COE CST Third Annual Technical Meeting: Ultrahigh Temperature Composites for Thermal Protection Systems (TPS)

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COE CST
Center of Excellence for Commercial Space Transportation

Overview

- Team Members
- Purpose of Task
- Research Methodology
- Results or Schedule & Milestones
- Next Steps
- Contact Information

Team Members

Principle Investigators

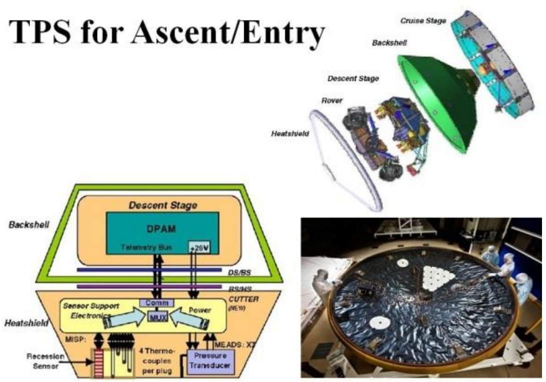
- **Jan Gou -** Composites design and manufacturing, composites mechanics
- **Jay Kapat -** Heat transfer, film cooling, aerodynamics testing
- **Ali Gordon -** Thermo-mechanical testing and modeling

Graduate Students

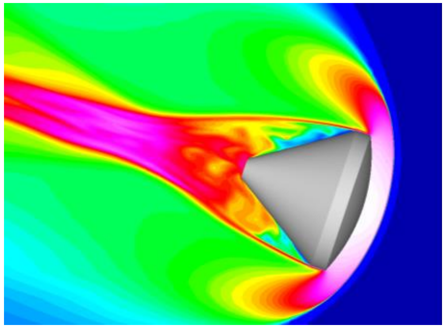
- **James McKee, Hongjiang Yang**: Composites TPS design & manufacturing
- **Donovan Lui**: Ablation testing
- **Cassandra Carpenter**: Aerothermal modeling

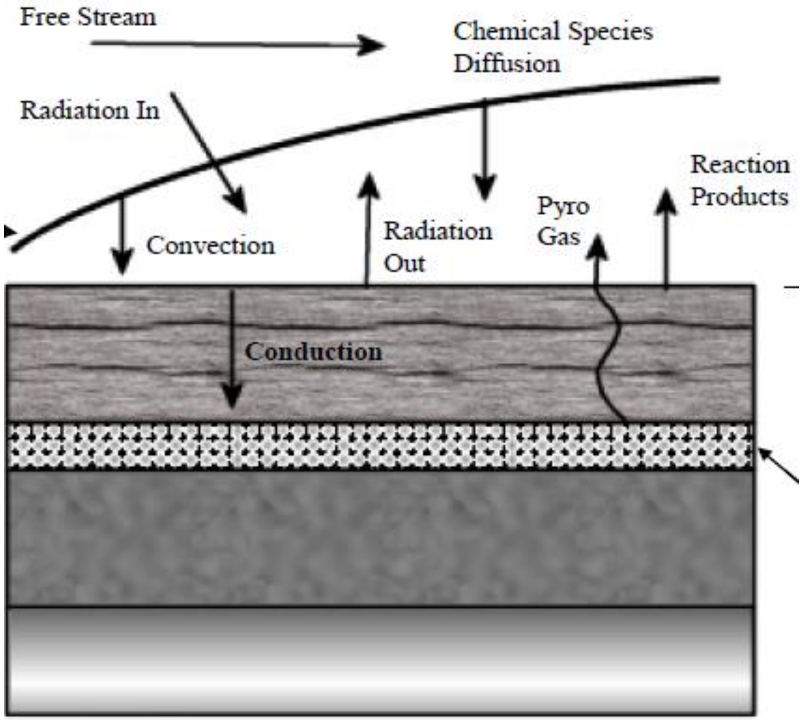
Purpose of Task

Develop **ultrahigh temperature**, **light weight**, **low erosion**, and **cost effective** ablative thermal protection systems with embedded health monitoring for inherent safety and real-time assessment of TPS performance in hypersonic space vehicles



Reentry Vehicles





Purpose of Task

RELEVANCE TO COMMERCIAL SPACE INDUSTRY

- Ultra-high temperature, light weight, low erosion, and cost effective thermal protection systems (TPS) are enabling technologies for viable commercial space transportation vehicles and their high-temperature systems.

