

# Orion Launch Abort System Nominal Jettison Performance on Exploration Flight Test – 1

R. McCauley, J. Davidson, and R. Winski  
NASA Marshall Space Flight Center  
NASA Langley Research Center  
Analytical Mechanics Associates, Inc  
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# Orion Multi-Purpose Crew Vehicle (MPCV)



Orion Multi-Purpose Crew Vehicle will serve as the next generation exploration vehicle

- Capable of transporting astronauts on a variety of expeditions beyond low Earth orbit

## Orion Spacecraft

- Crew Module is larger than Apollo
  - 16.5 ft diameter at the heat shield

- Can support crew members for short or long-duration spaceflight missions

- Crew up to 4
  - Deep space missions of up to six months

## Timeline

- Program started in 2005
- Contract awarded to Lockheed-Martin in 2006
- Abort system flight test May 2010 (Pad Abort – 1)
- Exploration Flight Test-1 successfully conducted December 2014
- Spacecraft orbit and re-entry test launched on Delta-IV Heavy from Space Launch Complex 37 at Cape Canaveral Air Force Station





# Orion Flights



**Exploration Flight Test-1 Uncrewed**

**Exploration Mission-1 Uncrewed**

**Exploration Mission-2 Crewed**

**Ascent Abort-2 Test Uncrewed**

# EXPLORATION FLIGHT TEST ONE

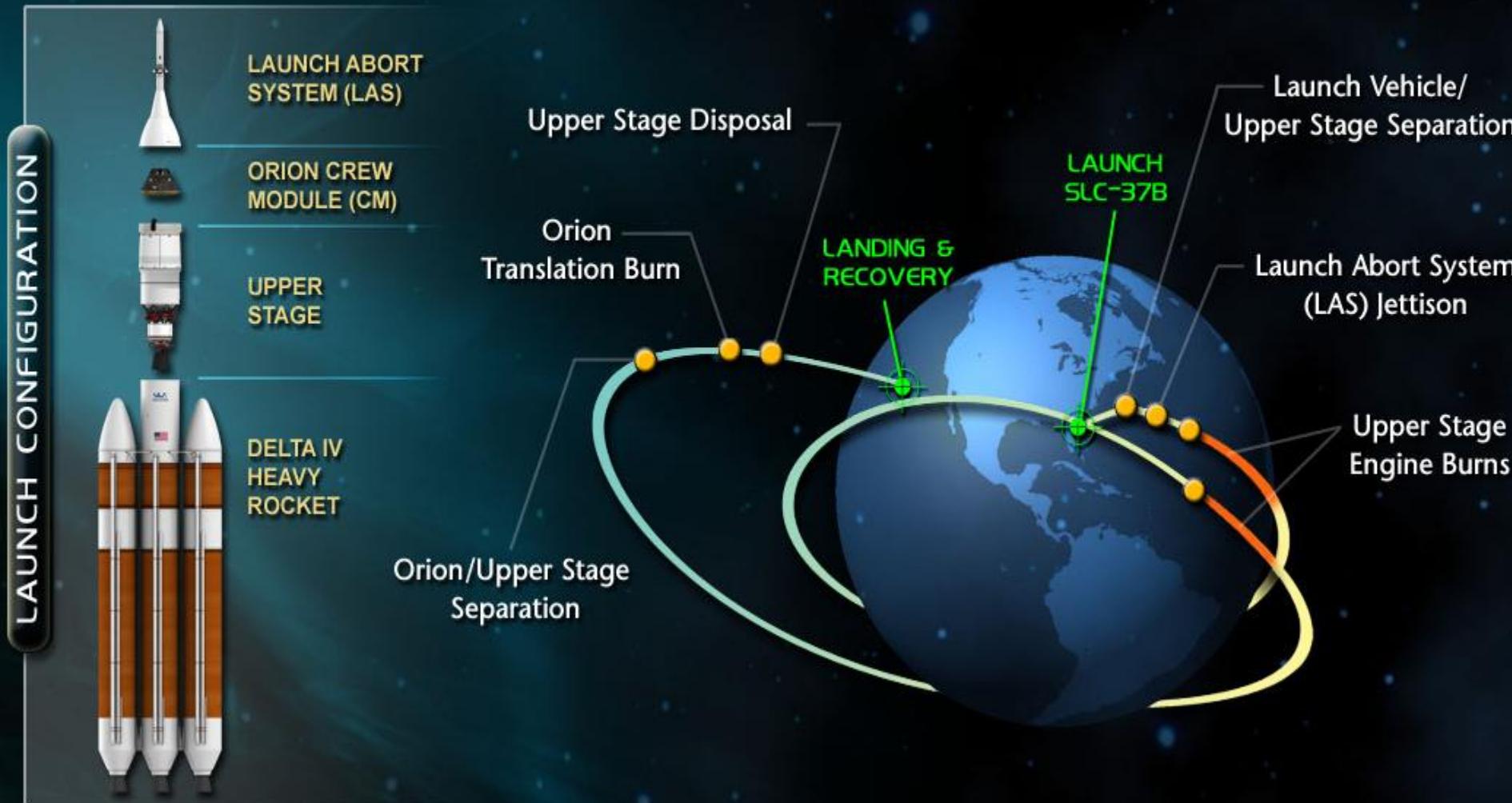
## OVERVIEW

TWO ORBITS

20,000 MPH ENTRY

3,671 MILE APOGEE

28.6 DEGREE INCLINATION



EFT-1 mission used to validate and test systems critical to crew safety

- Demonstrate nominal LAS jettison during ascent
- Demonstrate high speed entry, including Thermal Protection System, entry guidance and control, and landing recovery system



