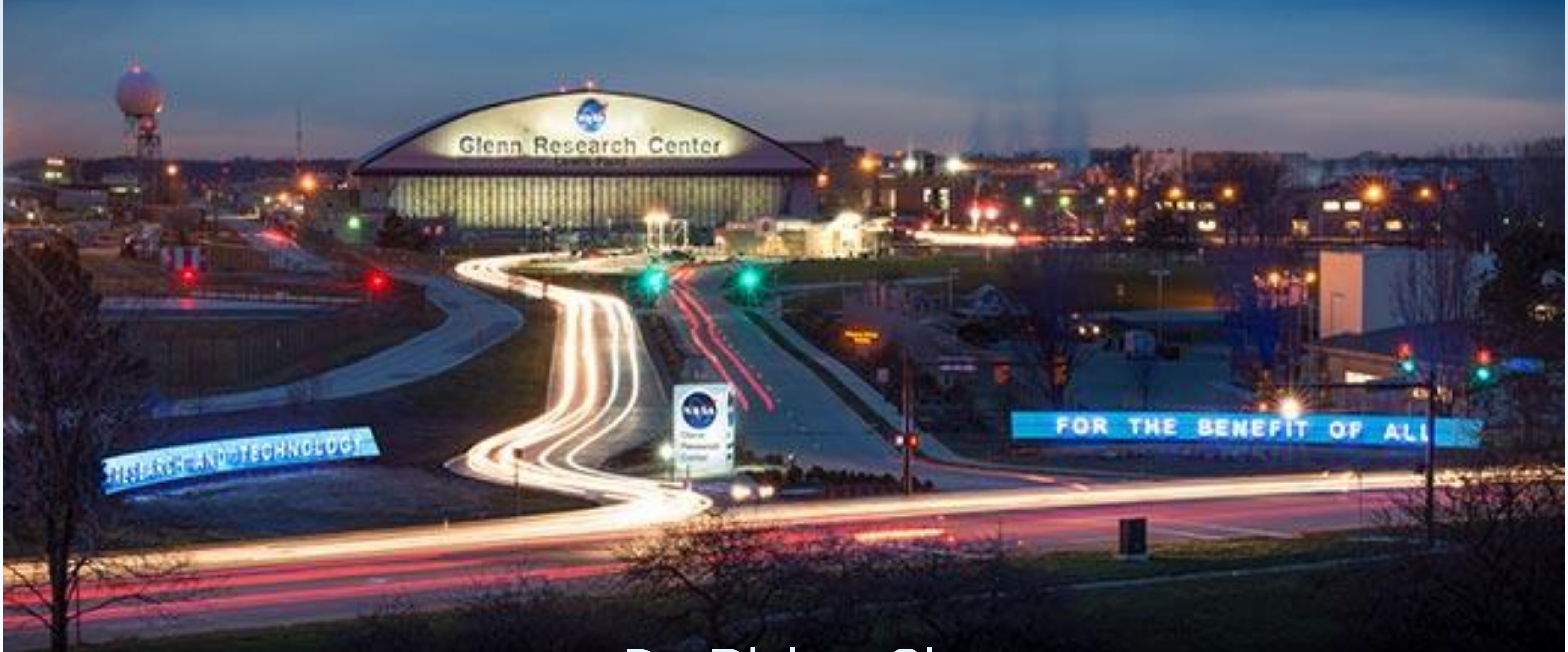
Advanced Ceramic Materials for Aerospace Propulsion and Power

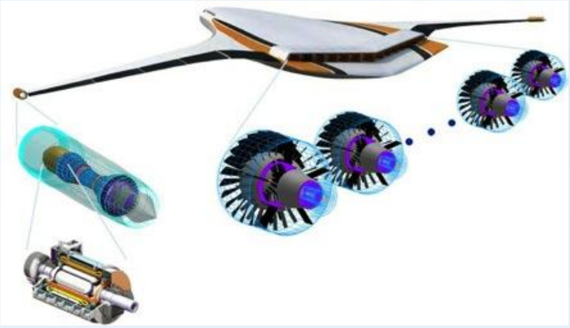


Dr. Rickey Shyne
Director, Research and Engineering

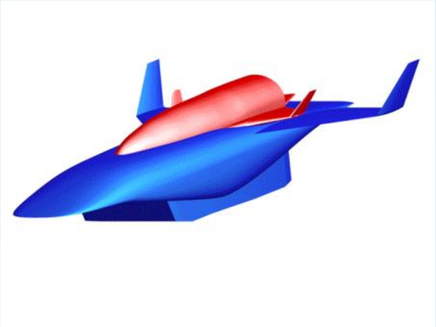
Presented at Ceramic Expo, April 26, 2016, Cleveland, OH

