Structures, Materials, and Mechanisms

TEC
Galveston, Texas
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ETDP Structures Materials and Mechanisms
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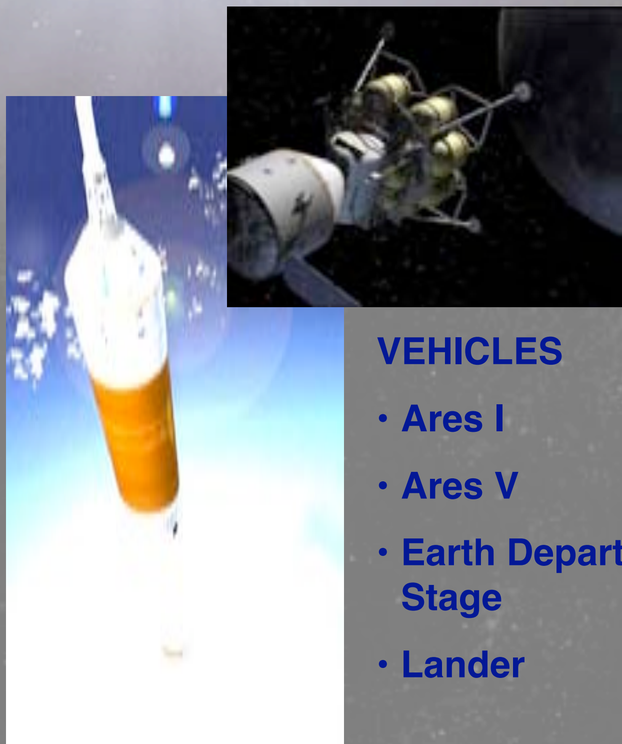
Agenda

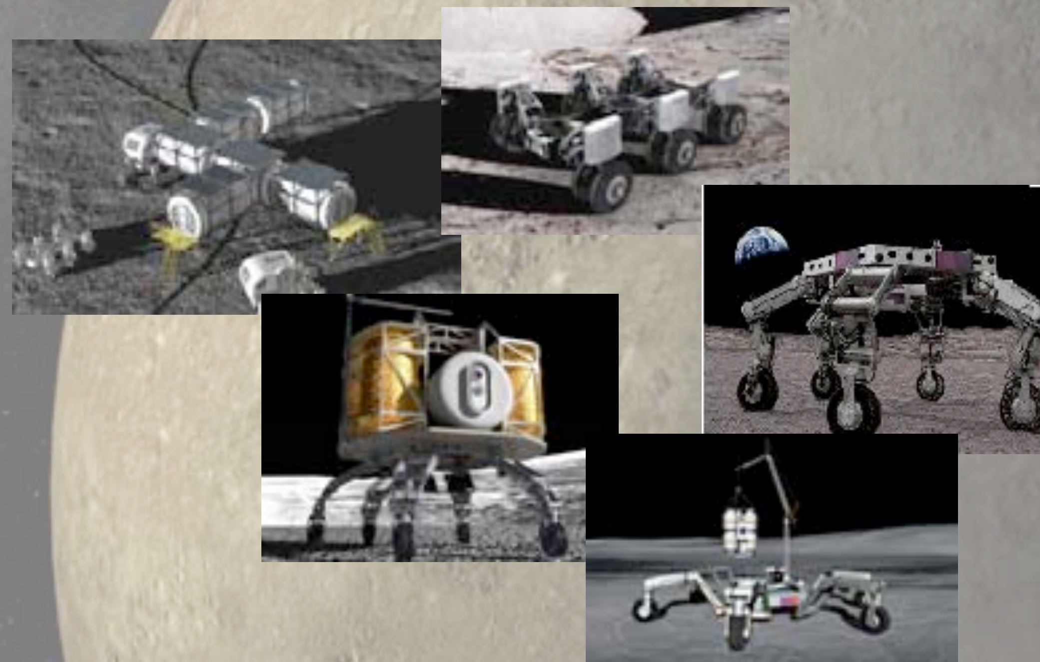
- Presentation on Technology Needs and Current ETDP Technology Development
- Panel Discussion and Questions

Constellation Targeted Areas of Application



VEHICLES

- Ares I
- Ares V
- Earth Departure Stage
- Lander



LUNAR SURFACE SYSTEMS

- Habitats
- Mobility and Payload Handling
- Other Surface Systems Structures and Mechanisms needs such as Power, ISRU…

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Structures, Materials and Mechanisms Needs Recently Indicated from Architecture Studies

From Focus Elements

ARES V
- Composite Structures

Habitation
- Composite Structures
- Hybrid Expandable Structures
- Radiation Shielding
- Lightweight windows

Mobility
- Low Temperature Mechanisms for at least night survivability
- Composite Structures

Lander
- Composite Structures?