# Orion Spacecraft Overview

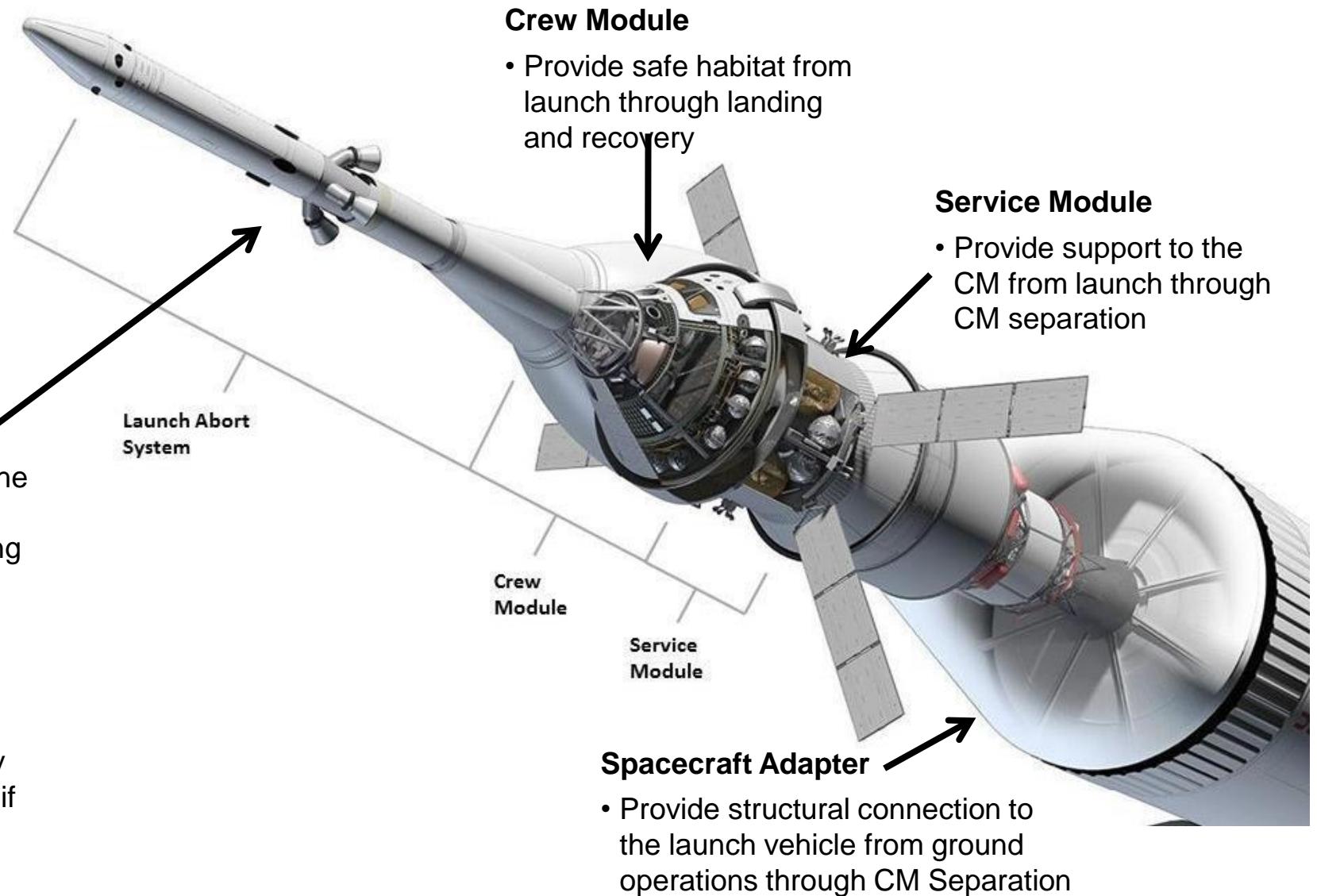


Orion consists of four modules:

- Spacecraft Adapter
- Service Module
- Crew Module
- Launch Abort System

## Launch Abort System

- Provide protection for the CM from atmospheric loads and heating during first stage flight
- Safely jettison after successful pad operations and first stage flight
- Provide abort capability from the pad to 300k ft if problem during ascent





