Additive Manufacturing of Ceramics for Extreme Environments

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Overview

- Current ceramic manufacturing methods (i.e. extrusion, slip casting, press molding, or injection molding) are often expensive and cannot create parts with complex geometries, thus leading to a limited use of ceramics in the aerospace industry.
- By using additive manufacturing methods, ceramic components can now be fabricated in complex geometries, such as converging nozzles, fuel injectors, and hypersonic leading edges, to near net shape components (part resolution of +/- 0.1mm) and would allow for faster production times (50% reduction in labor hours), lower material costs, and less waste material during the manufacturing process
- Previously funded CAN with Tethon 3D for $62k to study alumina slurry formulations to advance the TRL.
- A Center Investment was awarded for $815k
- End Use Cases:
  - Fuel Injectors
  - Combustion Chambers
  - Turbine Blades
  - High Heat Resistant Nozzles
  - Leading Edges
  - Hypersonic External TPS
  - Hypersonic Control Surfaces

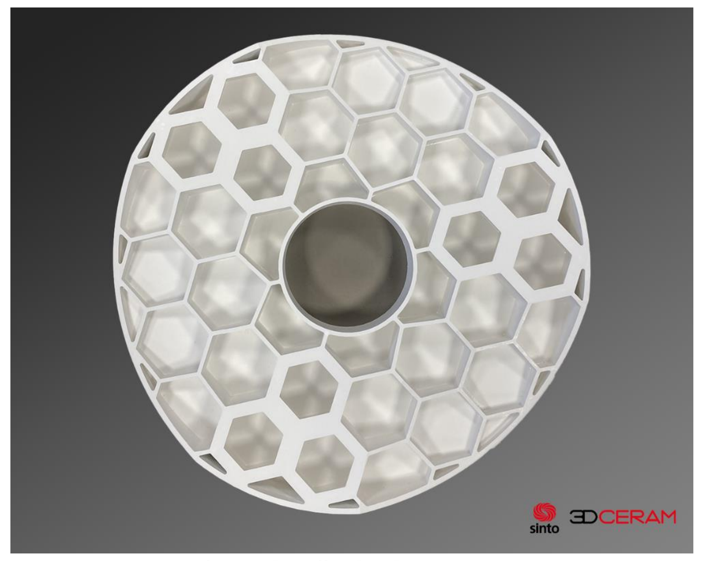
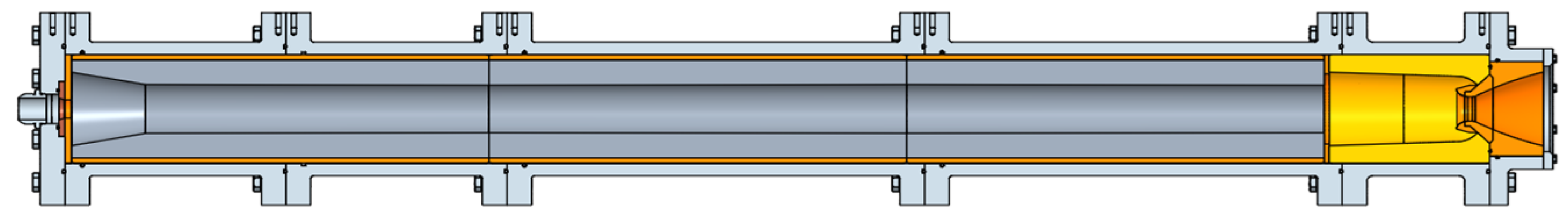
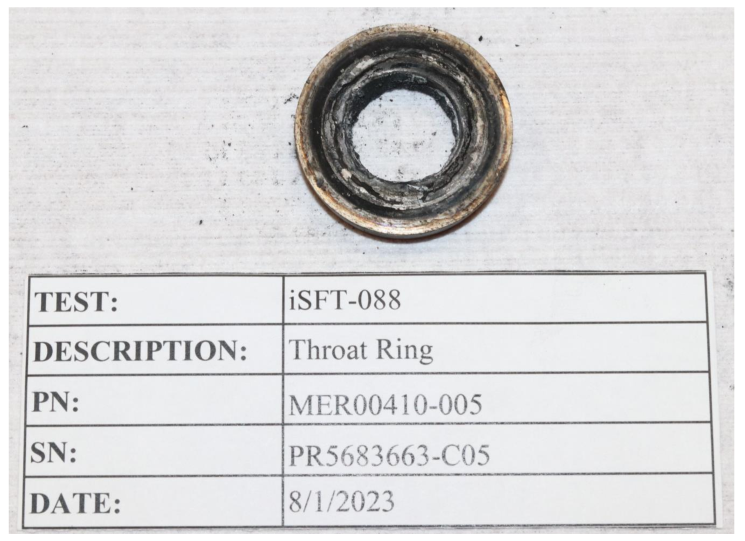