Power
- Deployable structures for solar arrays
- Insulation materials for cables

ISRU
- Lightweight/inflatable solar concentrators

From Technology Assessment in LAT II

Minimal set of technology needs include :
- MMOD protection,
- Radiation shielding,
- Lightweight Structural options and repair

Additional capabilities Identified
- Low temperature mechanisms
- Non Destructive Evaluation

Areas Of Interest to SMM:
- Flight System Mass- primary mass in landers and habitats
- Most massive elements: structure, propulsion, power, shielding

LAT 2 considered additional technologies for improvement:
- Commonality
- High strength/mass materials
  - Long term durability of composites
  - Minimum gage
- Expandable structures
- Wide temperature ranges

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Vehicles

LAUNCH VEHICLES (Ares I & V, EDS)

- Ares I limited advance technology needs due to schedule
- In General:
  - Advance lightweight structures and materials
  - Improved Manufacturing costs
  - Improved simulation/prediction of Damage and Durability
  - Material Physical and Mechanical Properties
- Metallic Structures additional areas of interest
  - Friction Stir Welding of AL-Li Alloy Tanks
  - Full Scale 2195 Spun Domes
- Composite Structures additional areas of interest
  - Delamination and Impact Failures of Composite Structures
  - Advanced Metal to Composite Joining Techniques
  - MMOD Resistance / Survivability and Protection of Critical Components
  - Composite Over Wrap Tanks in Cryogenic Environment
- Manufacturing and Design
  - Integrated Digital Design to Manufacturing
  - In-space Repair
  - Rapid Prototyping
- Non-Destructive Evaluation (NDE)
- Thermal Protection System (TPS) and Insulation
  - High Temperature Ablative TPS for Boosters
  - MMOD Resistance / Survivability of Multi-Layer Insulation (MLI) for Cryogenic Propellant Tanks

LANDER

- Still in design process
- Needs in technology still to be determined if they are: Technology advancement vs technology validation vs engineering design
- Early areas of consideration are:
  - Composite ascent module design and validation similar to Composite Crew Module Study
  - Tapered composite struts with composite end-fittings/joints
  - Composite cryo-tanks

Lunar Surface Systems

Issue/ Technology	Habitat	Surface Mobility	Lander	Power	Pressurized Rover	ISRU	Payload Handling
Composite (PMC) long term durability	X	X	X	X	X	X	X
Damage Tolerance Reqs for Primary structure (including threats, scenarios, etc.)	X	X	X	X	X	X	X
PMC min gage: non-pressure str.	X	X	X				X
PMC min gage: pressure str.	X		X	X	X	X	
Al-Li min gage: non-pressure str.	X	X	X				X
Al-Li min gage: pressure str.	X		X	X	X	X	
Light weight mating mechanism	X		X		X		
Advanced Matls. For High Stiffness (non-pressure)		X	X				X
Certified in-situ repair techniques for habitat structures	X	X	X	X	X	X	X
Certification Requirements for Inflatable Habitat Structures	X						
Efficient packaging, deployment, outfitting for Inflatable Habitats	X						
Reduction in Factor of Safety for Inflatable Habitat Structures	X						

Relationships to Other Technology Areas

- Human Robotic systems
  - Mobility, manipulation devices
  - Low temp mech., structures to move or manipulate
- ISRU
  - Excavations
  - Low temp mech., regolith covering structures,
- Dust
  - Protection of mechanisms, external surfaces and interior volumes
  - Low temp mech., hab structures, airlock, suit lock, etc. sealing surfaces
- Thermal Control for Surface Systems
  - Low temp mech. relationship
- Supportability
  - Structural repair, modularity, reusability
- Integrated Systems Health Management
  - NDE of for structural damage and repair

ETDP Structures, Materials, and Mechanisms Project Technology Development

Project Goals

Lightweight Structures and Materials

- Develop lightweight primary structures for the pressurized elements of the Lunar Landers and Surface Habitats with relevant technology made available to the CEV and CLV.
- Objectives
  - Reduce structural mass and launch volume
  - Improve performance to reduce risk and extend life
  - Reduce manufacturing and processing costs