STATEMENT OF WORK

- Develop nanocomposites TPS with embedded health monitoring for inherent safety and real-time assessment of hypersonic TPS applications.
- Provide an analysis tool for the aerothermal modeling of reentry vehicles and rocket propulsion.
- Provide an analysis tool for thermal degradation modeling of new ablative materials.
- Provide ablation sensing to monitor the structural health of the ablative thermal protection system.

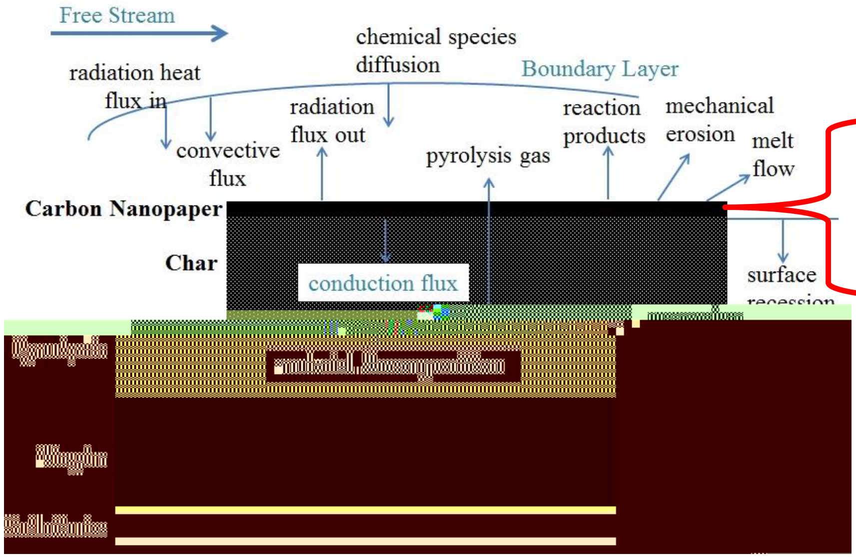
Current Approach

- PICA: Phenolic Impregnated Carbon Ablator
- SICA: Silicone Impregnated Carbon Ablator
- Carbon/Carbon Composites

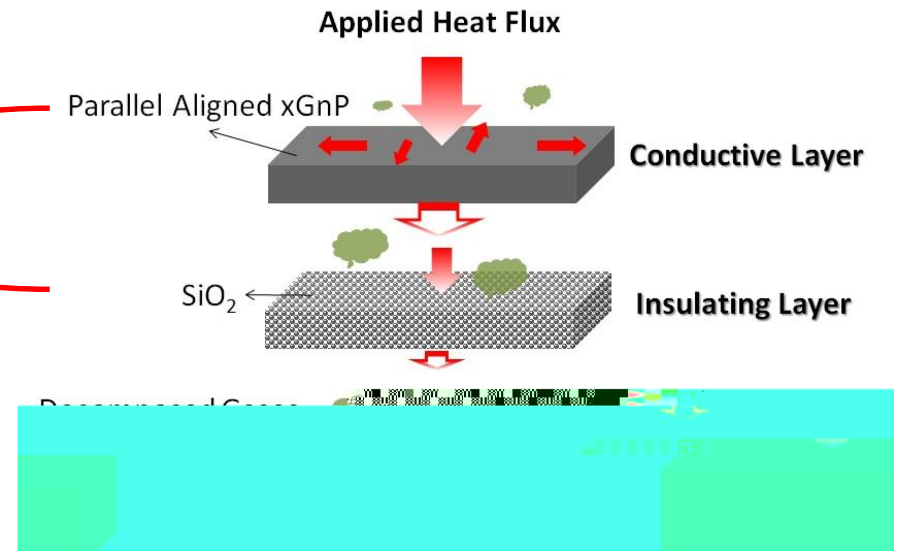
Problems

- The resulting chars are structurally weak and susceptible to mechanical erosion, severely reducing the lifetime of the TPS. Reducing spallation or erosion of the char can enable use of less ablative materials thereby reducing the total weight of TPS.
- The evaluation of ablation performance needs to consider the structural integrity of TPS structures
- Recession monitoring is most important measurement to the aerothermal analysis of the TPS structure. This measurement provides critical information about how the TPS mass and shape changes during the fight.

