



3D Printing Heat Shields

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Technology Taxonomy Area (TX): 9.1.1 Thermal Protection Systems; 12.1.4 Materials for Extreme Environments; 14.3.2 Thermal Protection Systems

TRL: start 3 / current 4

FY20 IRAD PROJECT OVERVIEW

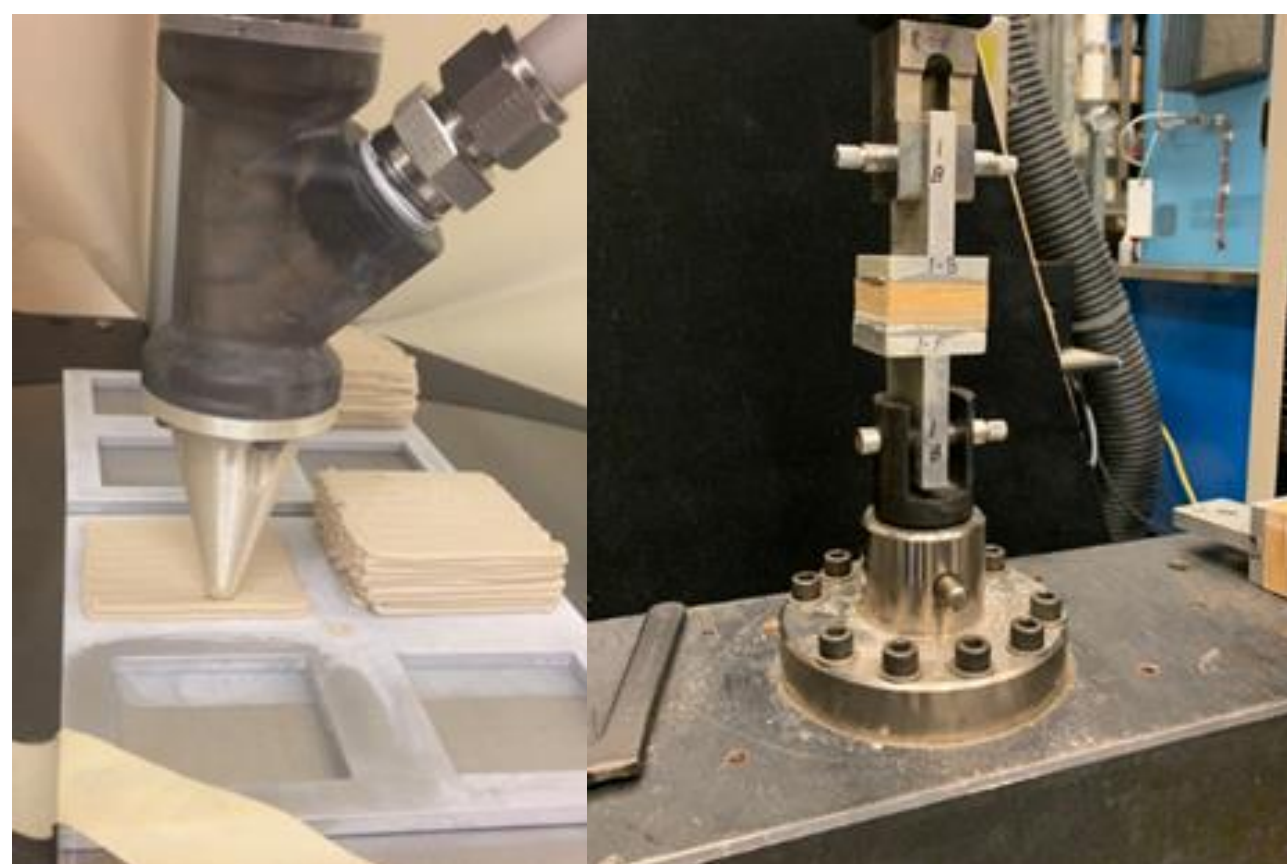
Heat shields that protect spacecraft from the heat of entering a planet's atmosphere are labor intensive to manufacture, cost prohibitive and the heat shield design is constrained by the manufacturing process. Little, if any, automation is used to manufacture and install the thermal protection system (TPS) on the vehicles and most heat shields are segmented with many seams and gaps. We plan to change this paradigm by developing new TPS materials and taking advantage of additive manufacturing technology. To demonstrate this technology a 3D printed heat shield for a flight capsule to be released from Cygnus was fabricated, and will be delivered to ISS in Summer 2021 and return to Earth in Fall 2021 sending thermal data to us on the ground.

INNOVATION

New TPS materials and the processes to print them on a structure are being developed. Printed materials are tested in a plasma torch to assess aerothermal performance and tested in the materials lab to obtain thermal and mechanical properties. Materials are also printed and cured on plates and then pull-tested to assess adhesion to a simulated structure. Tool path algorithms are developed to print the materials on sphere/cone structures used for small capsules.

