# Design, Development and Hotfire Testing of Monolithic Copper and Bimetallic Additively Manufactured Combustion Chambers

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NASA and industry partners are working towards fabrication process development to reduce costs and schedules associated with manufacturing liquid rocket engine components with the goal of reducing overall mission costs. One such technique being evaluated is powder-bed fusion or selective laser melting (SLM) otherwise commonly referred to as additive manufacturing. The NASA Low Cost Upper Stage Propulsion (LCUSP) program was designed to develop processes and material characterization for the GRCop-84 copper-alloy commensurate with powder bed additive manufacturing, evaluate bimetallic deposition and complete testing of a full scale combustion chamber. As part of this development, the process has been transferred to industry partners to enable a long-term supply chain of monolithic copper combustion chambers. As a direct spin off of this program, NASA is working with industry partners to further develop the printing process for the GRCop-84 material in addition to the C-18150 (CuCrZr) material. To advance the process further and allow for optimization with multiple materials, NASA is also investigating the feasibility of bimetallic additively manufactured chambers. A 1.2k sized thrust-chamber was designed and developed to compare the printing process of the GRCop-84 and C-18150 SLM materials. A series of similar MCC liners also completed development with an Inconel 625 jacket bonded to the GRcop-84 liner evaluating direct metal deposition (DMD) laser and arc-based techniques. This paper describes the design, development, manufacturing and testing of these combustion chambers and associated lessons learned throughout the design and development process.