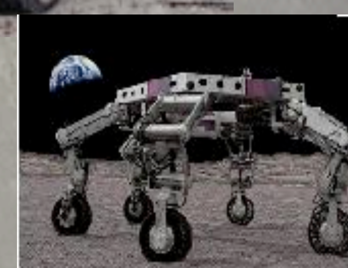
Low Temperature Mechanisms

- Develop low-temperature mechanisms to allow operation in temperatures below -200° C for missions to the lunar polar regions for lunar surface rovers, robotics, and mechanized operations.
- Objectives
  - Sustainable operation at -230° C for lunar shadow regions
  - Sustainable operation thru varying range of temperature -230° C to +120° C
  - Improve mechanism performance in lunar environment









SMM WBS Organization and Responsibilities

Judith Watson, Project Manager, PI LaRC

WBS 1.0 Program Management *PM, LaRC*

WBS 2.0 Low Temperature Mechanisms *Oversight: DPM*

- 2.1 Requirements and New Tech Development -Unfunded
- 2.2 Motors, Drive Systems and Actuators
  Task lead: Mohammed Mojarradi/JPL
  Co-leads: LaRC, GRC
- 2.3 Lubricants and Materials Unfunded

WBS 3.0 Advance Material Systems *Oversight: DPM*

- 3.1 Advance Material Development Unfunded
- 3.2 Radiation Shielding
  Task lead: Sheila Thibeault/LaRC
- 3.3 CEV Parachute Materials
  Task lead: MaryJaneO'Rourke/ JSC

WBS 4.0 Lightweight Structures *Oversight: PM*

- 4.1 Expandable Structures
  Task lead: Karen Whitley/LaRC
  Co-leads: JSC, ILC
- 4.2 AL-Li Manufacturing
  Task lead: Sandeep Shah/MSFC
  Co-Leads: LaRC, LM
- 4.3 Mulatifunctional/Integrated Structures -Unfunded
- 4.4 Advance Composite Materials
  Task lead: Dawn Jegley/LaRC

WBS 5.0 Other Directed Programs *Oversight: PM*

WBS 6.0 Education and Public Outreach *PM, LaRC*

Targeted Constellation Elements

Push- Elements Technology thinks they can be applied toward

Pull - Areas where agreements or discussions are on-going for integration of technology

CEV (Orion)

- **Radiation Shielding Kit - *pull/push***
- **CEV Parachute materials - *pull***

CLV (Ares I and V)

- **Al-Li Manufacturing (FSW/Spun Domes) - *pull***
- **Advanced Composite Structures - *pull/push***

Lander

- **Radiation Shielding Kit - *push***
- **Inflatable Structures -*push***
- **Al-Li Manufacturing (FSW/Spun Domes) -*push***
- **Advanced Composite Structures - *pull***

Lunar Surface Systems

- **Low Temperature Mechanisms - *pull/push***
- **Radiation Shielding -*push***
- **Inflatable Structures - *pull***
- **Al-Li Manufacturing (FSW) -*push***
- **Advanced Composite Structures-*push***