# Orion Launch Abort System (LAS)



## LAS Dimensions (approx)

- 45 ft tall
- 3 ft diameter at the Tower
- 16 ft diameter at the Base

### ◆ Attitude Control Motor (Inert on EFT-1)

- Enables active flight control for steering and stable nose-forward flight during abort
- Controls re-orientation to heat shield forward to enable LAS jettison and chute deployment

### ◆ Jettison Motor

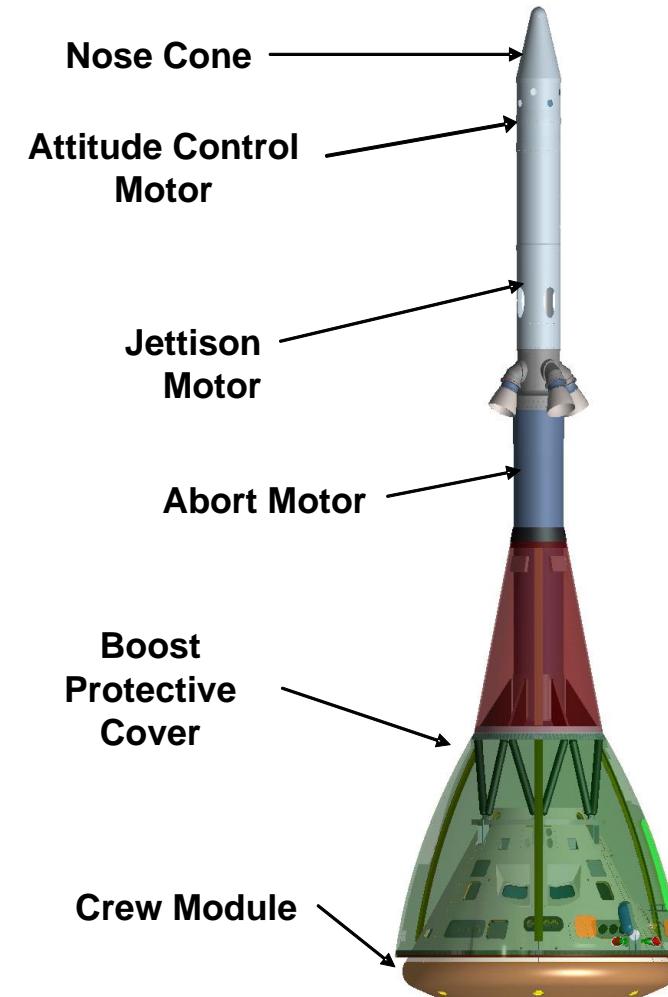
- ◆ Thrust for LAS jettison during nominal launch and abort