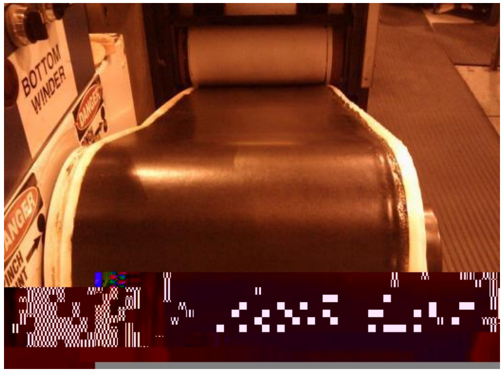
Ablative TPS Design - Nanocomposites Approach



TPS Materials Design



Bi-layer thermal protective coating



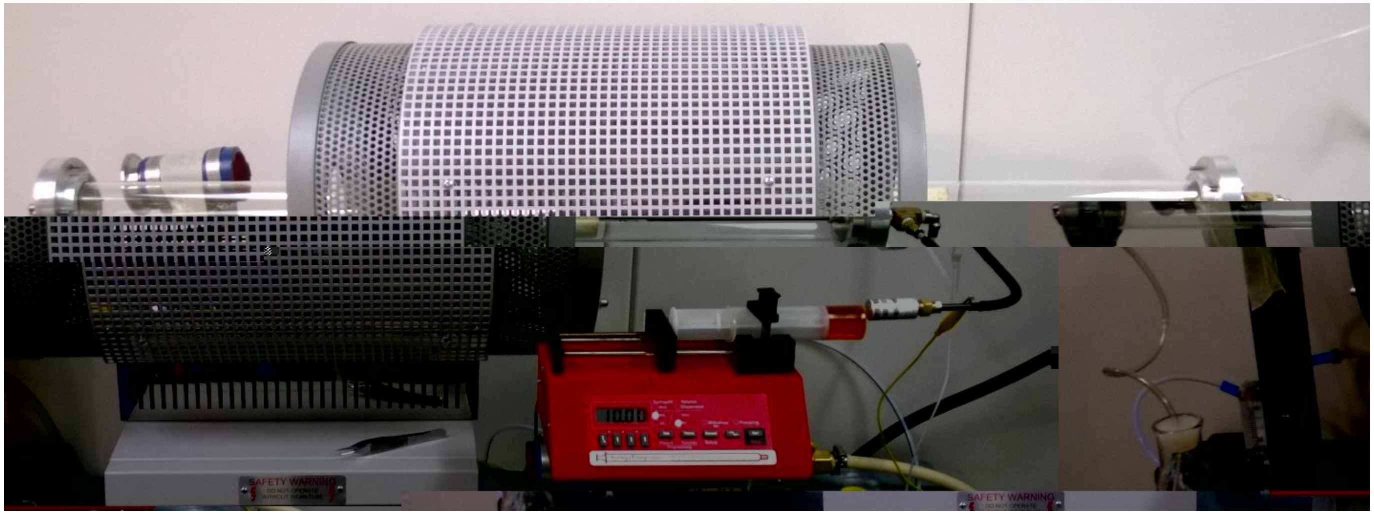
Nanocomposite prepreg systems

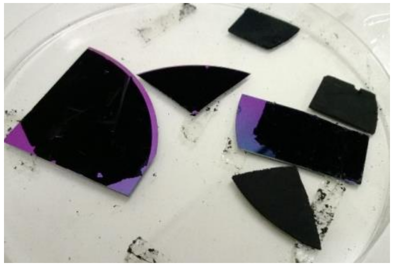
Nanocomposite thermal protective coating

Research Methodology

Vertically Aligned Carbon Nanotubes (VACNT)

- Aligned CNT Arrays grown by means of Chemical Vapor Deposition (CVD)
- Highly anisotropic properties
- Improved thermal soak rate
- Combinable with other technologies being explored





