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

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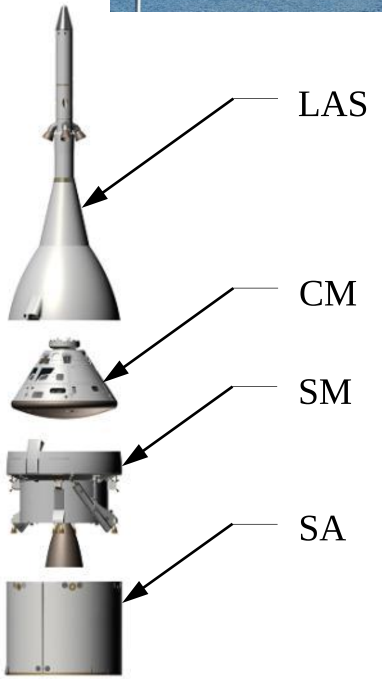
Outline

- 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

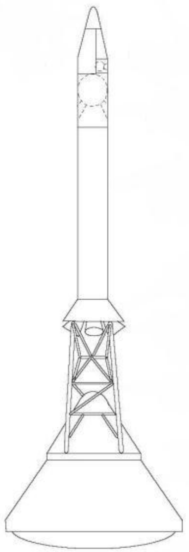


Introduction

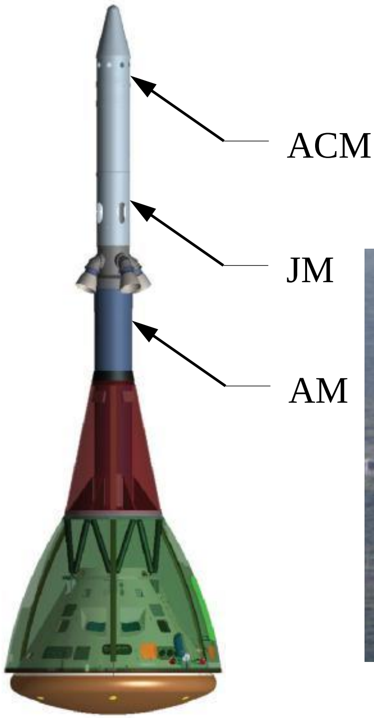
Orion LAS Motors, and a Review of the Apollo LES

- 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

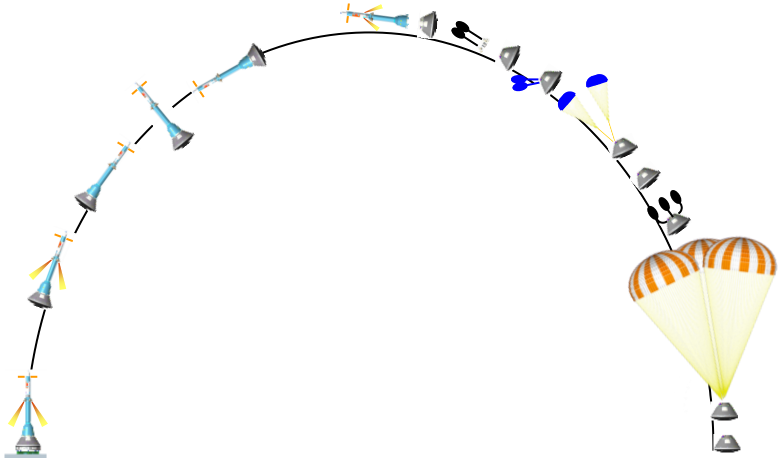


Apollo CM & LES



Orion Launch Abort Vehicle (LAV)

Orion PA-1 Launch, 06May10



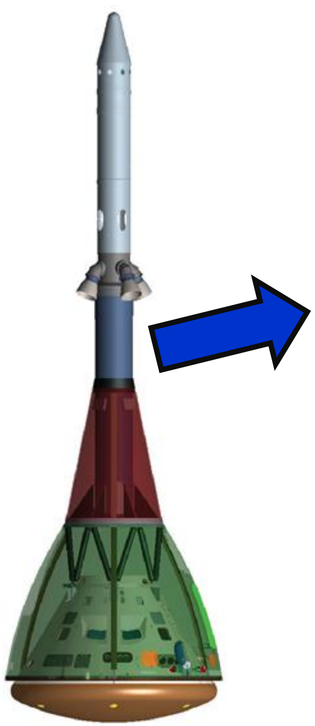
Typical Orion Pad Abort sequence of events

