Propulsion Overview of the Orion Pad Abort 1 (PA-1) Flight-Test Vehicle

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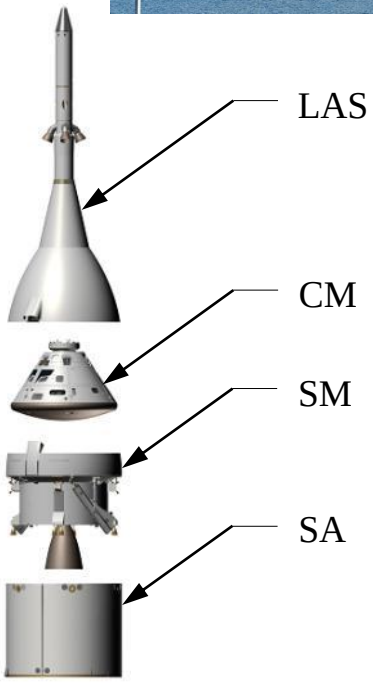
Outline

- Introduction
- Launch Abort System (LAS) Abort Motor (AM)
- LAS Attitude Control Motor (ACM)
- LAS Jettison Motor (JM)
- Conclusion

Introduction

Constellation, Orion, and the AFT Program

- Constellation Program – Background
  - Continue U.S. human transport capability to the International Space Station (ISS), after the retirement of the Space Shuttle (in 2011)
  - Return humans to the Moon, and eventually utilize for future human missions to Mars
  - Program was cancelled in 2010
- Space Launch System (SLS) Program – Background
  - Transport humans beyond low-Earth orbit, and take them further into our solar system than ever before
  - Provide a transport capability to the ISS, as a backup for commercially developed launch vehicles
- Orion Multi-Purpose Crew Vehicle (MPCV) – Background
  - The Constellation Ares I architecture included the Orion Crew Exploration Vehicle (CEV) (now the Orion MPCV)
  - The new SLS architecture includes the Orion MPCV
  - Consists of: the Launch Abort System (LAS), Crew Module (CM), Service Module (SM), and Spacecraft Adapter (SA)
- Orion Abort Flight Test (AFT) Program
  - Purpose: Conduct a series of flight tests in several launch abort scenarios to certify Orion LAS capability
  - Responsibility: The Orion Flight Test Office (FTO), at NASA JSC
  - The Orion flight-test vehicle integration and operations effort was led by the NASA Dryden Flight Research Center

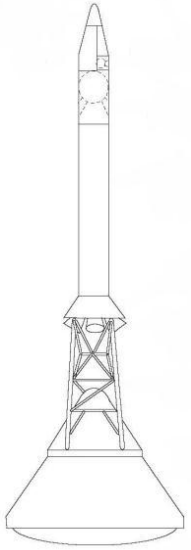


Introduction

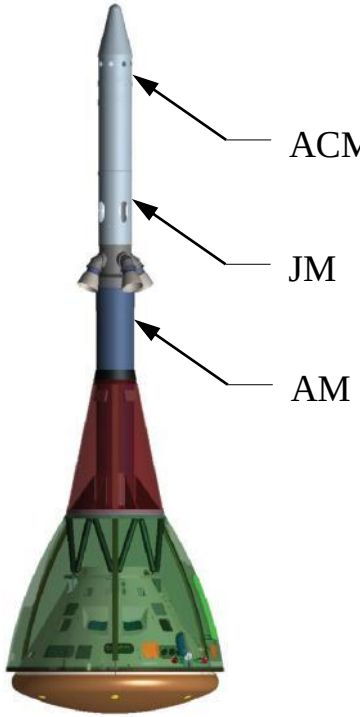
Orion LAS Motors, and a Review of the Apollo LES

- The LAS includes several subsystems, three of which are solid rocket motors: the Attitude Control Motor (ACM), the Jettison Motor (JM), and the Abort Motor (AM)
- Conducted a significant review of the Apollo architecture, including the Apollo Launch Escape System (LES)
- Review of the Apollo Flight Test Program facilitated the initial creation of the Orion AFT Flight Manifest

Apollo 11, during launch

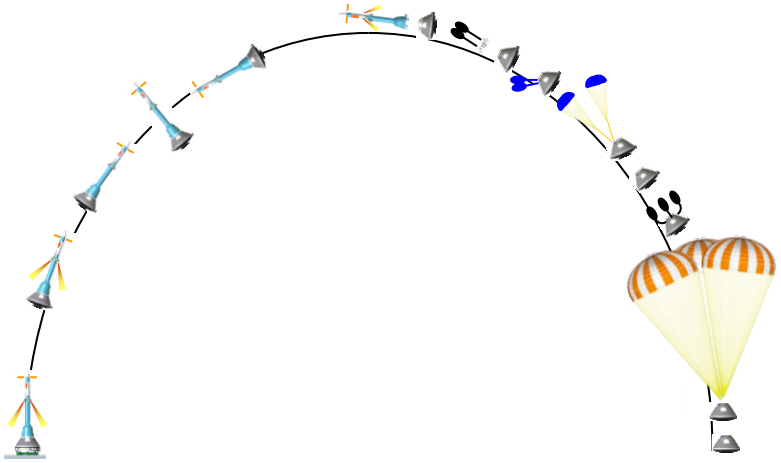


Apollo
CM & LES



Orion Launch Abort Vehicle (LAV)

