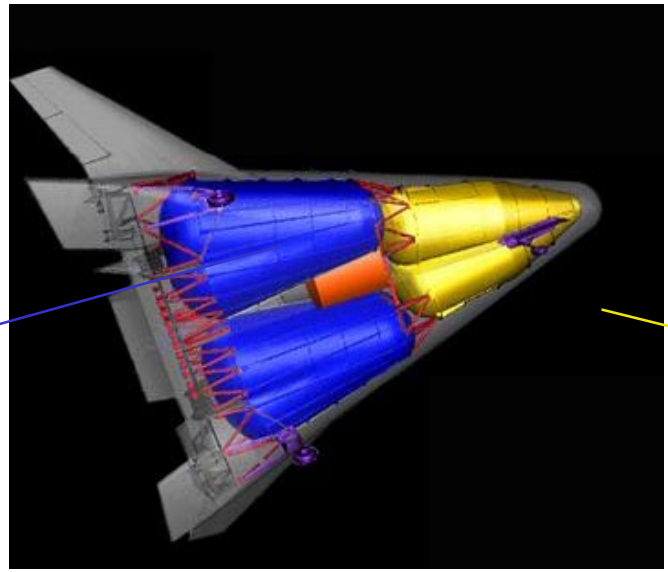
- **Enabling Technology for Large Composite Structures**
  - **Autoclave Size Limitations**
  - **Integrated Structures vs Bonded/Joined/Fastened**
- **Improves Affordability**
  - **High Non-Recurring Tooling Costs with Autoclave Processes**
  - **Large, Integrated Structures Reduces Assembly**
- **Reduces Cycle Times**
  - **Tooling Lead Times**
  - **Design Iterations, Lead Time**

Non-Autoclave Processing Enables Other Benefits

- Potential Performance Enhancements for Space Platforms
  - Dimensional Control
  - Integrated Elements
  - Unique Designs
- Affordable Performance for Air Platforms
- Non-Autoclave Materials and Processing Interests
  - Past Programs
  - Future Developments

‘98 Cryogenic Tank Challenges: Size



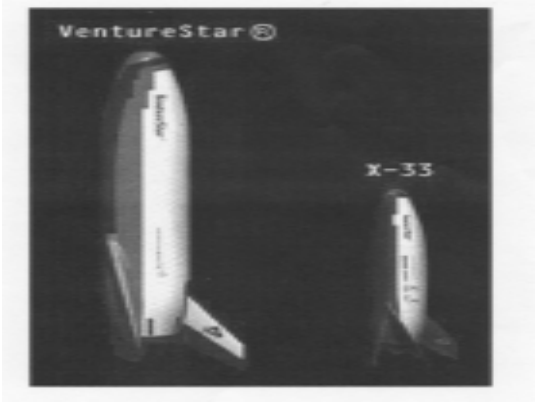


- Liquid Hydrogen Tank
- IM7/977 (Graphite/Epoxy)
- 30 Feet Long Overall…Barely Fits Into Autoclave

LOCKHEED MARTIN’S X-33*

- LOX Tank
- Aluminum
- 12 ft X 20 ft X 27 ft
- 5,500 Pounds

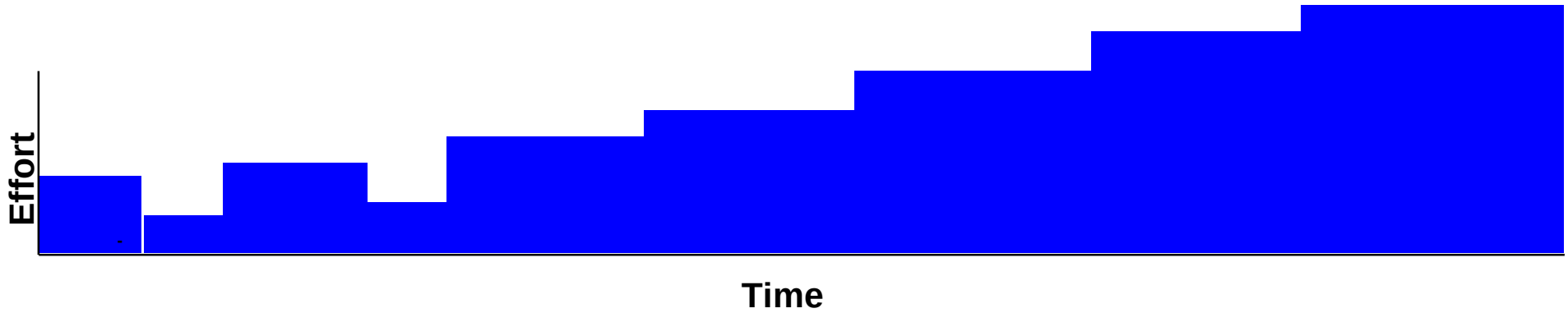
SOV -- About 1/2 to 3/4 the size of VentureStar: VS is
- about 2x length of X-33
- about 9 x weight of X-33