WBS 2.2
Low Temperature Mechanisms

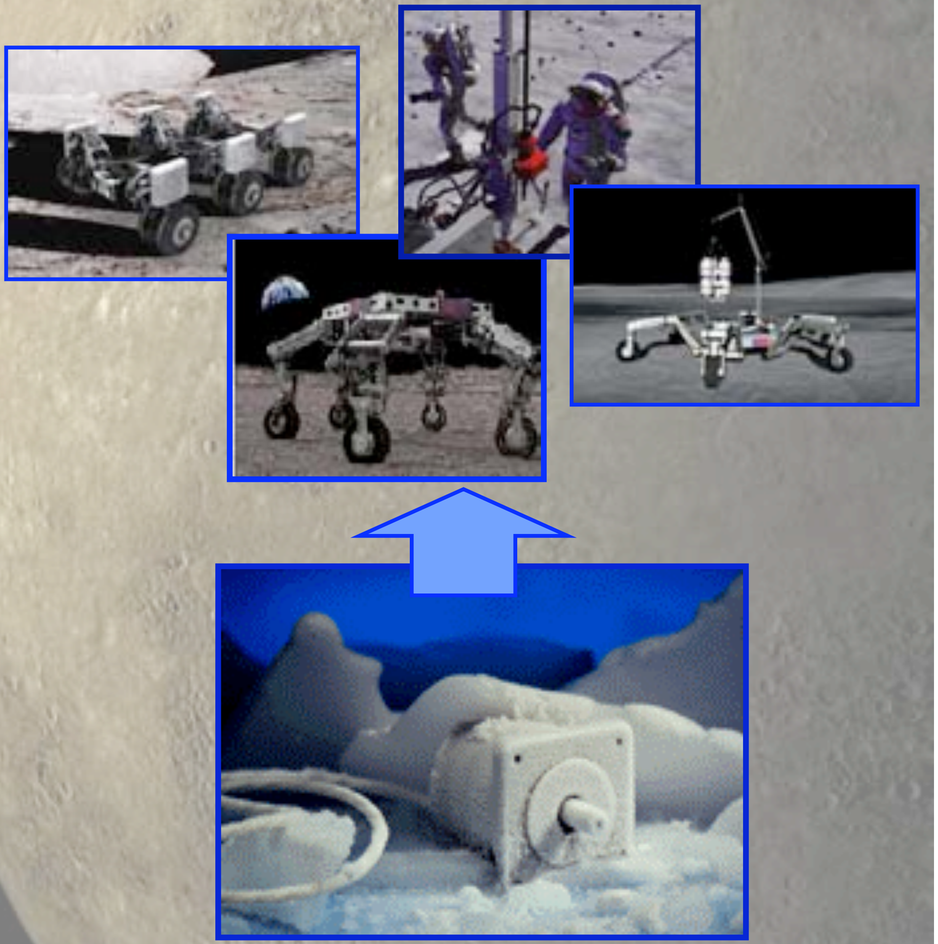
Project Lead:
Mohammad Mojarradi, JPL
Co-Leads: Tony Tyler (LaRC); Phil Abel (GRC)
Current TRL: 3

Responsibilities:

- JPL; Develop, Integrate and Characterize Mechanism
- GRC: Develop Low T Lubricants
- LaRC: Conduct Low T Life Test

Objective/Goals description:

- Develop a Low T Mechanism Consisting of Gear Box, Motor, Sensor (Resolver), and Motor Control Electronics:
  - Leverage MFT legacy hardware
  - Operate between -230C and 120C (Lunar surface)
  - Wide low temp, rad-hard (100Krad) electronics
  - Capable of long life, (five years operation) minimum of 50E6 revolutions, 150 Lunar temperature cycles
  - Enables distributed architecture
  - Achieve TRL 6 for the component technology by 2012



Low Temperature Integrated Mechanism: Motor, Gears, Sensor and Electronics for Lunar Robotics

The Need for Low Temp Mechanisms

Low temperature motors, drive electronics, gearboxes, actuators, and lubricants are needed for Lunar Surface Systems

Applications

Payload Handling

Rovers

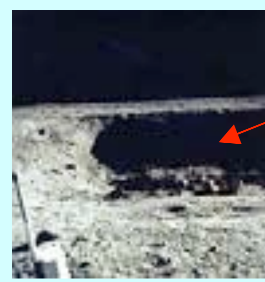
Cargo Carriers

Areas of Concern

Low Temperature Mechanism technology begins at temperatures as high as -50°C (transition from wet lube to dry lube)

Areas of Lunar Exploration where Low Temperature Mechanisms are Required (many conditions could reach -173 °C)

Excursions into permanently shadowed craters (as low as -233 °C)