Orion PA-1 Launch, 06May10



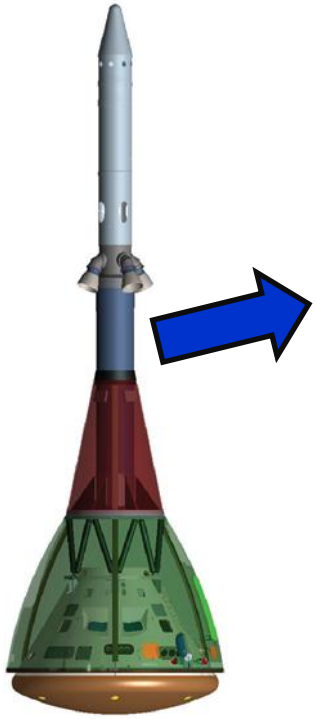
Typical Orion Pad Abort sequence of events

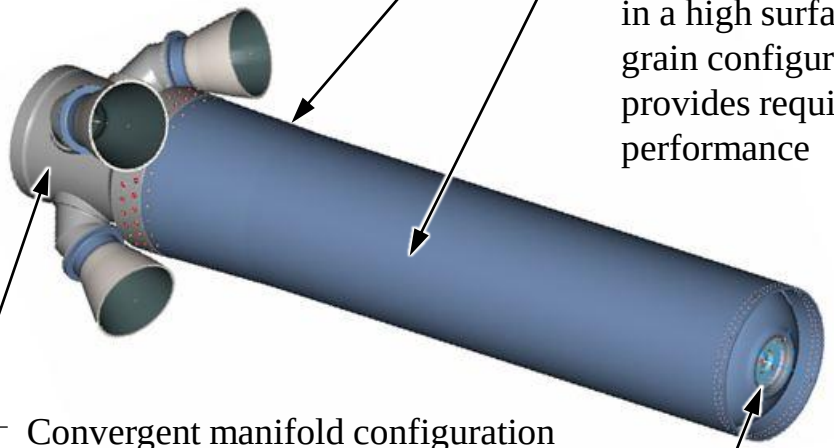
LAS AM Overview, for PA-1

Purpose, Design, and Development

- Purpose: Provide the thrust force necessary to propel the LAV safely away from a failed booster.
  - Thrust is balanced between the desire to escape quickly, and the human tolerance for acceleration.
- Developed by: Alliant Techsystems, Inc. (ATK) in Utah.

High performance turn-flow motor featuring 4 nozzles at an efficient 25 degrees cant
- Total flow turn = 155 degrees





LAS AM manifold during hydroproof testing at ATK

LAS AM Overview

Static Fire Testing and Performance

- Subscale Tests (SST) and one full scale Static Test (ST) were completed prior to PA-1

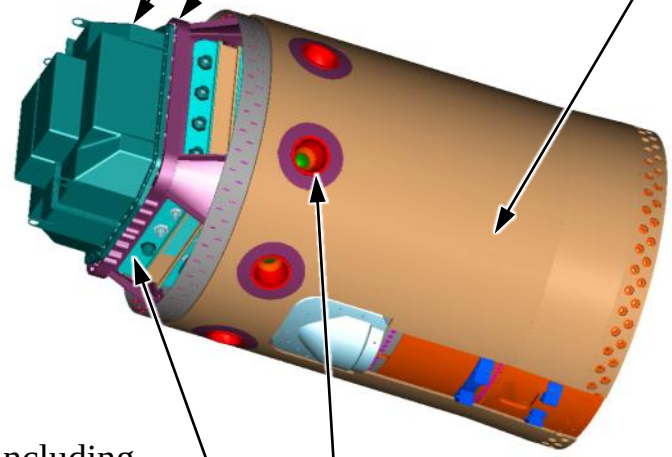
	SST-1	SST-2	ST-1
Static Fire Test Date	26Jun07	10Aug07	20Nov08
Description	Subscale test series: • ~1/4-scale of the geometry • ~1/25-scale of the overall thrust		First full-scale test
Test configuration	Horizontal		Vertical, upside-down
Nozzle configuration	• Two reverse flow nozzles • 180 degrees apart • Canted 25 degrees		• Four reverse flow nozzles • 90 degrees apart • Canted 25 degrees