Widespread Application of Ceramics in Aerospace Propulsion and Power Systems

Highly Efficient Gas Turbine Engine

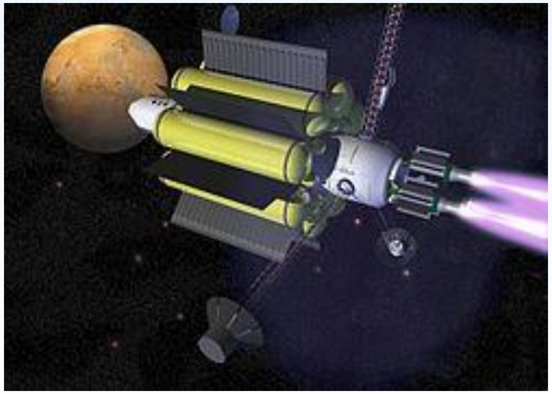


Hybrid Electric Propulsion



Lightweight Hypersonic Propulsion

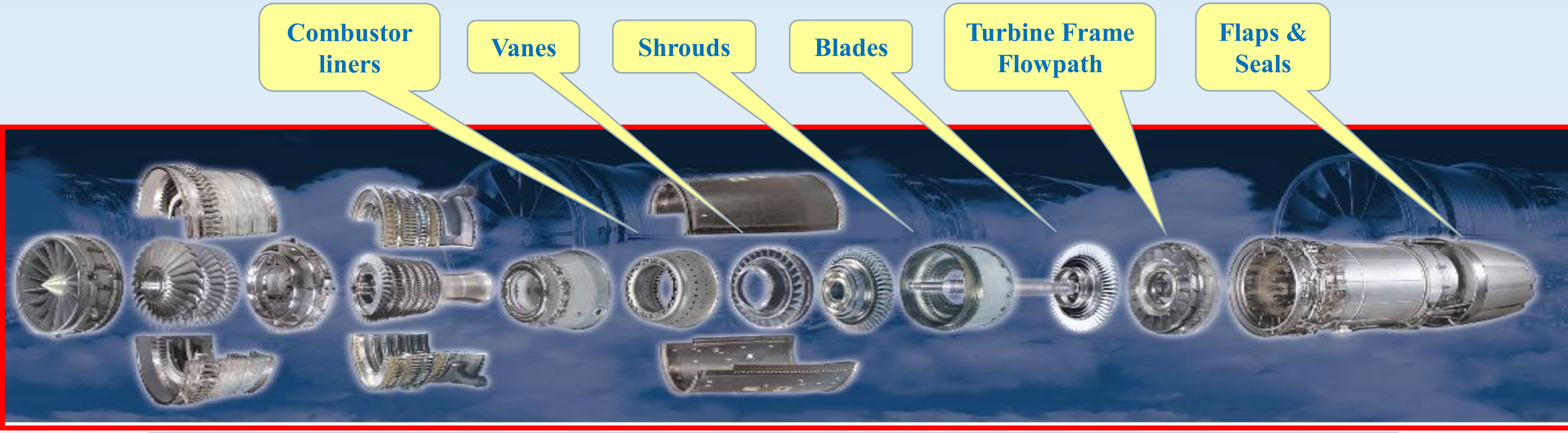
Rocket Propulsion



Nuclear Propulsion/Power

In-Space Propulsion

Ceramic Matrix Composites (CMCs) for Gas Turbine Engines



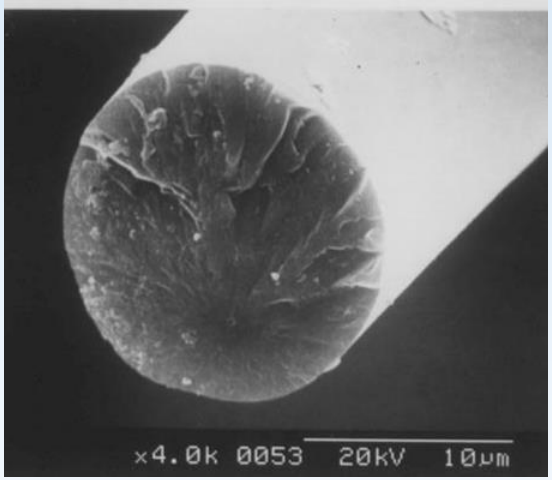
- **Enables higher temperature capability with 200 - 500 F + temperature advantage over metals for gas turbine engine hot section components**
- **Weight = 1/3 of metals**