Shading by local topography

Hardware located on appendages

Self shadowing of hardware

Operations during night cycle

WBS 3.2
Radiation Shielding Kit

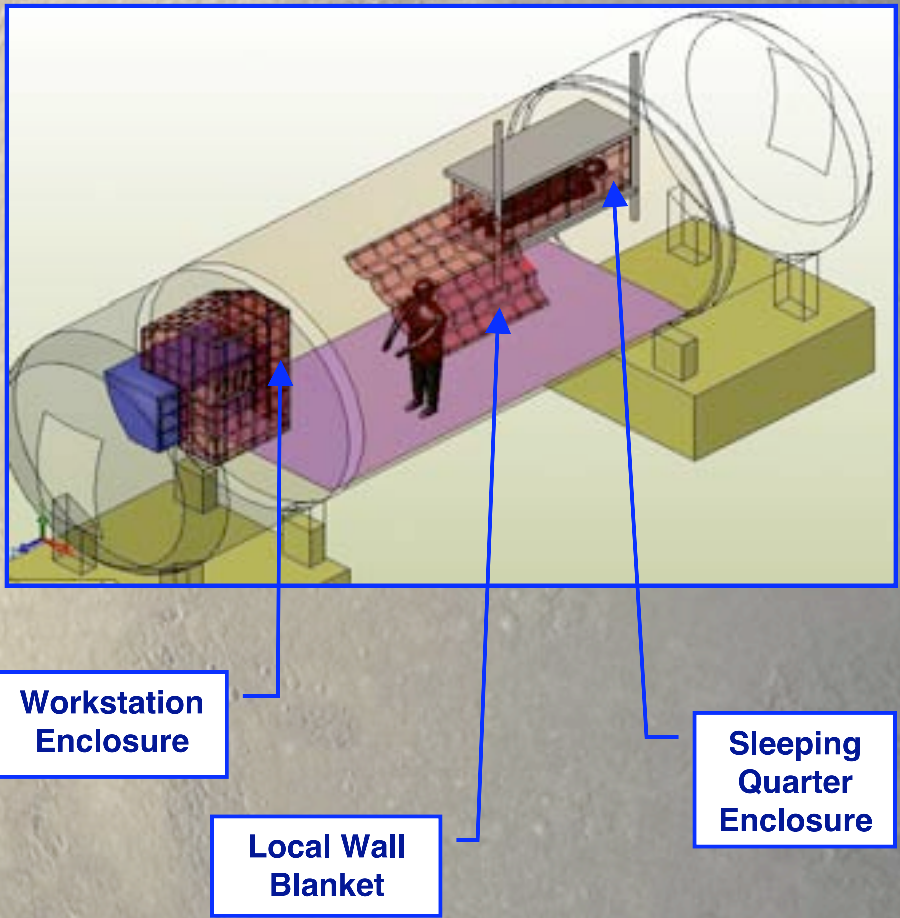
Lead: Sheila A. Thibeault (LaRC)
Partners:
- **ILC Dover (contract)**
- **Lawrence Berkeley National Lab (Interagency Agreement)**
- **College of William & Mary (Cooperative Agreement)**
- **White Sands Test Facility**

Objective/Goal:

Develop a lightweight flexible portable reconfigurable radiation shielding kit to augment the shielding already inherent in the vehicle, lander, or habitat.

Reduce the mission weight and volume because less shielding will have to be built into the expanse of the vehicle, lander, or habitat and because the kit can easily be moved from one element to the other.

Operational Concepts



WBS 3.3
CEV Parachute Materials

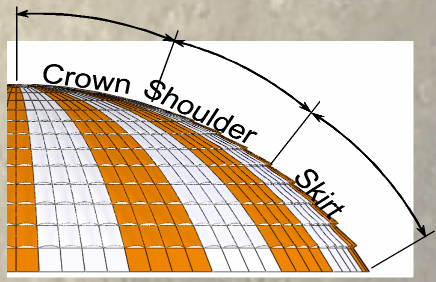
Lead: Mary Jane O'Rourke, JSC

<u>Objective/Goals FY08-FY13</u>

- The *CEV Parachute Assembly System (CPAS)* must meet launch weight constraints and requirements for volume and mobility in the parachute compartment.
- Pack density must be low enough to allow for complete and rapid deployment of chutes, without damage.

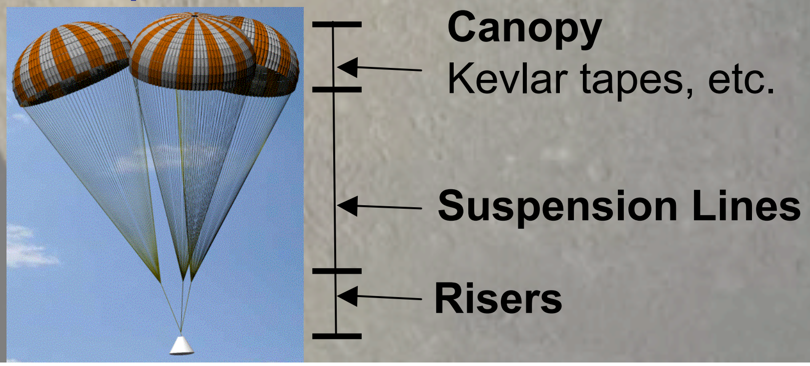
- *The objective is to develop two lightweight materials as a solution, each used for a unique purpose in CPAS, and both leading to a flight-demonstrated decreases in pack density as well as weight.*

- Lightweight Nylon broadcloth to be developed for skirt to shoulder region of main canopies, and M5 fiber-based fabrics to be developed for structural grids in all parachutes..