### ◆ Abort Motor (Inert on EFT-1)

- ◆ Thrust to quickly pull the Crew Module away if problems develop during the launch

### ◆ Boost Protective Cover (Fairing)

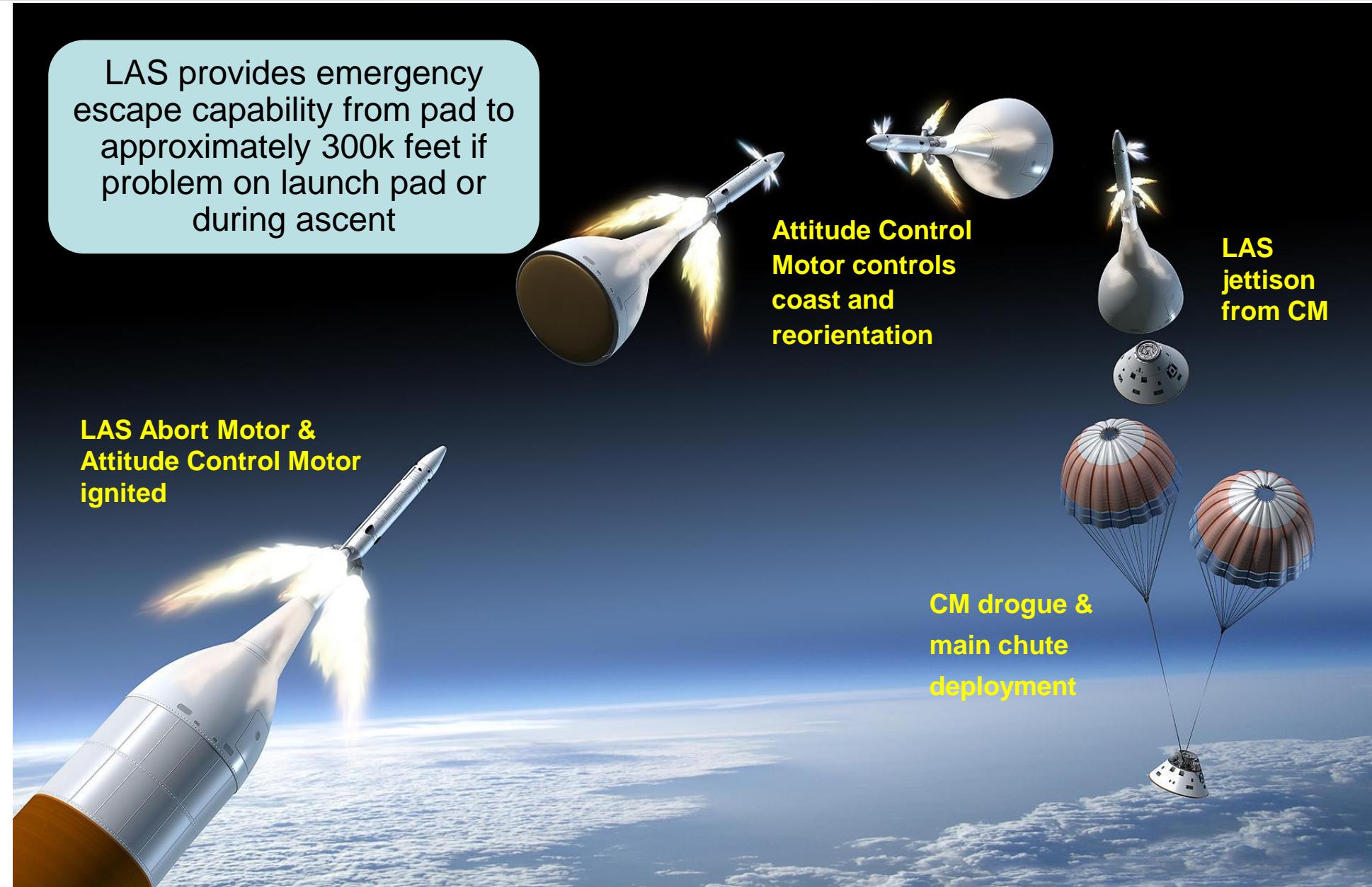
- ◆ Protection against aero-acoustic loading, heating, and Abort Motor plume impingement