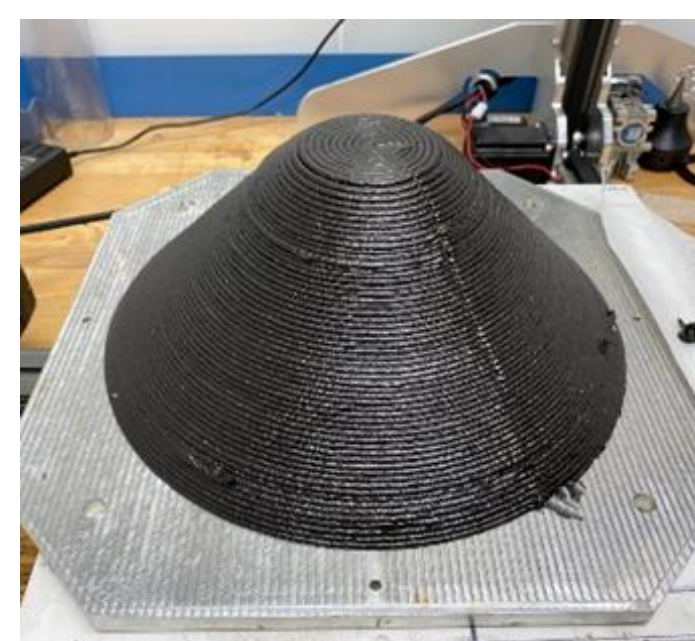
OUTCOME

- Based on printability and material properties, several resin mixtures were down selected. A graded material was developed with formulations for the outer robust layer, the inner insulative layer and the transition layers. Properties of each of these layers were evaluated in testing.
- Flat test articles were printed on plates and pull tested to confirm adhesion to the substrates.
- Algorithms and processes were developed and successfully demonstrated to print the graded material on a ~10-inch diameter sphere cone.



Printing on Plates and Testing the Material for Adhesion

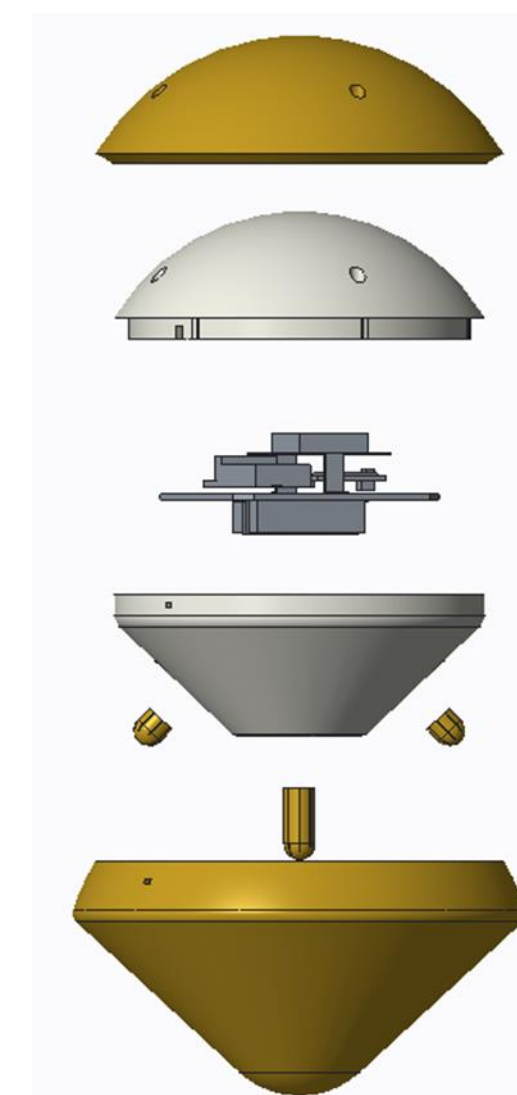
The 3D printed heat shield for a University of Kentucky (UK) capsule was fabricated, instrumented with thermocouples and delivered. Before printing and curing the full-scale heat shield, multiple tests were conducted and multiple trial prints were conducted. Issues with material deformation during the thermal cure were overcome.



Capsule heat shield after printing



Heat shield after machining. Graded material shown.



UK Capsule Assembly

INFUSION SPACE / EARTH

The technology is being transferred to companies through the SBIR/STTR program and these companies are developing their own material systems and means to print and cure the materials in situ on the structure. The technology has expanded beyond ablators on structures to also the fabrication of integrated aeroshells in which automated methods are used to fabricate high-temperature carbon composite structures and install insulation on the inside. These materials and manufacturing methods will be used to build the spacecraft of the future.

PARTNERSHIPS / COLLABORATIONS



A major collaborator for this project is Oak Ridge National Lab (ORNL) Manufacturing Demonstration Facility (MDF). They have modified our material formulations for printability and printed many of the test articles including the flight heat shield for the capsule. We also partnered with the University of Kentucky (UK) who provided us an opportunity to build the heat shield and obtain flight data for one of the capsules to be released from Cygnus during an ISS mission. We also partner with The University of Texas at Austin for conducting simulated entry heating tests in their Inductively Coupled Plasma torch.

FUTURE WORK

This work will continue during a STMD Early Career Initiative (ECI) project. During this project we will again be partnered with ORNL and UK. ORNL has already begun setting up a robotic cell that will print a 1-meter heat shield manufacturing demonstration unit. UK will be building another capsule to be flown on an UpAerospace launcher sponsored by the NASA Flight Opportunities Office. The heat shield for this capsule will be printed by ORNL and the capsule will be recovered.



Robotic Cell at ORNL MDF