- PA-1 LAS AM Performance:
  - Nominal maximum thrust: ~500,000 lbf
  - Action time: ~7 seconds

LAS ACM Overview, for PA-1

Purpose, Design, and Development

- Purpose: Provide pitch and yaw control to optimize the LAV abort trajectory.
  - Boost phase: Utilized for LAV directional control during ascent vehicle separation, and stabilizes the LAV during LAS AM operation.
  - Sustain phase: Utilized to pitch-over and reorient the LAV into a “CM heat-shield forward” attitude, and stabilize the LAV in preparation for LAS jettison.
- Developed by: Alliant Techsystems, Inc. (ATK) in Elkton, Maryland.



LAS ACM Overview

Static Fire Testing and Performance

- Several subscale High Thrust (HT) tests were completed
  - Primary focus: To develop the valve assembly

	HT-4	HT-5	HT-6	HT-7	HT-8A
Static fire test date	31Oct07	31Jan08	14Jan09	09Apr08	31Mar09
Number of valves	1	1	1	2	1
Burn time	~9 sec	~27 sec	~27 sec	~8 sec	~13 sec

- Two full scale Demonstration Motor (DM) static fire tests were completed prior to PA-1
  - DM-1: 15Dec09
  - DM-2: 17Mar10 (shown)

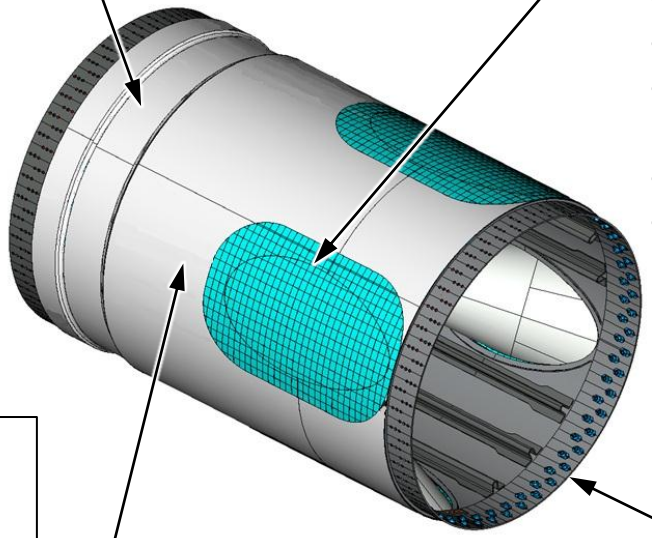
- PA-1 LAS ACM Performance:
  - Maximum thrust: 7,000 lbf
  - Action time: 35 seconds

LAS JM Overview, for PA-1

Purpose, Design, and Development

- Purpose: Provide the thrust force required to jettison the LAS from the Orion CM, in both the abort and nominal flight scenarios.
  - Abort scenario: Utilized after the AM and ACM have performed their functions.
  - Nominal scenario: Utilized with fully loaded AM and ACM propellant.
- Developed by: Aerojet in Sacramento, California.

Gas generator assembly, including a high performing propellant grain design, with a pyrogen igniter



Nozzle assembly, 4 each:
- 17-4 stainless steel housing
- Canted 35 degrees
- 3 nozzles with a large throat, and 1 nozzle with a small throat
- Scarfed to OML of LAS
- (shown with nozzle covers)

Case, aft closure, and shroud assembly, all made with 6AL-4V titanium

Aft closure assembly (not shown)

Shroud assembly: clamshell configuration with structural ribs

LAS JM Overview
Static Fire Testing and Performance

- Subscale Ballistic Test Evaluation System (BATES) tests were successful

	BATES-1	BATES-2	BATES-3
Static Fire Test Date	02Oct07	09Oct07	17Oct07
Top-Level Description	Igniter assembly test in free volume simulator	Axial nozzle assembly test	Canted and scarfed nozzle assembly test
Test Configuration Details	• Full-scale igniter • Open BATES chamber • No nozzle	• Sub-scale igniter • BATES chamber with ~1/4 flight mass propellant • Single nozzle, axial, with flight-like throat	• Sub-scale igniter • BATES chamber with ~1/4 flight mass propellant • Single nozzle, canted and scarfed, with flight-like throat

- Two full scale DM static fire tests were completed prior to PA-1
  - DM-1: 27Mar08
  - DM-2: 17Jul08 (shown)
- PA-1 LAS JM Performance:
  - Nominal maximum thrust: Over 40,000 lbf
  - Action time: ~2 seconds

Conclusion

- The architecture of any human-rated launch vehicle and spacecraft will always require the greatest level of safety.
- PA-1 required the use of three propulsive subsystems: the AM, ACM, and JM.
  - All three successfully demonstrated their required functions during the PA-1 flight.
- Since 2004, hundreds of people across the country have been devoted to increasing flight safety, with the development and testing of the Orion LAS.
  - Includes numerous government and private sector organizations.
- Future flight testing (beyond PA-1) will ensure LAS capability on the SLS/Orion MPCV.

