National Aeronautics and Space Administration

NASAfacts

Space Technology

Game Changing Development

Low Cost Upper Stage-Class Propulsion (LCUSP)

Overview

NASA is making space exploration more affordable and viable by developing and utilizing innovative manufacturing technologies. Technology development efforts at NASA are committed to continuous innovation in rocket engine design and manufacturing technologies in order to reduce the cost of NASA's journey to Mars. The Low Cost Upper Stage-Class Propulsion (LCUSP) effort will develop and utilize emerging additive manufacturing (AM) to significantly reduce the development time and cost for complex rocket propulsion hardware.

Aft chamber segment of a development unit printed with GRCop-84 demonstrating the ability to print features required for thrust chamber.

Additive Manufacturing (3-D Printing) Benefits

Current rocket propulsion manufacturing techniques are costly and have lengthy development times. In order to fabricate rocket engines, numerous complex parts made of different materials are assembled in a way that allow the propellant to collect heat at the right places to drive the turbopump and simultaneously keep the thrust chamber from melting. The heat conditioned fuel and oxidizer propellants come together and burn inside the combustion chamber to provide thrust. The efforts to make multiple parts precisely fit together and not leak while experiencing cryogenic temperatures on one side and combustion temperatures on the other is quite challenging.

AM has the potential to significantly reduce the time and cost of making rocket parts, like the copper liner and nickel-alloy jackets found in rocket combustion chambers where super-cold propellants are heated and mixed to the extreme temperatures needed to propel rockets in space. The selective laser melting (SLM) machine fuses 8,255 layers of copper powder to make an LCUSP chamber section in 20 days. Machining an equivalent part and assembling it with welding and brazing techniques could take months to accomplish with potential failures or leaks requiring fixes.

The design process is also enhanced because it does not require the 3-D model to be converted to 2-D drawings. The design and fabrication process can be accelerated with fewer errors and completed in weeks instead of months.

Project Description

The LCUSP project focuses on two manufacturing processes. The first process takes place at NASA's Marshall Space Flight Center and will enable complex coolant passages to be directly printed using SLM 3-D printing technology out of GRCop-84 powder, a copper alloy developed by NASA's Glenn Research Center. GRCop-84 is an alloy that combines the excellent copper heat conduction property with higher strength material properties. The GRCop-84 powder was procured from Allegheny Technologies Incorporated. The second process utilizes the E-Beam Free Form Fabrication (EBF3) Technology, under development by the Langley Research Center, to deposit a nickel-alloy structural jacket to the GRCop-84 liner. These processes enable previously unachievable design features that will be demonstrated by fabrication of chamber and nozzle test articles. The process and design development goal is to enable a repeatable process that industry can quickly and reliably adopt to manufacture advanced engine parts.

In 2017, the engine combustion chamber component will be hot-fire tested at Marshall to determine the engine performance under extreme temperatures and pressures on the test stand. In the summer of 2017, the tested combustion chamber will be integrated into a 25,000-pound force engine test bed simulating an entire rocket thrust chamber assembly and will advance this 3-D manufacturing technology for application toward a flight engine.

AM technologies are maturing rapidly and appear to be a viable option to reduce production time and cost. Although AM is currently being used for other industries, rocket-specific materials and applications are not widely available. The extreme conditions and stringent requirements for high value components and human-rated flight systems call for a different level of materials and supporting characterization than typical AM applications. The datasets on AM-produced materials are rare compared with traditional manufacturing capabilities like casting, forging, and rolling.

With limited materials characterized for AM for NASA's particular applications, Marshall and Glenn will perform

NASA engineers used 3-D printing to make the first full-scale copper engine part, a combustion chamber liner that operates at extreme temperatures and pressures. Structured light scanning, seen on the computer screen, helped verify that the part was built as it was designed.

extensive analysis and materials characterization to help validate the 3-D printing processing parameters and ensure build quality. Material properties will be measured and collected; and processes will be improved for industry applications in unpredictable, productive, and profitable ways. The data will be added to information already collected on 3-D printed parts made out of steel and other materials. All data will be made available to American manufacturers to increase U.S. industrial competitiveness. LCUSP presents an opportunity to develop and demonstrate a process that can infuse these technologies into industry, build competition and drive down costs of future engines.

The Game Changing Development (GCD) Program investigates ideas and approaches that could solve significant technological problems and revolutionize future space endeavors. GCD projects develop technologies through component and subsystem testing on Earth to prepare them for future use in space. GCD is part of NASA's Space Technology Mission Directorate.

For more information about GCD, please visit
http://gameon.nasa.gov/

National Aeronautics and Space Administration

Marshall Space Flight Center
Huntsville, AL 35812
www.nasa.gov/marshall

www.nasa.gov

FS-2017-01-003-MSFC