3D Printing Heat Shields

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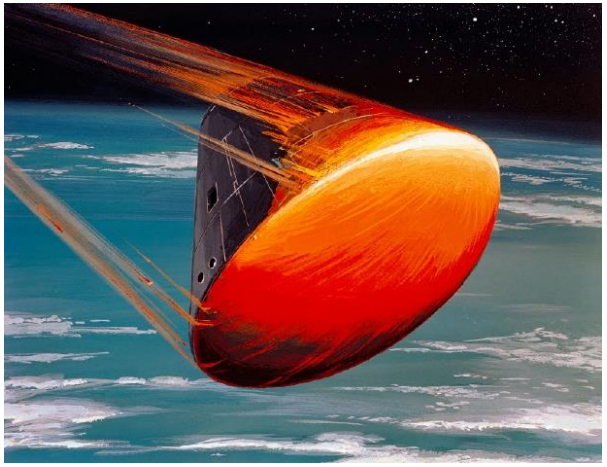
What are Heat Shields?



Space Vehicles are exposed to extreme heating when entering Earth or Mars atmosphere.

Heat shields protect the vehicle from high heating.
Thermal Protection System (TPS)

Apollo heat shield

EFT-1 Orion heat shield
5 meter diameter

Changing the Way We Build Heat Shields

Past & Present

Apollo

Orion EFT-1

Dragon

Labor intensive
Heat Shield Manufacturing

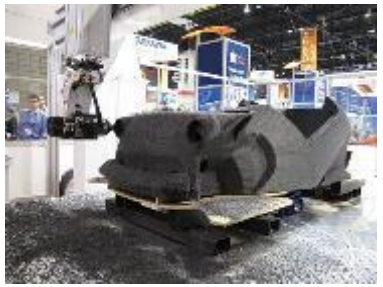
- High cost
- Long duration builds
- Quality issues

Manufacturing Technology

3D Printing

Auto Production

Future



Automated
Heat Shield Manufacturing

- Reduced cost
- Rapid build
- Improve Quality

The Challenge

Develop TPS materials compatible with additive manufacturing techniques.

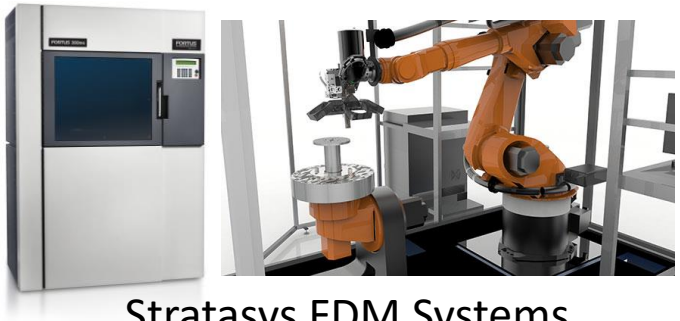
Desired Thermal Protection Material Characteristics

- Typical heat shield materials consist of a binder/resin and fillers
  - Fillers: carbon or glass fibers; phenolic or glass microballoons
- Material Density < 0.7 g/cc
- Material Performance Goals
  - Well-behaved ablator during transient heating of at least 50 W/cm^2, preferably >100 W/cm^2
    - Stable, robust char
    - Minimal spallation
  - High char yield
  - Low thermal conductivity
  - Low coefficient of expansion: CTE < 10 x e-06
- Integration onto Structure
  - Deposited directly onto pre-built structure (preferred)
    - Self-adhering or with adhesive layer already applied
  - Large surface areas – 20+ m^2
  - Thermal post-cure acceptable but limited to <350 F.