**Launch Abort Vehicle:  
Crew Module + LAS**



# Orion Launch Abort System Abort Sequence





## EFT-1 and LAS Nominal Jettison



For a nominal ascent, LAS provides protection for the CM from atmospheric loads and heating during first stage flight

- Nominal Jettison occurs every launch after successful first stage flight
- ♦ **EFT-1 mission used to validate and test systems critical to crew safety**
  - One of the key separation events tested during EFT-1 was the nominal jettison of the LAS
  - LAS nominal jettison event on EFT-1 occurred at approx. six minutes and twenty seconds after liftoff

A suite of developmental flight instrumentation (DFI) was included on the flight test to provide data on spacecraft subsystems and separation events

- Data used to verify function of the jettison motor to separate the Launch Abort System from the crew module

LAS Nominal Jettison demonstrated on EFT-1



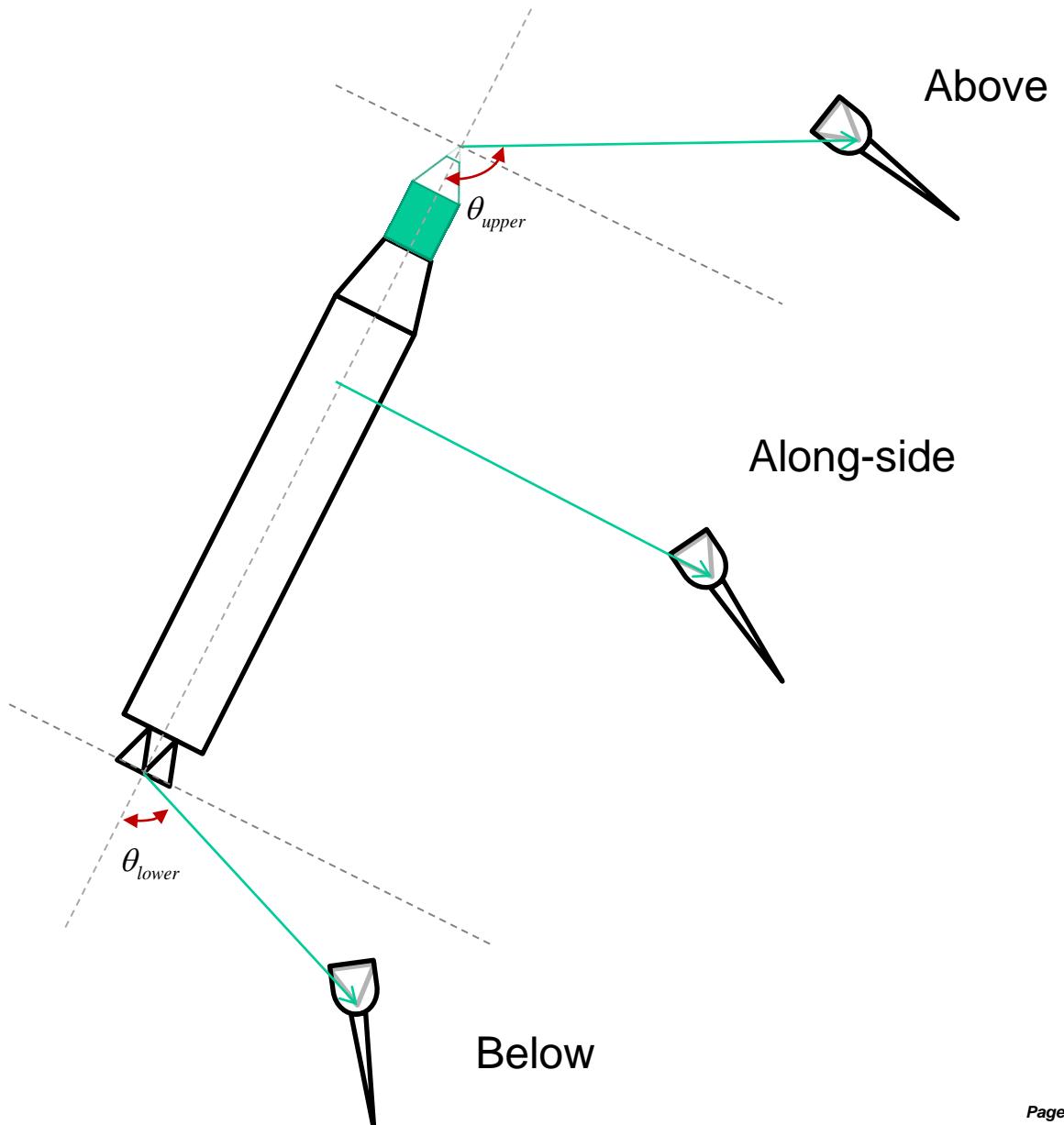


# EFT-1 LAS Nominal Jettison Flight Test Objectives



- ♦ Demonstrate LAS separation during nominal ascent