2400ºF Today — 2700ºF + Future

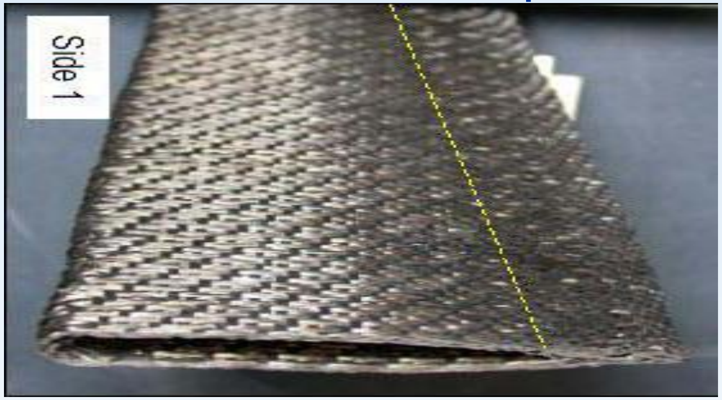
Development of a 2700ºF Capable CMC offers the potential of 6% fuel burn reduction

Ongoing Research at NASA GRC to Develop 2700ºF-Capable CMC

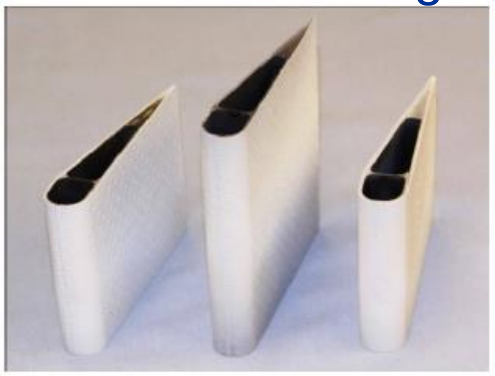
Advanced Silicon Carbide Fiber



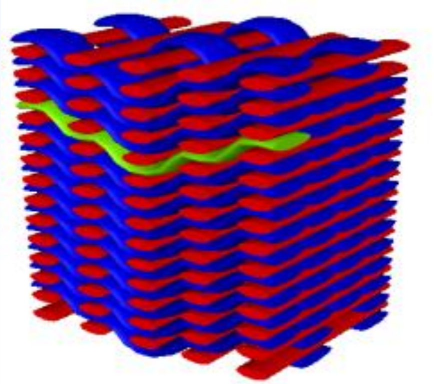
Fabrication Process for Producing Silicon-Free Composite



