



# 3D Printing Heat Shields

Stan Bouslog/NASA-JSC

Stan.a.Bouslog@nasa.gov

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# What are Heat Shields?



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



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



Apollo heat shield

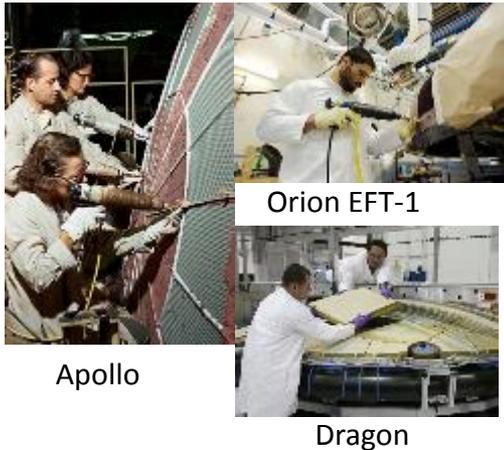


EFT-1 Orion heat shield  
5 meter diameter



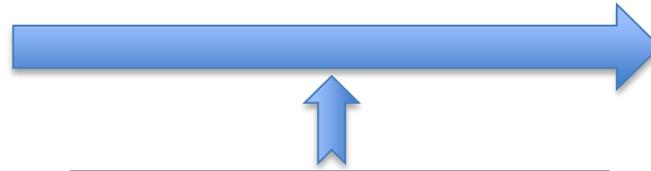
# Changing the Way We Build Heat Shields

## Past & Present



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

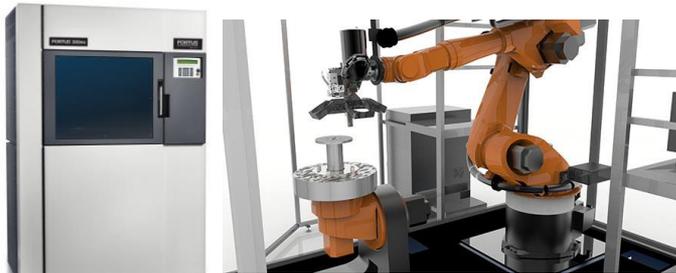
- Typical heat shield materials consist of a binder/resin and fillers
  - Fillers: carbon or glass fibers; phenolic or glass microballoons
- Material Density < 0.7 g/cc
- Material Performance Goals
  - Well-behaved ablator during transient heating of at least 50 W/cm<sup>2</sup>, preferably >100 W/cm<sup>2</sup>
    - 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<sup>2</sup>
  - 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

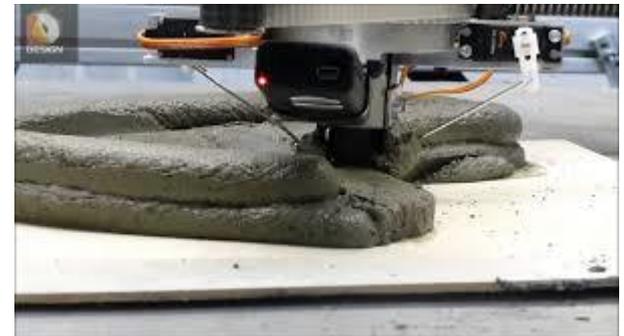
- Fused Deposition Modeling (FDM)
  - Filament or pellet feedstock
    - Several base materials – Nylon, PEI (ULTEM), PEEK (KetaSpire)
    - Polymer additives – fibers, microspheres, others
  - Machines under consideration – Stratasys, Thermwood, Cosine Additive, Made-In-Space, Mark Forged, and open 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 Thermoset Plastics
  - 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.

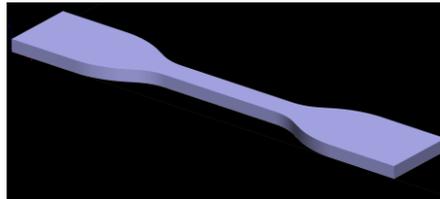




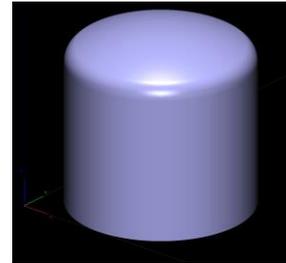
# 3D Printed TPS Material Screening

## Manufacture Test Articles

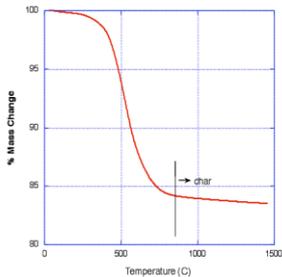
Tensile Test Article



Thermal Test Article (30 mm)



## Material Characterization



Thermal Decomposition



Tensile Strength



Air Plasma Tests

## Manufacturing Demonstration Unit (MDU)



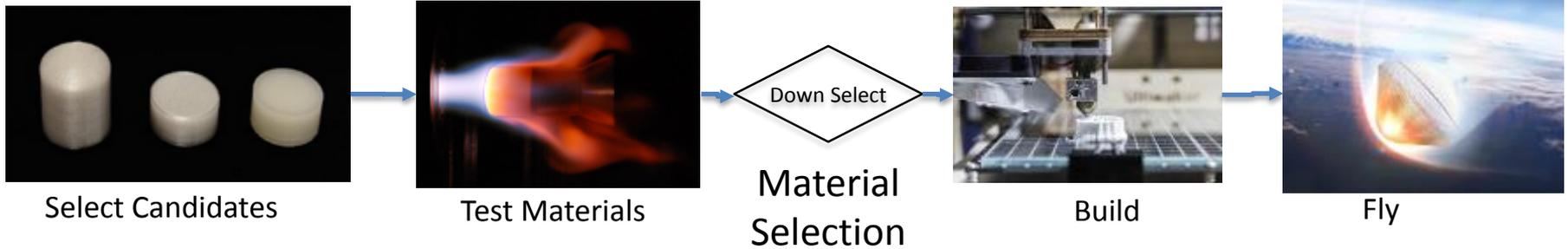
3D Print Heat Shield



# Technical Goal: Build and Fly

## Material Development

## Flight Performance Demo



**Fast Track TPS Materials to Flight**