- No CM/LAS recontact detectable by onboard data or post-flight inspection of the CM.
- Visual observation of LAS jettison to include onboard observation assets to observe *initial release and separation dynamics, LAS fly-away trajectory, and second approach and clearance of the Orion spacecraft and launch vehicle.*
- No LAS contact with launch vehicle after separation detectable by onboard observation assets.





# EFT-1 LAS Nominal Jettison Trajectory Reconstruction

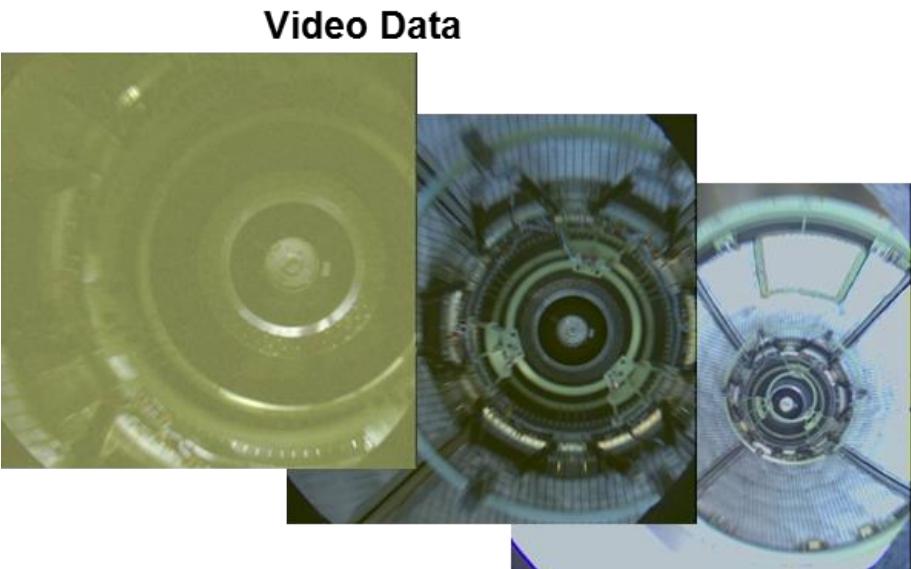


EFT-1 LAS nominal jettison flight trajectory reconstruction being used for

- Assessment of performance vs flight test objectives
- JM thrust profile assessment and LAS water impact analysis

Two measurements being used to analyze the near/mid-field LAS-to-CM relative motion

- Docking hatch window camera video frame dimensional analysis
- String potentiometer (3x) lanyard spool DFI measurement
  - Lanyard Extension Displacement Transducer (String Pot) uses a lanyard to turn a rotary potentiometer to measure extension of lanyard from lanyard drum