*www.venturestar.com/pages/x33dem/internal.index.html

EVOLUTION OF PMC CRYOTANK TECHNOLOGY

1970 - 1990 Space Shuttle & Other Hypersonic Programs	1986 - 1994 NASP	1990 - 1999 DC-XA, X-33, X-34	1997 - Bantam- X	1998 - 2000 RLV	1999 - 2010 Future X	1998 - ~ 2015 SOV
	• Material Screening LH2 • IM7/977-2 • Coupon cycling/fatigue • Fabbed Small Bottles; LH2 Testing • LOX testing	• Demonstrators • IM7/977-2 LH2 • Metal LOX • Oven Epoxies Structures • Alternate Materials •Composite fuel lines, valves • Flight tests	• Tech Dev't and Flight Demo • Reusable Tech • Low Cost Earth-to-Orbit	• Reusable • Commercial • Non-autoclave • PMC LH2 Tank • PMC LOX Tank • Shorter Term	• Tech Dev't • Cross-Cutting Core Technologies • Pathfinder Flight Experiment • Pathfinder X-Plane	• Reusable • Military • Non-autoclave • PMC LH2 Tank • PMC LOX Tank • Long term



(AF) SOV? (NASA) RLV?

- Both are Reusable Launch Vehicles
  - Many Similarities
  - Many Similar Requirements
- RLV Technology Base can be Broader and Encompass Future Developments
- SOV will build on RLV technology
  - Has Larger Window for Technology Development
  - Some Unique Requirements

Unique Military Requirement Drive Materials and Processing Activities

- Short Turn-around Times -- Thermal Shock
- High Sortie Rates - 1,000 Cycles
- Higher Temperatures
  - Tank: 250F (and cryo)
  - Structure: Higher is Better
- Large Composite Cryo Tanks
  - LH2 (-423 F TO +250 F)
  - LOX (-297 F TO +250 F)
- Alert Times Result in Long Term Exposure Effects
- High G Maneuvers
- Loading into the Tank Structure

Cryo Compatible Materials

LOX Compatible Materials

Long Term Performance, Durability

Non-Autoclave Processes

Good Mechanical Property Performance

Higher Use Temperature Resins

CTE Issues

PMC Critical Issues/Questions for Cryotank

- **Material Behavior at Environmental Extremes?**
  - **LOX**
  - **LH2**
  - **Limited Testing Performed to Date on Limited Resins**
- **How will the Material Behave over Time?**
  - **Durability/Life Time Prediction**
  - **Property Prediction/Life Time Modeling of Material Behavior with Exposure to Time and Environment (LOX)**
  - **Thermal-Structural Cycling**
- **Can It be Processed for Large Structures ?**
  - ***Non-Autoclave Processable Resins, Properties***
  - **Process Control**

Non-Autoclave Technology Needs

- **Material Properties Improvements**
  - **Current Properties Reduced Compared to Autoclave Processed Materials**
  - **Interface Questions**
  - **Key Property Improvements for SOV Applications**
    - **Interlaminar Shear Strength, Toughness, Tensile Strength**
    - **Higher Temperature Performance**
    - **Low Temperature (Cryo) Performance**
  - **Material Performance Questions**
    - **LOX, LH_2 Exposure, Permeability**
    - **Long Term Thermal and Mechanical Stability**
- **Material Data Generation**
- **Process Scale-up Issues**

Current Related Areas of Research

- **Non-Autoclave Processing**
  - **FY99 Contractual Program (On Street)**
  - **E-Beam Processing SBIRs**
  - **NASA Coordination: E-beam**
  - **ORNL CRADA: E-Beam Interface Issues**
  - **In-House**
- Nanocomposites
  - Barrier Properties for Cryo Tanks
  - Enhanced Ablation Resistance
- Mechanics/Residual Stress/Dimensional Control
- Liquid Crystalline Polymer Micro-Composites for Low-Pressure LOX Feedlines (F&S, Inc. SBIR)
- 2-Photon Cure Mechanisms

Future Technologies

- Non-Autoclave Processable Materials for Large Composite Structures (PRDA)
- Novel Materials for Cryo Tank Applications (00 SBIR)
- Non-Autoclave Fundamentals: Interface, etc.
- Long-Term Durability Issues for Cryo Tanks, Extreme Environments
- Non-autoclave Processing for High Temperature Applications
- Nanocomposites for Improved Performance
- Property Prediction/Life Time Modeling of Material Behavior with Exposure to Time and Environment (LOX)

Summary

- Polymeric Composites Crucial for Meeting Mass Fractions for Reusable Launch Vehicles…Flying Cryo Tanks
- Non-Autoclave Processing may Enable Mission
- Many Benefits Already Documented
- Many Technical Issues Remain
- Will work Issues of Most Importance to Space Customers

Points of Contact

Structural Nonmetallic Materials - Mr Scott Theibert, 937-255-9070

Composite Mechanics - Dr Steve Donaldson, 937-255-9096

M&P for Space Platforms - Ms Kris Kearns, 937-255-3670

Electron Beam Processing - Dr Janis Brown, 937-255-0968, Dr Vernon Bechel, 937-255-9077

Nanocomposites - Dr David Curliss, 937-255-9078, Dr Rich Vaia, 937-255-9184, Dr Janis Brown, 937-255-0968