Lightweight Nylon broadcloth for skirt to shoulder region of main canopy

M5 fiber-based fabric for structural grids of <u>all</u> parachutes:



WBS 4.1
Expandable Structures

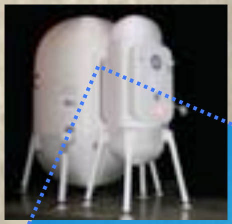
Lead: Karen Whitley (LaRC)
Co-Lead: Gerard Valle (JSC)
Co-Lead: John Lin (ILC Dover)

Photo Source: LaRC (Sean Smith)

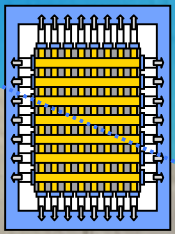
Objective/Goal

The objective is to develop the technology needed to design and build expandable structures for pressurized elements for lunar surface architectures such as landers, crew habitats and airlocks.

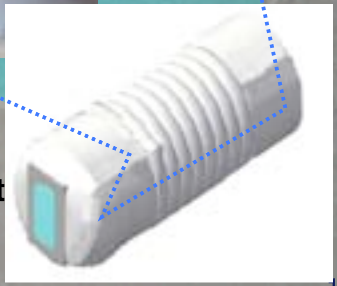
The goal of the program is to develop expandable technology for increased habitable volume for minimal mass, including advancing and validating the technology to provide constellation required structural and environmental protection.



Technology Demonstrator 2007



Structural Validation 2007-2009
- Creep
- Damage Tolerance



EDUs 2008-2010
- Operational Unit
- Structural Unit
- Regolith Lifter

WBS 4.2
Manufacturing
Friction Stir Welded Spun Formed Al-Li Domes

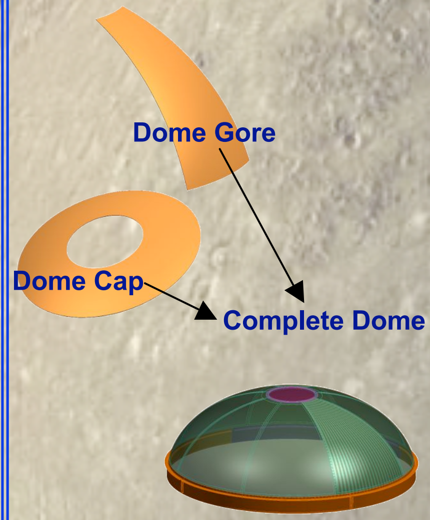
Task Leads:
J. Brewster (Lockheed Martin)
S. Shah (MSFC)
E. Hoffman (LaRC)

Support organizations:
MSFC, LaRC & MAF

Objectives:
- Mature spin forming and friction stir welding (FSW) technologies through the construction of large-scale 5.x m DIA domes which are representative of Ares I launch vehicles
- Establish the process through spin forming sub-scale domes and then mature the process in 4 trials of spin forming large-scale domes
- TRL 6 and Process Specification by Nov 2009 - Ares I Upper Stage CDR

- Validate the process through structural verification of the design and dome.
- Develop material property design allowable data base

Current Welded Assembly



Technology Development
One-piece
Spun Formed Dome

Sub-scale Friction Stir Welded Domes

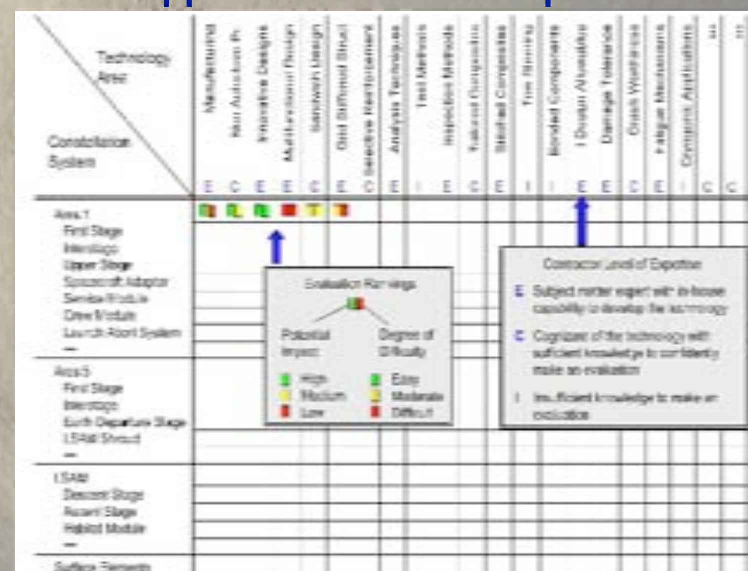
WBS 4.4
Advanced Composite Structural Technology

