Development and Testing of a Prototype LOX/propylene Upper Stage Engine

Kay Gemba[1], Deepak Verma[1], and Eric Besnard[2]

Mechanical and Aerospace Engineering Department
California State University, Long Beach
1250 Bellflower Blvd.
Long Beach, CA 90840

Abstract

The objective of this paper is to present an early prototype of an upper stage engine which could be evolved into a second stage engine for a Nanosat Launch Vehicle (NLV). The NLV (Figure 1)[i] is designed to deliver a nominal 10 kg payload to LEO and is being developed by the California Launch Vehicle Initiative (CALVEIN), a partnership program between Garvey Spacecraft Corporation and California State University, Long Beach.

The engine uses LOX/propylene, is pressure fed, operates at a chamber pressure of 1 MPa (approx. 150 psi) and provides a vacuum thrust of 2000 N (approx. 450 lbf). Propylene was chosen as the propellant because it provides a higher specific impulse than RP-1 with comparable density at cryogenic temperatures[ii].

This paper presents the preliminary design intended for space operations with an expansion ratio of 70. The targeted combustion efficiency is 95% and nozzle efficiency is 98%, corresponding to a specific impulse of 347 s.

Consistent with the incremental approach used by the team, these requirements are relaxed for the first prototype version of the engine in order to conduct a static fire test (SFT) demonstration at sea-level conditions. Figure 2 displays a previous CALVEIN LOX/propylene test that serves as the reference for this next phase of research. For the SFT design, the expansion ratio of the nozzle is reduced to 3 by truncating the nozzle, the targeted combustion efficiency is 90% and nozzle efficiency is 95%.

The combustion chamber assembly is built using an ablative liner and a carbon fiber overwrap, while a flat head injector provides additional film cooling to minimize ablation rates. A pyrotechnic igniter mounted in the center of the injector face is used instead of what will likely be a direct-spark or torch igniter. Also, this first version of the engine uses propylene at room temperatures instead of densifying it.

CFD analyses are performed to correlate the engine prototype performance with test data. Analyses are also conducted for the larger expansion ratio engine in order to quantify whether the NLV goals can be met.

The paper finishes with lessons learned from the engine development and demonstration which will help refine the NLV second stage design and define a set of technical areas to be addressed such as direct spark ignition of LOX-GOX and propylene.

---

[1] AIAA Student Member

[2] Professor, AIAA Senior Member

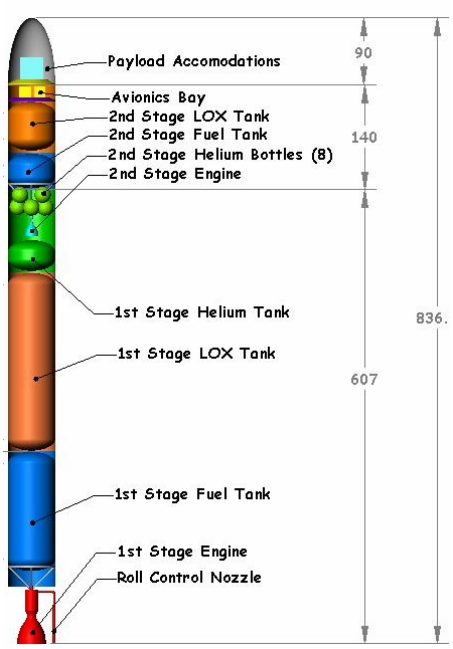

Figure 1. Reference NLV Concept (dimensions in cm). Vehicle diameter is 66 cm.

Figure 2. CALVEIN LOX/Propylene Engine Static Fire Test 11/2004[iii]

---

[i] J. Garvey and E. Besnard, "A Status Report on the Development of a Nanosat Launch Vehicle and Associated Launch Vehicle Technologies," AIAA Paper No. 04-7003, presented at the 2nd Responsive Space Conference, Los Angeles, CA, April 2004.

[ii] Pioneer Astronautics, "LOX Olefin Rocket Propulsion for Deep Space," proposal abstract, NASA SBIR 02-1 Solicitation, proposal no. 02- S1.02-7918, 05 September 2002

[iii] J. Garvey and E. Besnard, "LOX-Propylene Propulsion Testing for a Nanosat Launch Vehicle", AIAA Paper 2005-4294