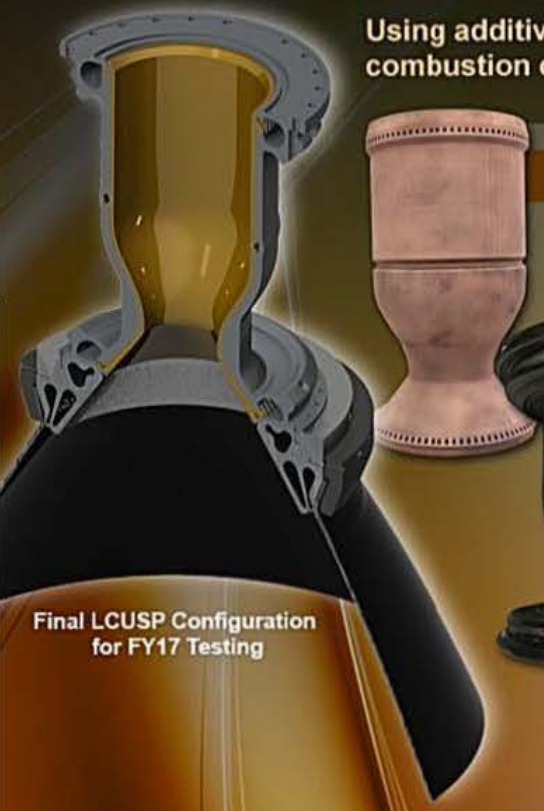
National Aeronautics and Space Administration

NASA

ADVANCED MANUFACTURING TECHNOLOGY

Low Cost Upper Stage-Class Propulsion

Using additive manufacturing to develop high pressure/high temperature combustion chambers and nozzles with copper and nickel alloys



Final LCUSP Configuration for FY17 Testing

Selective Laser Melting (SLM) of GRCop-84

Metal powder bed fusion builds the part by melting layer upon layer at a time.

SLM benefits include:

- Ability print complex integral coolant passages
- Ability to print complex geometries previously not possible with conventional machining fabrication methods

Electron Beam Free Form Fabrication (EBF^3) of Inconel 625

A nickel structural jacket was applied over the copper liner.

EBF^3 benefits include:

- Ability to directly deposit onto liner
- Ability to integrate jacket, manifold and flanges in one step

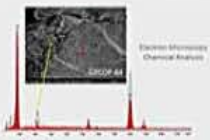
Integrated Nozzle Film Coolant Ring

Includes regen coolant channels on the hotwall and integrated inlet and outlet manifolds
(Printed at API in one-piece)

Materials Characterization & Analysis ...

Throughout the process of building between the two additive manufacturing methods, material characterization and analysis helps develop relationships between build parameters, microstructure, and mechanical performance that can be used to inform future manufacturing and design decisions.

Initial Tensile Testing
Fractography
Hot Isostatic Pressure
SEM Observations
Structured Light Scanning
Computed Tomography NDE analysis
AM GRCop-84 and IN-625 mechanical properties



Printed faceplate for ox-rich staged combustion testing

Hot Fire Test in relevant environments demonstrates the technologies and advances Technology and Manufacturing Readiness Levels of the copper alloy additive manufacturing process, the Electron Beam Free Form Fabrication process and the combination of both for rocket engine components.

LCH4 Cooled 3D SLM Printed GRCop-84 Chamber