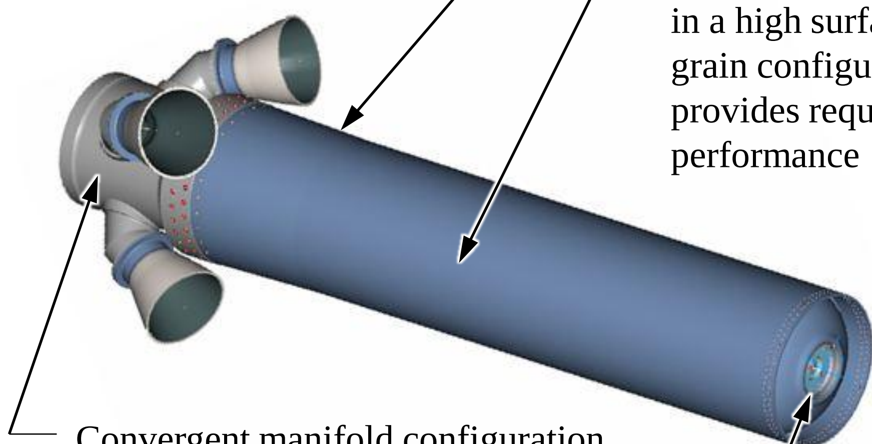
LAS AM Overview, for PA-1

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





Light weight high performance carbon fiber composite case

High burn rate propellant in a high surface area grain configuration provides required abort performance

Convergent manifold configuration stabilizes flow, balances thrust, and maximizes performance

High performance pyrogen igniter

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

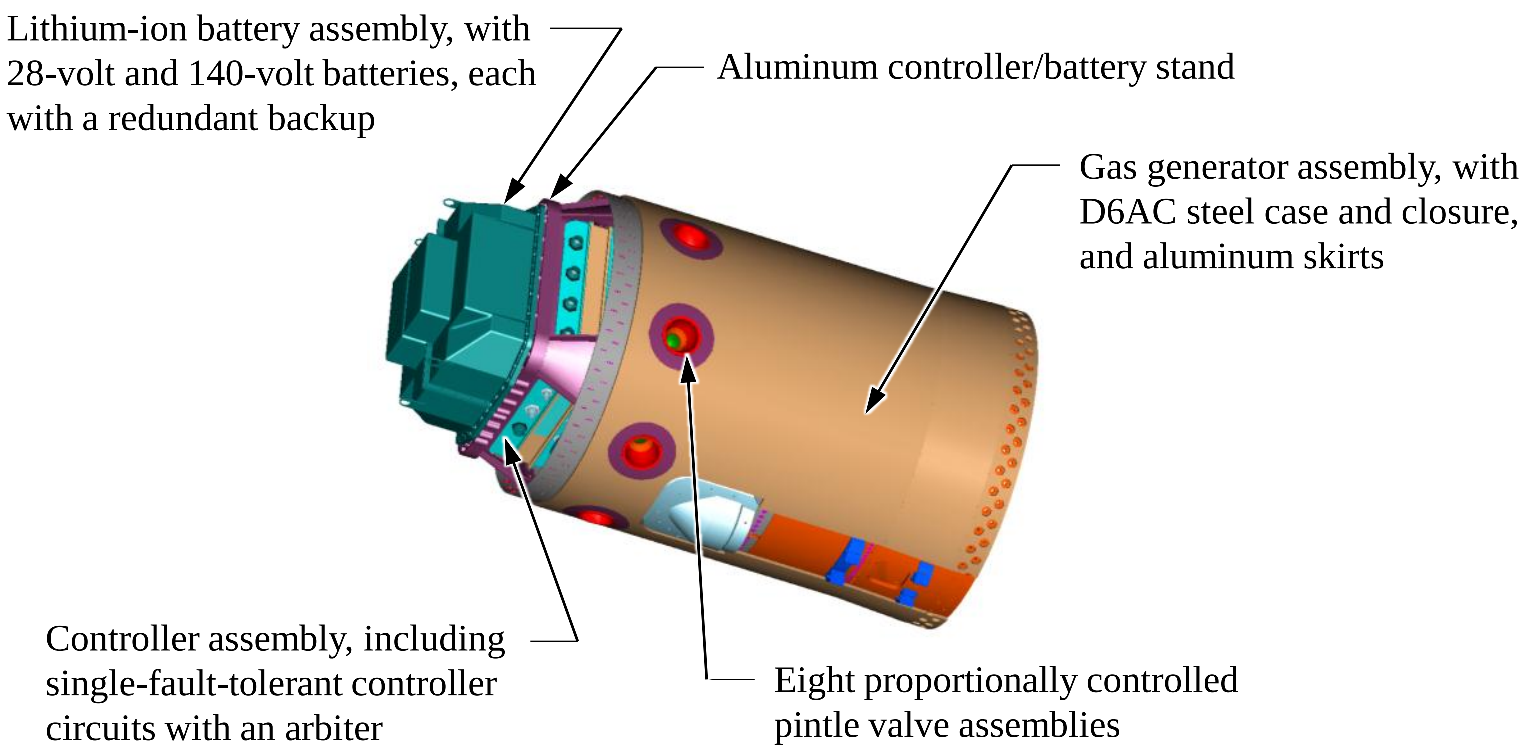
	SST-1	SST-2	ST-1
Static Fire Test Date	26Jun07	10Aug07	20Nov08
Description	Subscale test series: • ~1/4-scale of the geometry • ~1/25-scale of the overall thrust		First full-scale test
Test configuration	Horizontal		Vertical, upside-down
Nozzle configuration	• Two reverse flow nozzles • 180 degrees apart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