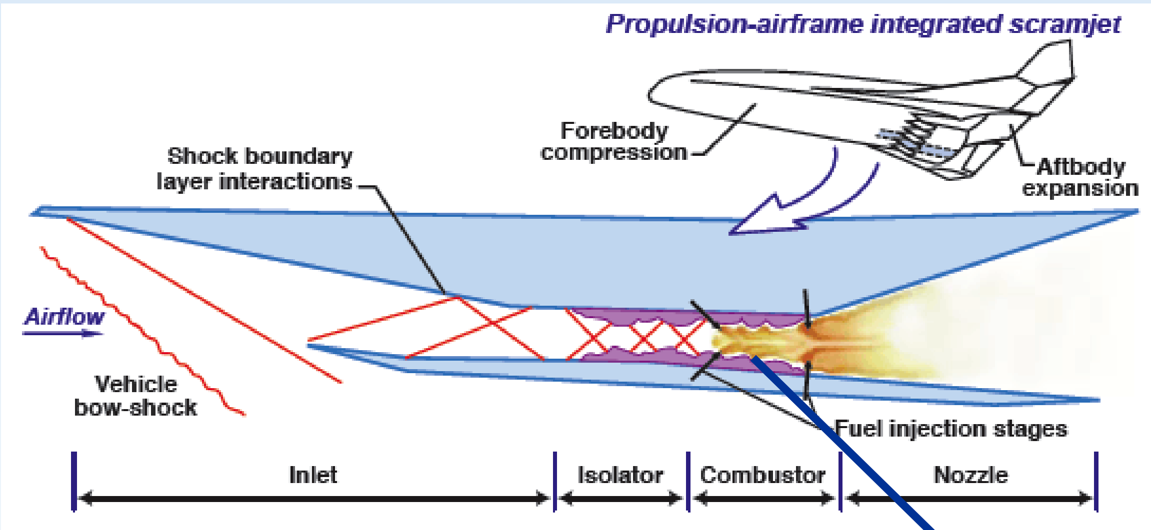
Advanced Environmental Barrier Coatings



Engineered Textile Architecture

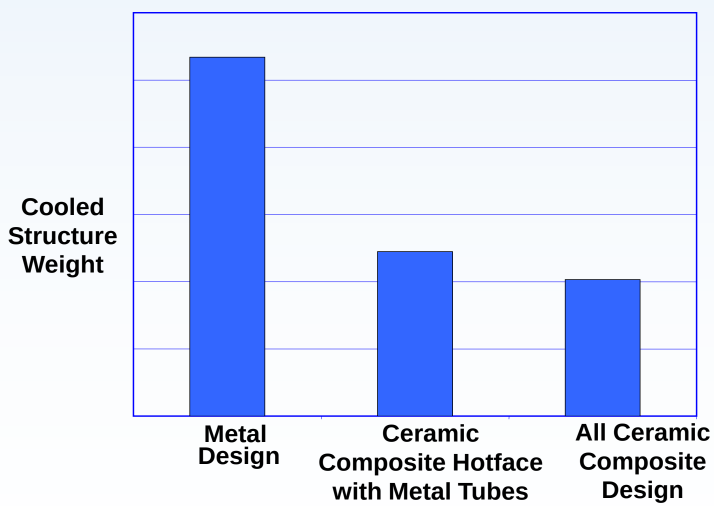


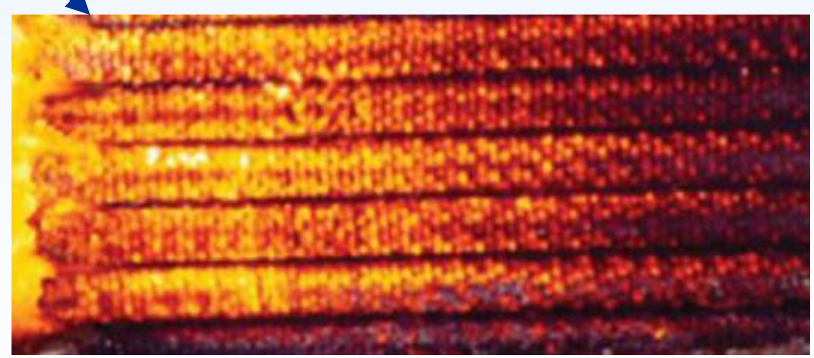
Cooled Ceramic Matrix Composite Structures for Hypersonic Propulsion



Challenges:

- Fabrication of complex fiber architecture
- Durability for Reusability
- New designs



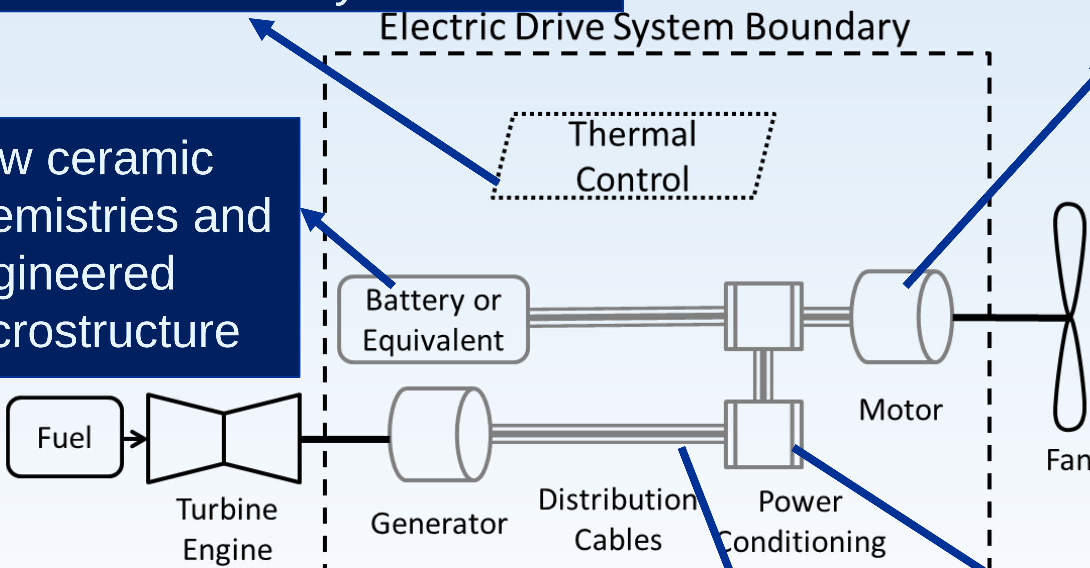


Cooled CMC concepts also applicable to rocket propulsion

Advanced Ceramics Materials Are Enabling for Hybrid Electric Propulsion

- Ceramic thermal interface and substrate materials with high thermal conductivity