Lead: Dawn Jegley (LaRC)
Also participating: MSFC, GSFC, GRC
Boeing, Northrop-Grumman, AS&M

Objective:
Advance the state-of-the-art in composite structures through technology development aimed at the most critical issues limiting the use of composite materials and structures in Constellation vehicles and systems.

Approach:
- **Evaluate existing composite material technologies and manufacturing methods**
- **Identify tall-pole, highest impact technology areas**
- **Carefully select areas for investment/development**
  - **achievable/affordable goals (cost and time)**
  - **broad impact across mission applications**
- **Four broad teams of experts formed that includes NASA, academia, and industry partners with extensive manufacturing experience**
- **Leverage existing knowledge base (space and aeronautics)**

Technology evaluation and ranking for application and development



Panel Discussion

- **Judith Watson, LaRC** — **ETDP Structures, Materials, and Mechanisms Project Manager**
- **Eric Hoffman, LaRC** — **Metals; Al-Li Manufacturing**
- **Greg Lavanas, JPL** — **Low Temperature Mechanisms**
- **Terry Nienaber, LaRC** — **Lander, Structures Deputy Lead**
- **John Dorsey, LaRC** — **Lunar Surface Systems, Structures and Habitats**

Backup

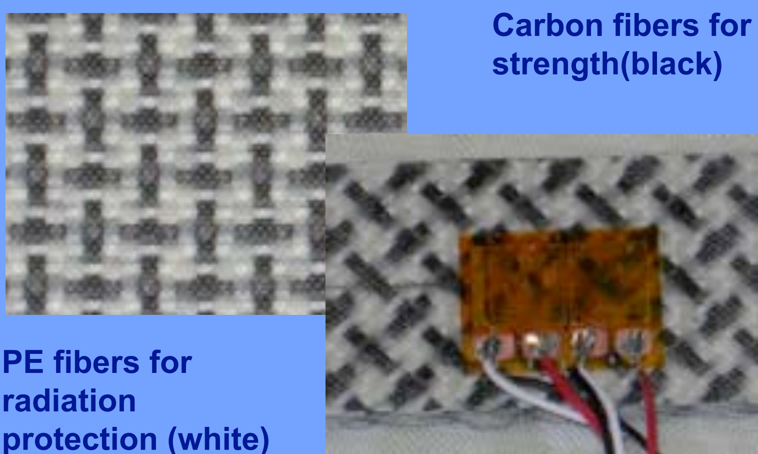
Multifunctional Material for Structures

(NASA Marshall, Raj Kaul)

- Development of multifunctional materials for load, radiation protection and MMOD protection properties

- Material candidate tested for multifunctional performance with promising results
  - Radiation testing at the NSRL facility
  - Mechanical properties at 3 temperature conditions (20^{o} C, 90^{o} C, -100^{o} C)
  - Hypervelocity Impact testing at MSFC

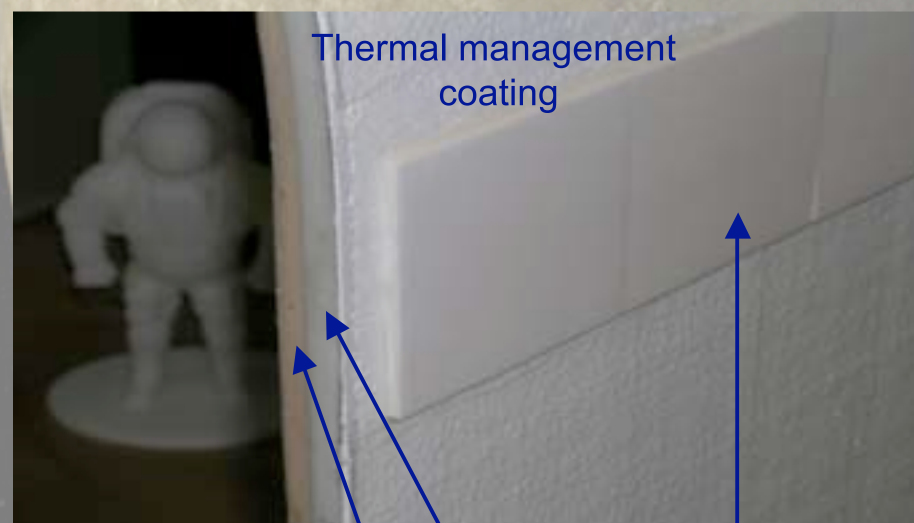
- Recent Work: Fabrication of specimen of hybrid composite/ PE material completed. Mechanical testing started, 60% completed. Radiation specimen fabricated for testing