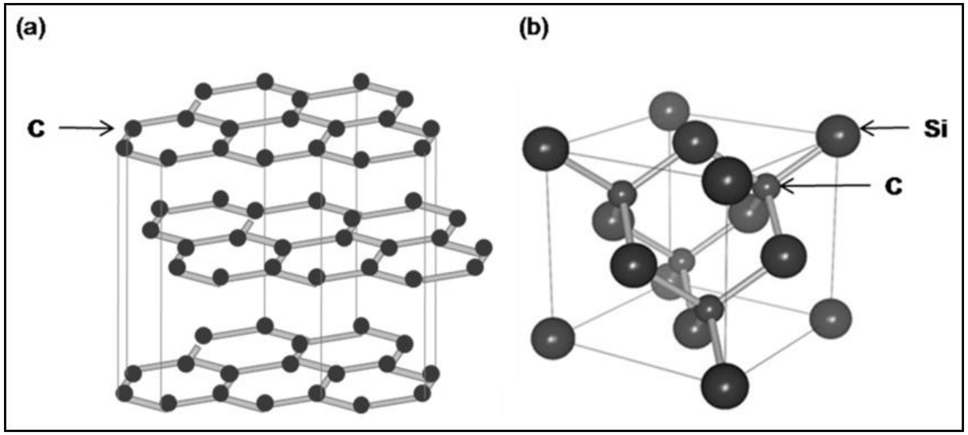
Research Methodology

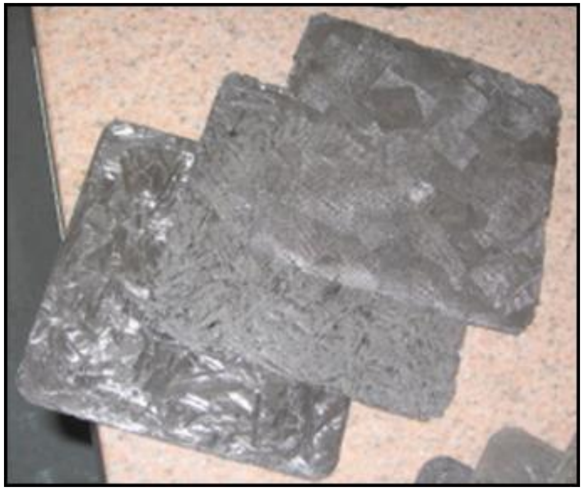
Polymer Derived Ceramics (PDC)

- Corrosion and wear resistant
- Simple processing with moldable geometries
- Strong and high quality ceramic matrix yield
- Lower thermal material requirement

Fiber Reinforced Ceramic Matrix Composites (CMC)

- High fracture toughness, crack resistance
- Resistance to thermal shock
- Higher oxidation temperatures (>1000°C)

