Distro A: Approved for Public Release; Distribution Unlimited

Recent development activities at NASA ARC in reusable TPS materials

Adam Caldwell*, Jay Feldman*, Peter Marshall*

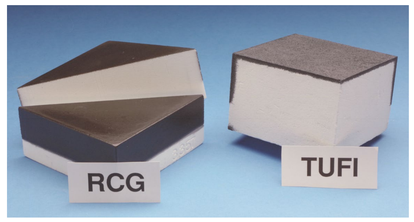
* NASA Ames Research Center

Overview

- Recent developments in low-cost access to low-earth orbit (LEO) and hypersonic flight are driving renewed demand in reusable thermal protection systems (RTPS) that have not had broad application since the Space Shuttle era
- ARC has a long history of inventing RTPS including FRCI, AETB, and TUFROC as well as high performance coatings like RCG, TUFI and HETC
- Continued efforts for development of next generation solutions:
  - Leveraging computational modeling and novel characterization to accelerate developments in alternative materials and processing
  - Collaborations with commercial space and government agencies to support technology transfer, material development, and ground testing

Background and Collaboration

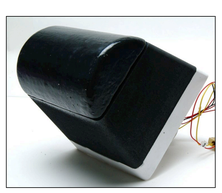
- Space Shuttle Orbiter's thermal protection systems (TPS's) are the flight proven starting point for reusable entry systems
- State-of-the-art insulative tile material - Alumina Enhanced Thermal Barrier (AETB)
  - Multi-use temperature 1427°C (2600°F)
  - Single-use 1538°C (2800°F)
  - Historically derived from NASA heritage raw material stockpiles that required updating to modern variants
  - Standard coatings include Reaction-cured glass (RCG) and Toughened Uni-piece Fibrous Insulation (TUFI)
- Collaboration with commercial space partners for RTPS technology transfer, material development and ground testing (RSAAs, ACOs etc.) include:
  - Blue Origin
  - Canopy Aerospace
  - Lockheed Martin
  - Space X
  - Stratolaunch

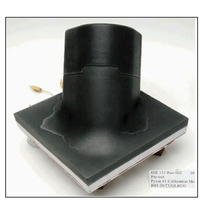


Coated ceramic tile material

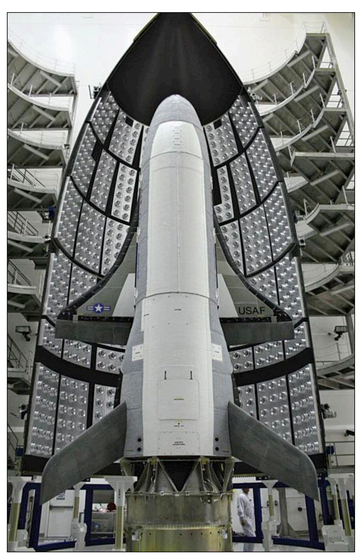
TUFROC and Alternatives

- "Toughened Uni-piece Fibrous Reinforced Oxidation-Resistant Composite"
- A multi-component tiled TPS system that is the state-of-the-art reusable material system used on the leading edges of X-37B
- Features (vs. C/C or C/SiC)
  - Low cost (10x cheaper than C/C)
  - Light weight (~0.3 g/cm^3)
  - Insulative
  - Multi-use temperature 1593°C (≥3, 5 min exposures)
  - Single-use temperature ≥1700°C
- **Current development efforts**:
  - Increased single and multi-use operating temperatures
  - Reduced complexity and cost


Wedge


Pylon

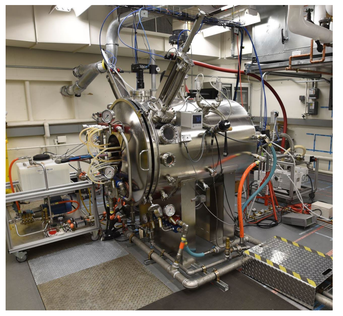

Sharp Wing Leading Edge

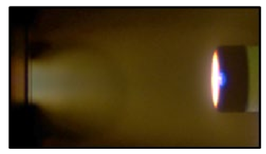


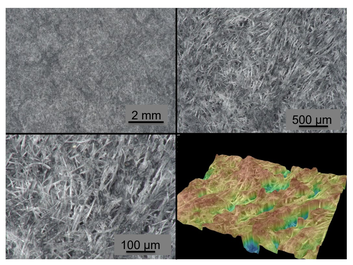
X-37b preparing for first launch, 2010

Material Development and Characterization

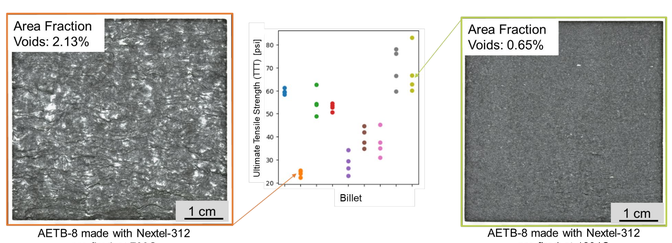
- Aerothermal Testing
  - Large scale arc jet testing up to 60 MW
    - Constricted, Linde, Panel, and Turbulent Facilities
    - Nozzle sizes ranging from 3 in to 41 in
    - Radiative heat augmentation up to 45 kW/cm2 (Gaussian)
  - New small scale arc jet testing: (mARC II)
    - High enthalpy facility at 30 kW
    - Low-cost development of low-maturity technologies
    - Sample geometries up to 1"
    - Air, N_2, and CO_2
- Characterization
  - Micro/macroscopy: X-ray radiography, scanning electron microscopy (SEM), optical
  - Spectroscopy: UV-Visible, Infrared, Energy-dispersive
  - Other: X-ray diffraction (XRD), Dilatometry, TGA/DSC
- Material development efforts
  - Modernization of heritage systems:
    - Transitioned from NASA stockpiles to modern constituents achieving heritage specifications
  - Alternate systems
    - Considerations for compliance and integration as well as improved thermal performance
    - Coating systems for improved performance


Newsmall scale arc jet (mARC II) test facility


1" RTPS sample in the mARC II plasma



Optical micrograph of ceramic fiber material



AETB-8 made with Nextel-312 pre-fired at 700C

AETB-8 made with Nextel-312 pre-fired at 1204C

Transmission optical microscopy of AETB correlating structure and defects to tensile strength

- Computational modeling:
  - Applying and modifying established capability (e.g. PuMA) to RTPS
  - Multiscale analysis from full scale down to atomistic
  - Informing material selection and processing for rapid development of next-generation material systems


Computationally generated ceramic material in PuMa

Contact information:
Dr. Adam Caldwell email: Adam.Caldwell@nasa.gov

Distro A: Approved for Public Release; Distribution Unlimited