- New ceramic chemistries and engineered microstructure



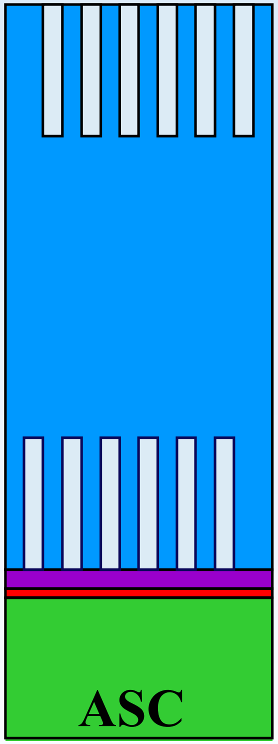
- Small diameter (10 micron) superconducting ceramic coils
- Ceramic or polymer-ceramic composite electrical insulation materials with high thermal conductivity and breakdown voltage

- Durable packaging for high temperature silicon carbide semiconductor
- Ceramic capacitors with high energy density and higher temperature capability

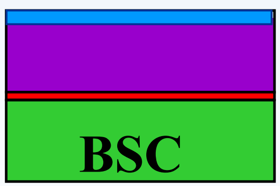
Need 3-5X increase in power density/energy density of components

- Lightweight, high voltage insulation material

Ceramic Material and Processing Innovations for Increasing Power Density of Solid Oxide Fuel Cell



Commercial Design



NASA Design

Interconnect
Cathode
Electrolyte
Anode

	W/kg	W/L
SOA ASC	200	470
NASA BSC	1100	4000

Power density increased by:

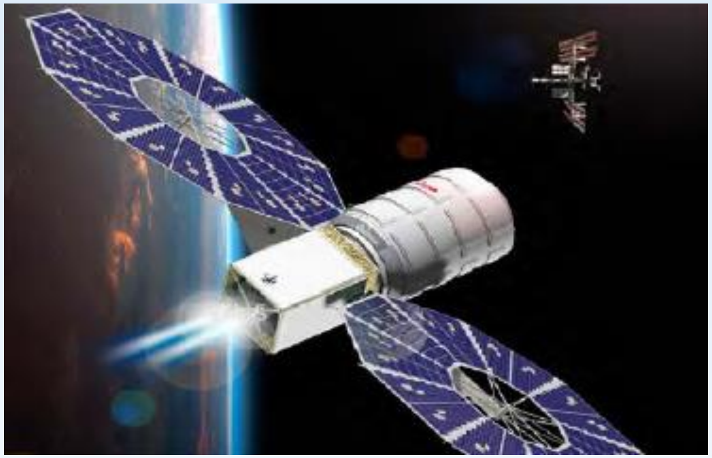
- Microstructural engineering of porous ceramic materials through innovative processing
- Substitution of metallic constituents with ceramic materials
- Integrated ceramic seal design

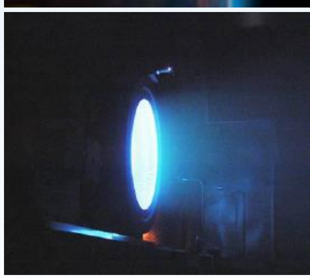
Further increases in power density required for hybrid electric aircraft applications

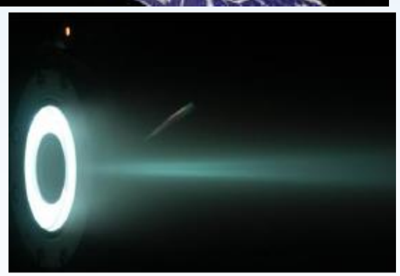
ASC = Anode Supported Cell
BSC = Bi-electrode Supported Cell

Advanced Ceramic Material Needs for High Power (30 kWe or Higher) Solar Electric Propulsion System

Solar Electric Propulsion Incorporating Ion/Hall Thrusters







Provides higher exhaust velocity than chemical rockets – reduces propellant mass and reduction in launch mass – Enabler for space exploration

Need:

- Sputter-resistant boron nitride or advanced ceramics (with low sputter yield, high voltage isolation capability, and low electron emission) for Hall Effect Thrusters (life limited by erosion of boron nitride ceramic discharge chamber)

- Silicon carbide components and lightweight heat sink technology for power processing unit

Emerging Trends

- Additive manufacturing
- Multifunctionality
- Integrated computational materials engineering
- Use of big data analytics
- Engineering of microstructure at atomic level