Carbon fibers for strength(black)

PE fibers for radiation protection (white)

PE/Graphite hybrid composite



MMOD protection

Structural element/ radiation shield

Radiation/MMOD shield

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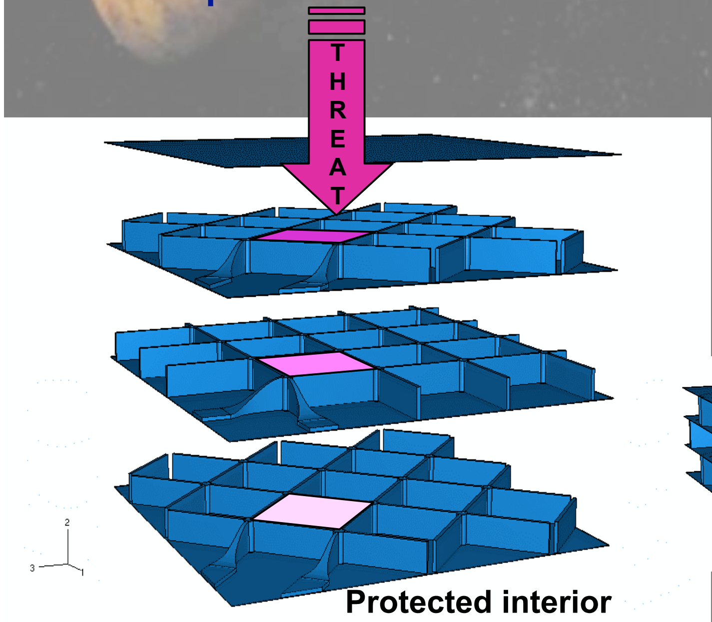
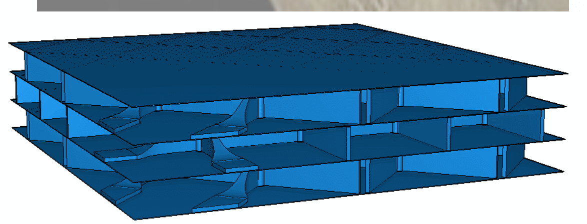
Integrated Structures

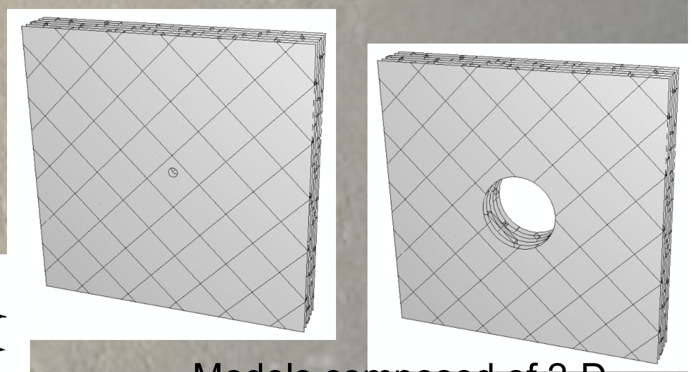
(NASA Langley, Dawn Jegley)

Multi-layer Grid Stiffened Structure

- Grids are oriented to provide structural support MMOD protection
  - Exterior and interior skins can be made from radiation shielding material
  - Cells can be filled with foam or other lightweight material that can provide insulation, further MMOD protection, radiation shielding, etc.
- Tow steered concepts and multi-layered grid stiffened concepts are extensions of work begun under several aircraft programs such as TCAT, ITAS and Subsonic Fixed Wing and army programs.
- Recent work:
  - Analysis being developed for modeling of multfiunctional structures with damage, 2-D operational, 3-D almost complete.
  - Specimens fabricated and being prepped for testing







Models composed of 2-D shell elements