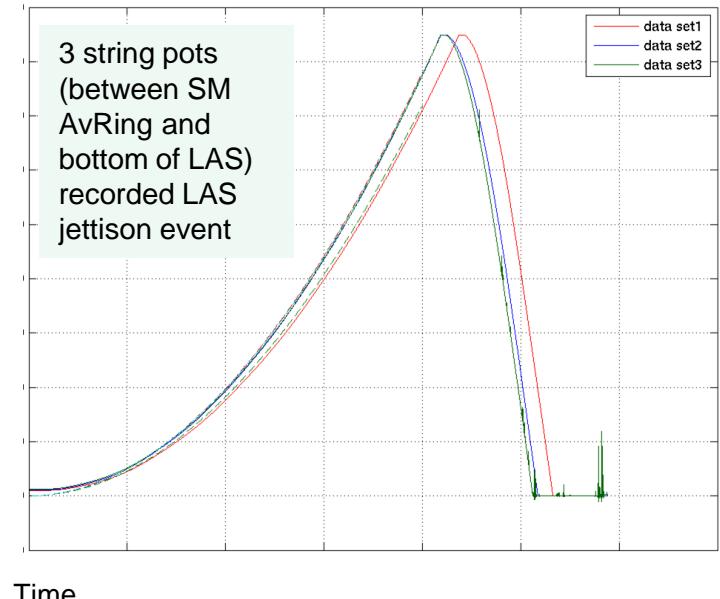


Video Data



EFT-1 LAS Nominal Jettison Trajectory Analysis

EFT-1 String Pot LAS Jettison Data





# EFT-1 LAS Nominal Jettison Trajectory Reconstruction from Flight Data



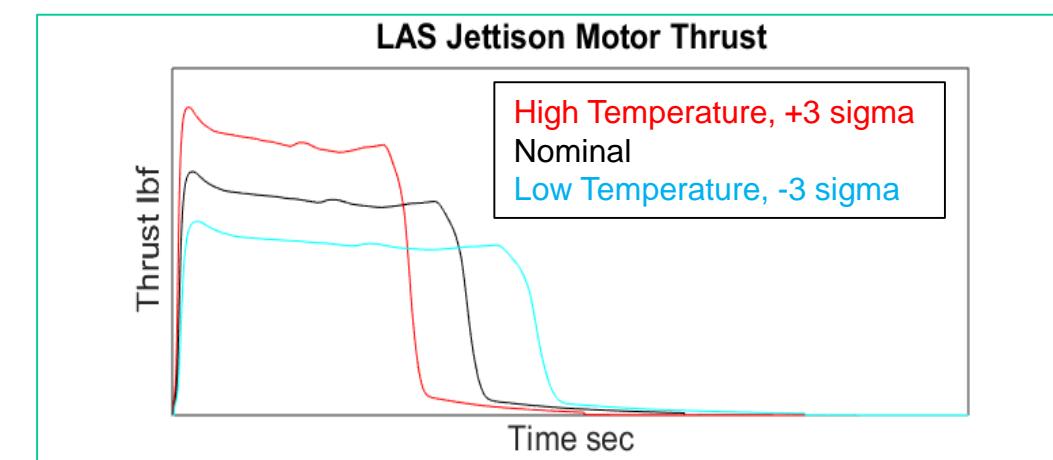
Conducted comparison of EFT-1 LAS jettison separation potentiometer flight data with LAS POST2 Non-Linear 6-Degree-of-Freedom trajectory simulation results

- Simulation model analysis includes
  - EFT-1 Day of Launch Mass Properties
  - EFT-1 Best Estimated Trajectory LAS Jettison initial conditions
  - Jettison Motor thrust model
    - Includes effects due to propellant temperature variations and motor burn rate uncertainty