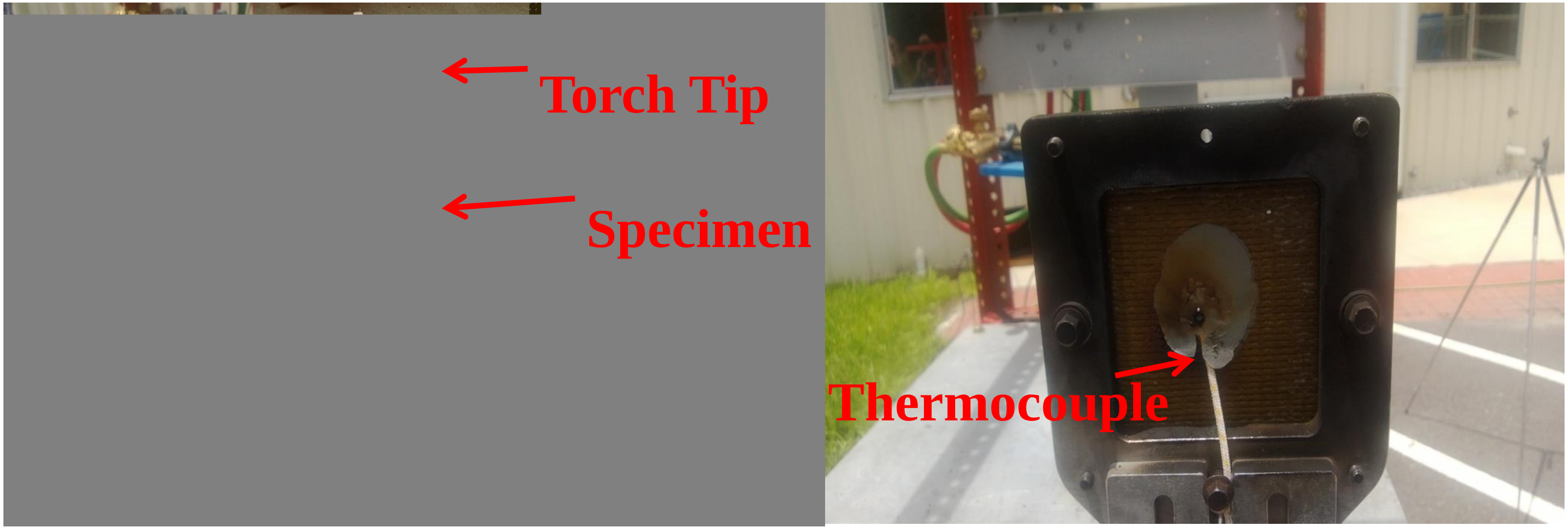




Results

PICA - Nanocomposite Thermal Protective Coating

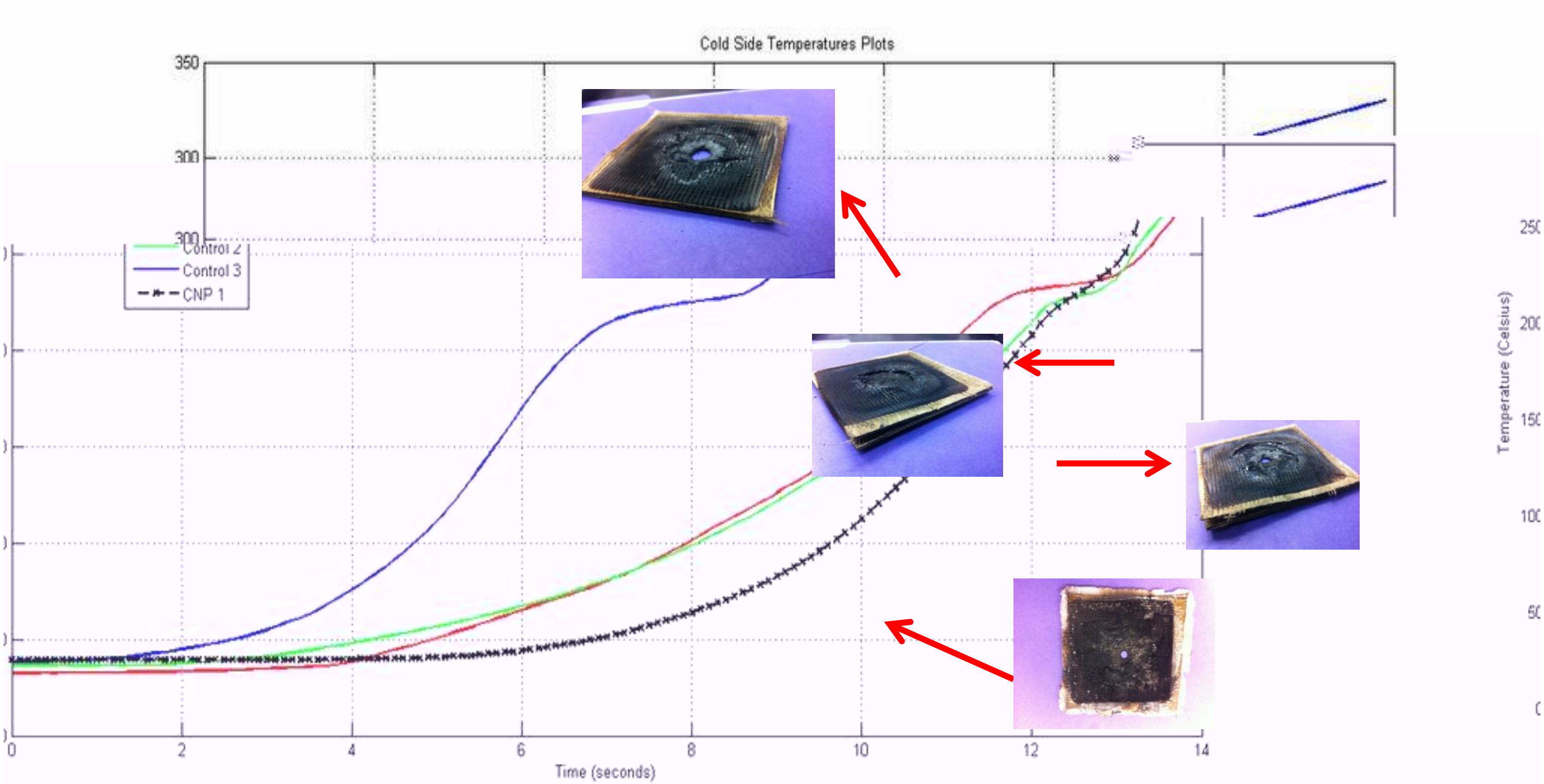
- Introduction of organized, structured carbon layer
- Improvement in insulation as well as ablative regression
- Delays first layer delamination



Oxyacetylene Ablation Testing

Results

Cold Side Temperature from Ablation Test



A delay of the increase of cold side temperature for the specimen coated with nanopaper indicates the nanopaper provided good thermal protection for the composites at high heat flux.

Next Steps

- Continue oxyacetylene torch testing of composite panels
- Integration of nanoparticles into PDC composites
- Incorporation of VACNT into composite panels
- Aerothermal analysis of TPS structures with curved geometry
- Thermomechanical characterization and testing for structural integrity evaluation

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