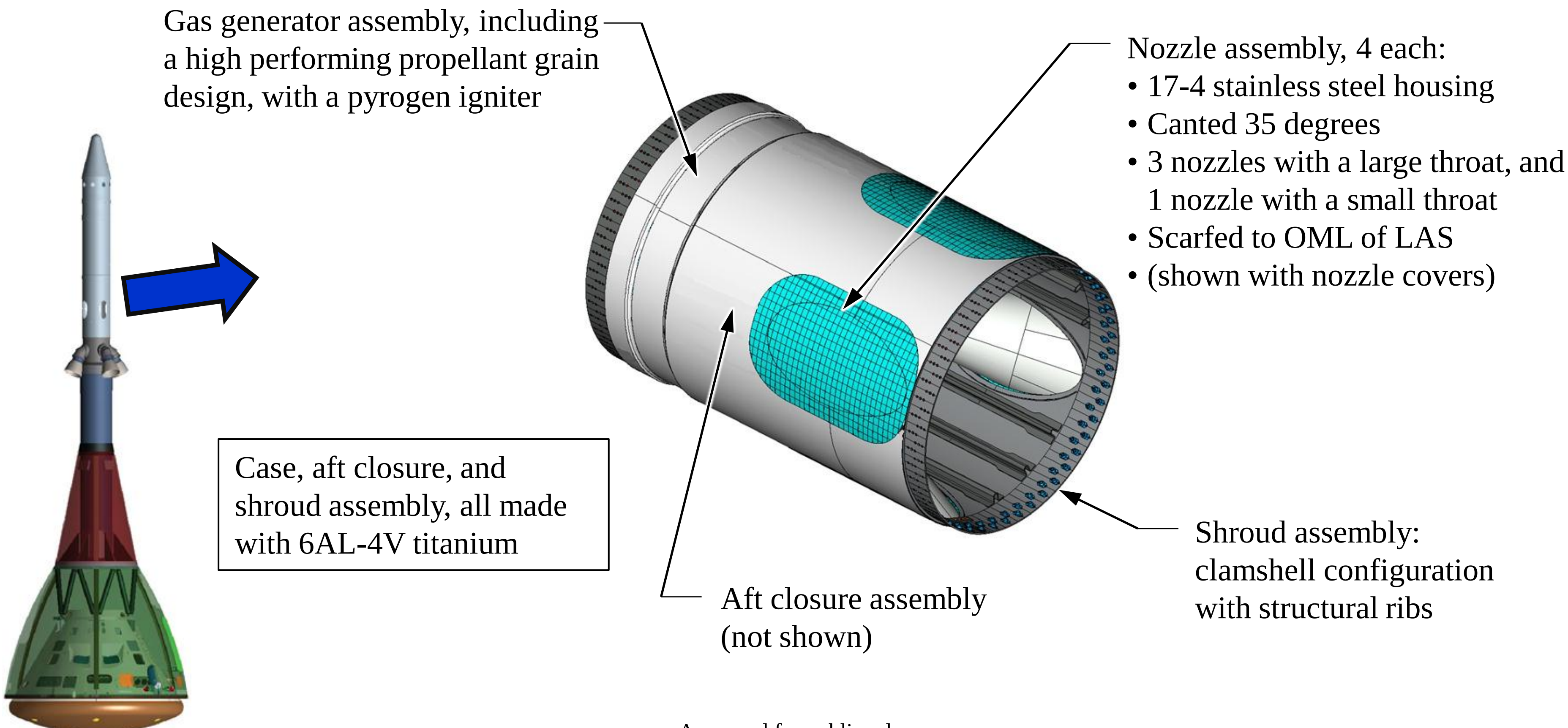
- Two full scale Demonstration Motor (DM) static fire tests were completed prior to PA-1
  - DM-1: 15Dec09
  - DM-2: 17Mar10 (shown)

- 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.



