2010 JPC Abstract
Ares I First Stage Propulsion System Status

Alex S. Priskos[1]
Ares First Stage Element Manager
NASA, Marshall Space Flight Center, Huntsville, Alabama, 35812

Abstract

In November 2005, NASA created the Constellation Program to develop an entirely new fleet of spacecraft to include the Ares I Crew Launch Vehicle and Ares V Cargo Launch vehicles. This mission architecture included the Orion capsule (which would be used to transport astronauts to low-Earth orbit and beyond), the Altair lunar lander, and an Earth departure stage.

The Ares First Stage Team has made significant progress on the design of a propulsion system to meet the objectives of the Constellation Program. Work on a first stage element propulsion system capable of lofting a new fleet of spacecraft is well underway.

To minimize technical risks and development costs, the Solid Rocket Boosters (SRBs) of Shuttle served as a starting point in the design of a new motor that would meet the requirements of those new vehicles. This new propulsive element will provide greater total impulse utilizing a fifth segment to loft a safer, more powerful fleet of space flight vehicles. Performance requirements, basic architecture, and obsolescence issues were all factors in determining the new first stage element design and configuration.

Early efforts focused on creating designs that would be capable of supporting the requisite loads and environments. While the motor casings are Shuttle legacy, because of Ares I's unique in-line configuration, the first stage will require entirely new forward structures (forward skirt, forward skirt extension, aeroshell, and frustum) and a modified systems tunnel. The use of composites facilitated a change in the geometry, which in turn afforded the ability to focus strength where it was needed without additional mass.

The Ares First Stage rocket motor casting tooling was designed and built to achieve a propellant grain geometry that produces the specific required ballistic profile. The new propellant formulation is a polybutadiene acrylonitrile (PBAN) copolymer, which has been modified to attain the desired burn rate and retain adequate tailoring capability.

Figure 1. Ares I-X.

[1] Ares First Stage Element Manager, JP20, NASA, Marshall Space Flight Center, Huntsville, Alabama, 35812

Other significant upgrades are in a new internal insulation system. Although it will support the thermal protection demands of the new propellant formulation, with the elimination of asbestos from the formulation, it will be lighter and more environmentally friendly than the current insulation used on the Shuttle RSRBs. Incorporation of new lower temperature materials in the O-rings of the motor will facilitate the removal of joint heaters and further simplify launch site operations.

Although functionally similar to the Space Shuttle SRB avionics system, the new first stage element has a brand new state of the art avionics subsystem (FSAS). Going from a four to a three-channel single fault tolerant avionics system, six Line Replaceable Units (LRUs) will replace the two Integrated Electronic Assemblies (IEAs) of Shuttle.

The Ares I First Stage element is longer and heavier, and it reenters the Earth's atmosphere from a higher altitude and at a significantly higher velocity than does the Space Shuttle SRB. Consequently, a redesigned reentry Deceleration Subsystem (DSS) was required for the safe recovery of the Ares I First Stage booster. The system includes three distinct parachutes: the pilot, the drogue, and three main parachutes. With more scheduled, NASA has already been conducting design development, concept, drop and flight-tests for the Ares I parachute recovery system. The entire system was tested as a unit in the Ares I-X flight test.

Significant progress has been made in the design, development and testing of the new Ares First Stage Element. Although ongoing and in progress, testing to date has included pyro and igniter testing, deceleration subsystem testing, separation testing, thermal protection system testing, avionics, and motor testing, including the DM-1.

Figure 2. DM-1 Test Fire

The four development motors (DMs) will represent a configuration and ballistics test progression, which will then move through three qualification motor (QM) tests before reaching the final Ares First Stage flight configuration. The DM-1, which was the first in this series, validated much of the engineering development to date. All of the motor's ballistic performance parameters were within the allowable requirement limits. Initial evaluations indicating the primary test objectives, which included developing an understanding of delivered motor ballistics, internal insulation performance, and nozzle performance were all met. Although hardware assessments are still in progress and will continue into the spring of 2010, substantive data has already been collected and analyzed, allowing the Ares First Stage team to move forward, fine-tune the design, and advance to DM-2, which is currently in fabrication. Tentatively scheduled for the summer of 2010, DM-2 will demonstrate cold motor performance and provide the opportunity to evaluate design upgrade options.

In the meantime, the suborbital development flight, Ares I-X, provided the opportunity to gather critical data about the flight dynamics of the integrated launch vehicle stack. Incorporating a mix of flight and mockup hardware, along with a vehicle length and weight similar to that of the operational Ares I, the Ares I-X provided the engineering and development team data on controlling the long, narrow crew launch vehicle configuration. This provided an improved understanding of the performance and roll characteristics of the new in-line solid rocket design. It allowed a fuller characterization of the new first stage parachute and recovery system. The Ares I-X test flight validated a significant number of the Ares First Stage design objectives. It also brought a more comprehensive understanding in a number of areas (which are now being analyzed and will be discussed more fully in the final paper), allowing the team to move forward toward the final design of the new Ares First Stage element.

This paper will provide an overview of the design, development, challenges, and progress on the production of the new Ares First Stage propulsion system. Challenges and mitigation strategies, such as with tribo-electrification, recovery dents, and thrust oscillation will be addressed. An overview will be included of testing to date and an analysis of the results of the DM-1 test firing and the Ares I-X flight test.

Nomenclature

BDM = Booster Deceleration Motor
BTM = Booster Tumble Motor
CEV = Crew Exploration Vehicle
CLV = Crew Launch Vehicle
DDT&E= Design, Development, Test, and Evaluation
DM = Development Motor
DSS = Deceleration Subsystem
EDS = Earth Departure Stage
EELV = Evolved Expendable Launch Vehicle
FSE = Forward Skirt Extension
FSAS = First Stage Avionics Subsystem
ICD = Interface Control Document
ICD = Interface Control Drawing
IEA = Integrated Electronic Assemblies
ISS = International Space Station
LAS = Launch Abort System
LEO = Low-Earth Orbit
LRU = Line Replaceable Unit
MSFC = Marshall Space Flight Center
NASA = National Aeronautics and Space Administration
PBAN = Polybutadiene Acrylonitrile
QM = Qualification Motor
RSRB = Reusable Solid Rocket Booster
SRB = Solid Rocket Booster
SSME = Space Shuttle Main Engine
TPS = Thermal Protection System