Acknowledgments & References

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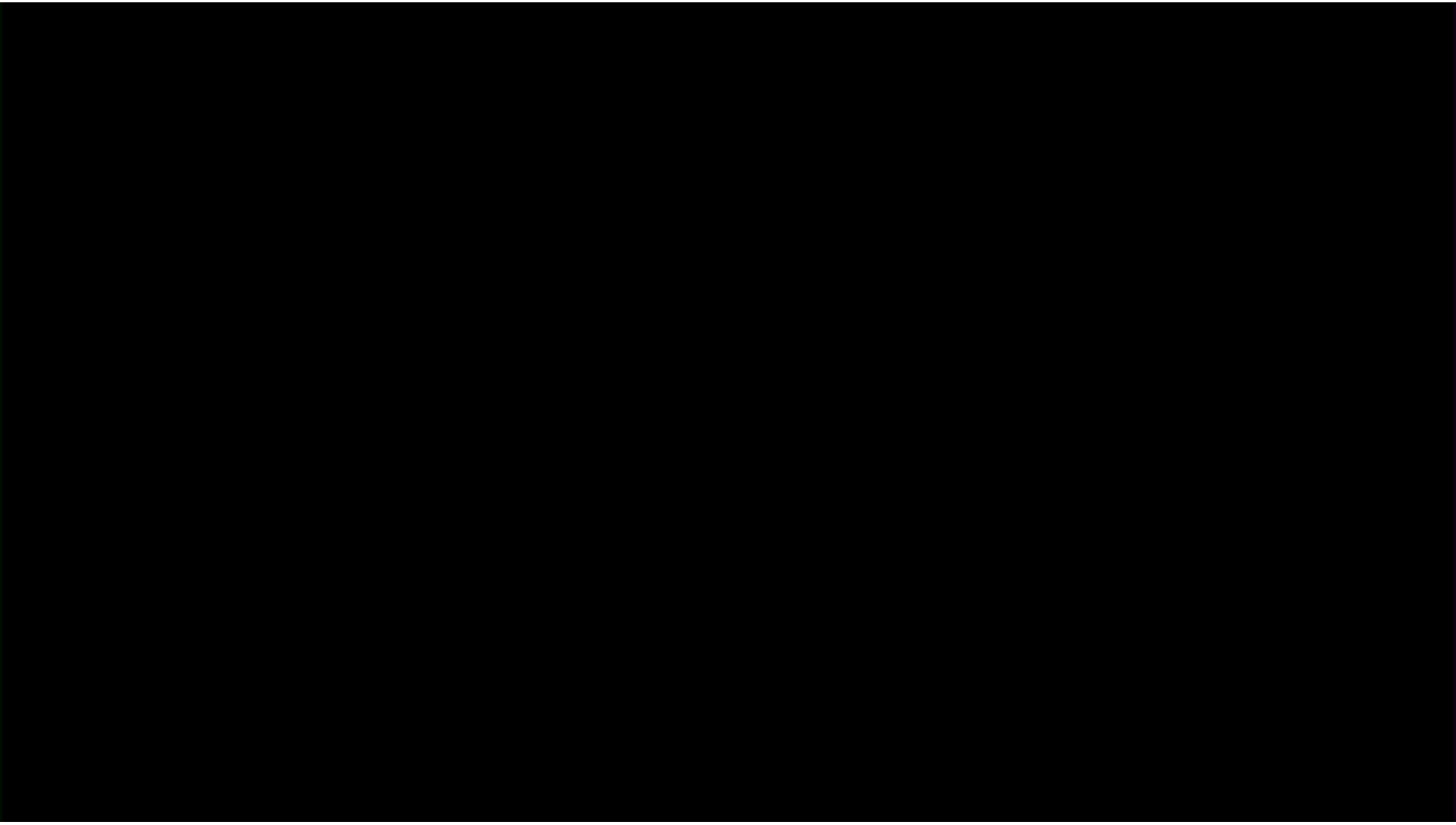
  - Brian Reed, NASA Glenn
  - C. Miguel Duncan, TASC RSLP

- For more detailed information, please refer to the following publication:
  - "Executive Summary of Propulsion on the Orion Abort Flight-Test Vehicles," AIAA 2012-3891.
  - Additional documents have been published, and are available upon request.

Orion PA-1 Video

http://www.youtube.com/watch?v=wzIcDDJyTRI



Courtesy: Space City Films