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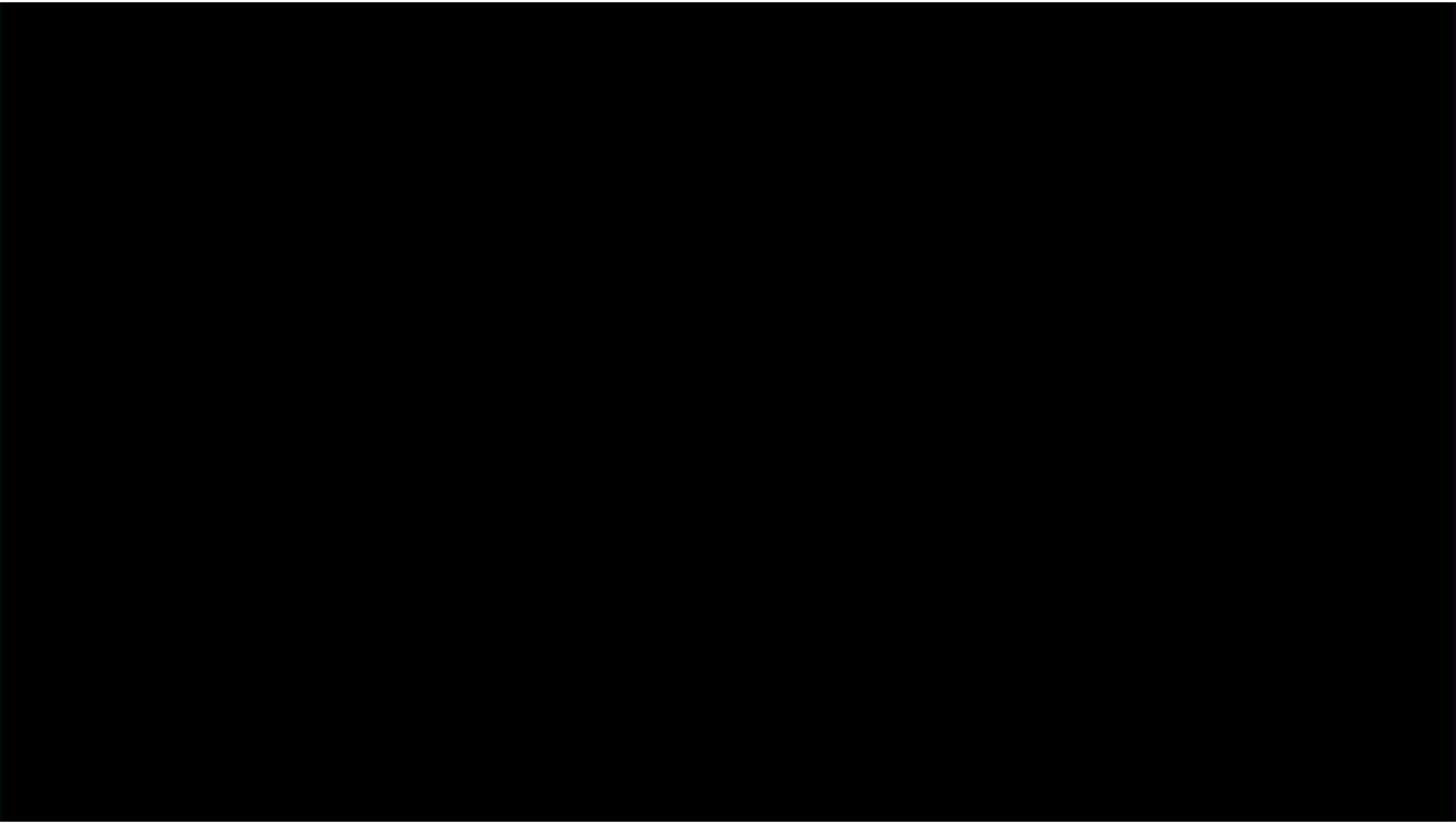
  - Terry Wall, NASA Marshall
  - Brian Reed, NASA Glenn
  - C. Miguel Duncan, TASC RSLP

- 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