Approaches: 1) Modify current 3D printed materials with additives
2) Develop new materials

Potential 3D Printing Techniques

- Fused Deposition Modeling (FDM)
  - Filament or pellet feedstock
    - Several base materials – Nylon, PEI (ULTEM), PEEK (KetaSpire)
    - Polymer additives – fibers, microspheres, nanoclays, others
  - Machines under consideration – Stratasys, Thermwood, Cosine Additive, Made-In-Space, Mark Forged, and open source consumer grade machines
- Contour Crafting
  - TBD 'slurry' deposited
  - Thermal curing or sintering



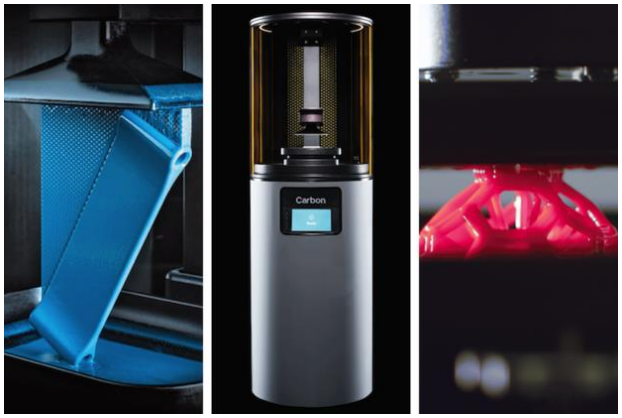
Stratasys FDM Systems

Thermwood LSAM

3D Concrete Printer

Opening the 3D Printing Trade Space

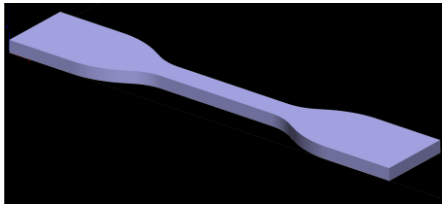
- Printing Thermosets
  - Carbon's Continuous Liquid Interface Production (CLIP)
    - Cyanate ester resin with additives
    - Thermal post-cure
- Challenge is how to apply, cure and attach thermoset materials onto a structure.



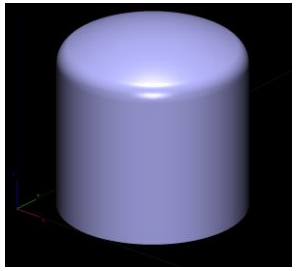
3D Printed TPS Material Screening

Manufacture Test Articles

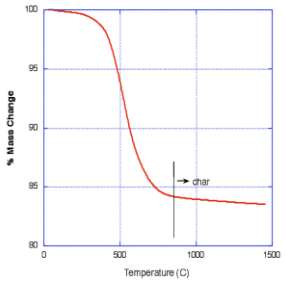
Tensile Test Article



Thermal Test Article (30 mm)

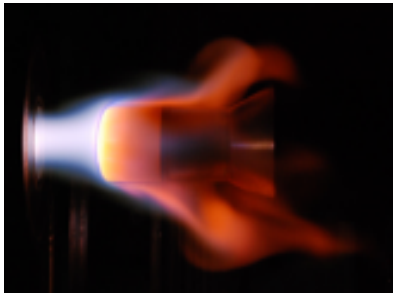


Material Characterization



Thermal Decomposition

Tensile Strength



Air Plasma Tests

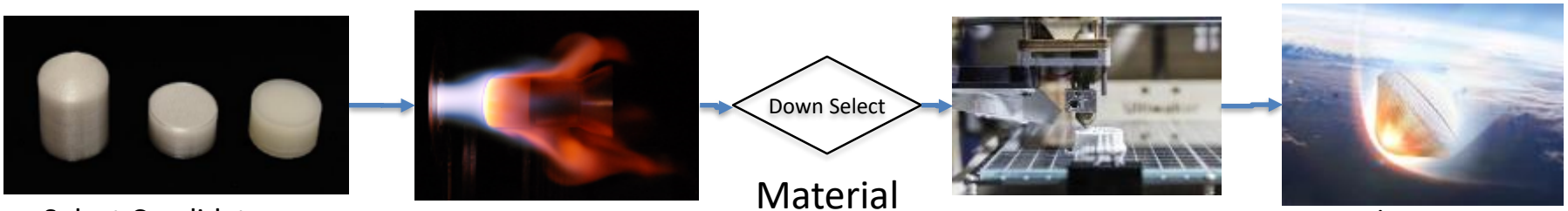
Manufacturing Demonstration Unit (MDU)

3D Print Heat Shield

Technical Goal: Build and Fly

Material Development

Flight Performance Demo



Select Candidates

Test Materials

Material Selection

Build

Fly

Fast Track TPS Materials to Flight