Subscale Carbon-Carbon Nozzle Extension Development and Hot Fire Testing in Support of Upper Stage Liquid Rocket Engines

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Upper stage and in-space liquid rocket engines are optimized for performance through the use of high area ratio nozzles to fully expand combustion gases to low exit pressures increasing exhaust velocities. Due to the large size of such nozzles and the related engine performance requirements, carbon-carbon (C/C) composite nozzle extensions are being considered for use in order to reduce weight impacts. NASA and industry partner Carbon-Carbon Advanced Technologies (C-CAT) are working towards advancing the technology readiness level of large-scale, domestically-fabricated, C/C nozzle extensions. These C/C extensions have the ability to reduce the overall costs of extensions relative to heritage metallic and composite extensions and to decrease weight by 50%. Material process and coating developments have advanced over the last several years, but hot fire testing to fully evaluate C/C nozzle extensions in relevant environments has been very limited. NASA and C-CAT have designed, fabricated and hot fire tested multiple subscale nozzle extension test articles of various C/C material systems, with the goal of assessing and advancing the manufacturability of these domestically producible materials as well as characterizing their performance when subjected to the typical environments found in a variety of liquid rocket and scramjet engines. Testing at the MSFC Test Stand 115 evaluated heritage and state-of-the-art C/C materials and coatings, demonstrating the capabilities of the high temperature materials and their fabrication methods. This paper discusses the design and fabrication of the 1.2k-lbf sized carbon-carbon nozzle extensions, provides an overview of the test campaign, presents results of the hot fire testing, and discusses potential follow-on development work.