Photo Credit: 3DCeram

KPP:	SOA	Target	Goal
Part Resolution	+/- 0.1 mm	+/- 0.05 mm	+/- 0.025 mm
Build Time	80 hours	40 hours	20 hours
Compressive Strength	690-2500 MPa	2500 MPa	3000 MPa
Thermal Conductivity	23.3 W/m.K	20 W/m.K	12 W/m.K





Technical Approach

- Procure SLA additive manufacturing system and complete all necessary training and facilities startup work
- Identify material property and performance requirements necessary to close materials for extreme environments gap
- Identify key existing ceramic materials of interest and develop new candidate formulations with ORNL and 3D Ceram to target high temperature extreme environments for propulsion applications
- Build and test coupons with various printing parameters per design of experiments
- Analyze materials testing data to drive design of components
- Develop the quality management plan for ceramic additive manufacturing such that it meets the requirements or intent outlined in NASA-STD-6030 and NASA-STD-6033
- Build component(s) for existing solid fuel torch tests, thus demonstrating material use in relative extreme heat environments and increasing TRL
- Potential risks may include: issues understanding green body shrinkage, complications in the sintering process, constituent material / additives availability issues, facilities upgrades exceeding predicted budgets

3D Ceram C1000

- The C1000 printer is a dual laser stereo lithography printer which provides a constant laser output for more precise control of dimensional changes resulting in homogeneous polymerization of material
  - Printing Volume: 320 x 320 x 200 mm
  - Layer Thickness: 0.020-0.125 mm

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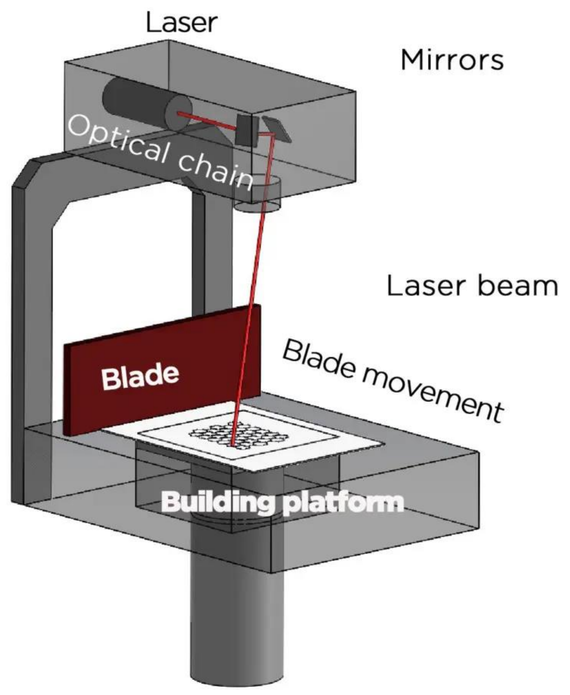

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Future Work

- Partnership with Langley Research Center to manufacture wind tunnel test specimens representative of hypersonic control surfaces.
- Partnership with Oak Ridge National Labs to formulate and manufacture new material variations.
- Permanent replacement for current non-reusable ablative components on MSFC subscale rocket motor testbeds
- Pursue partnerships with human lander system, nuclear thermal propulsion projects, and moon to mars surface technologies.

Acknowledgements

- Special thanks to EM40 and ER60 leadership, Chris Protz, John Vickers, Materials and Processes Lab leadership, and Center leadership for their mentorship and support