Analysis results show LAS jettison consistent with pre-flight analysis

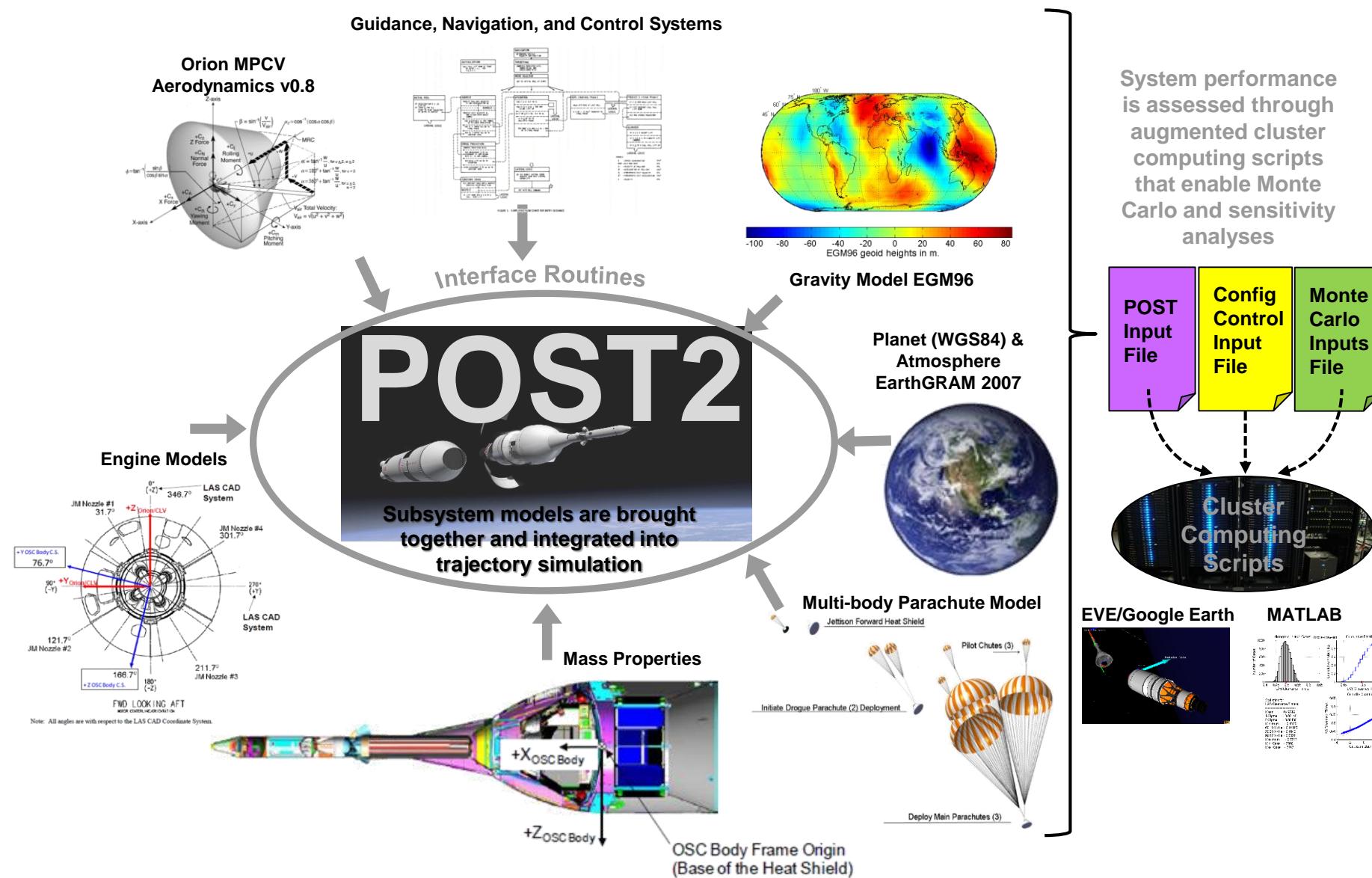
- Analysis indicates a strong correlation between LAS separation distance trajectories and JM propellant temperature
- Daily temperature varied between 60 degF and 78 degF during 2 days before launch
- Estimated internal LAS temperature at jettison point = 73.7 degF

Temperature Data (degF)	Dec 3, 2014	Dec 4, 2014	Dec 5, 2014
Maximum	77	78	77
Average	68.5	69.5	71.5
Minimum	60	61	66



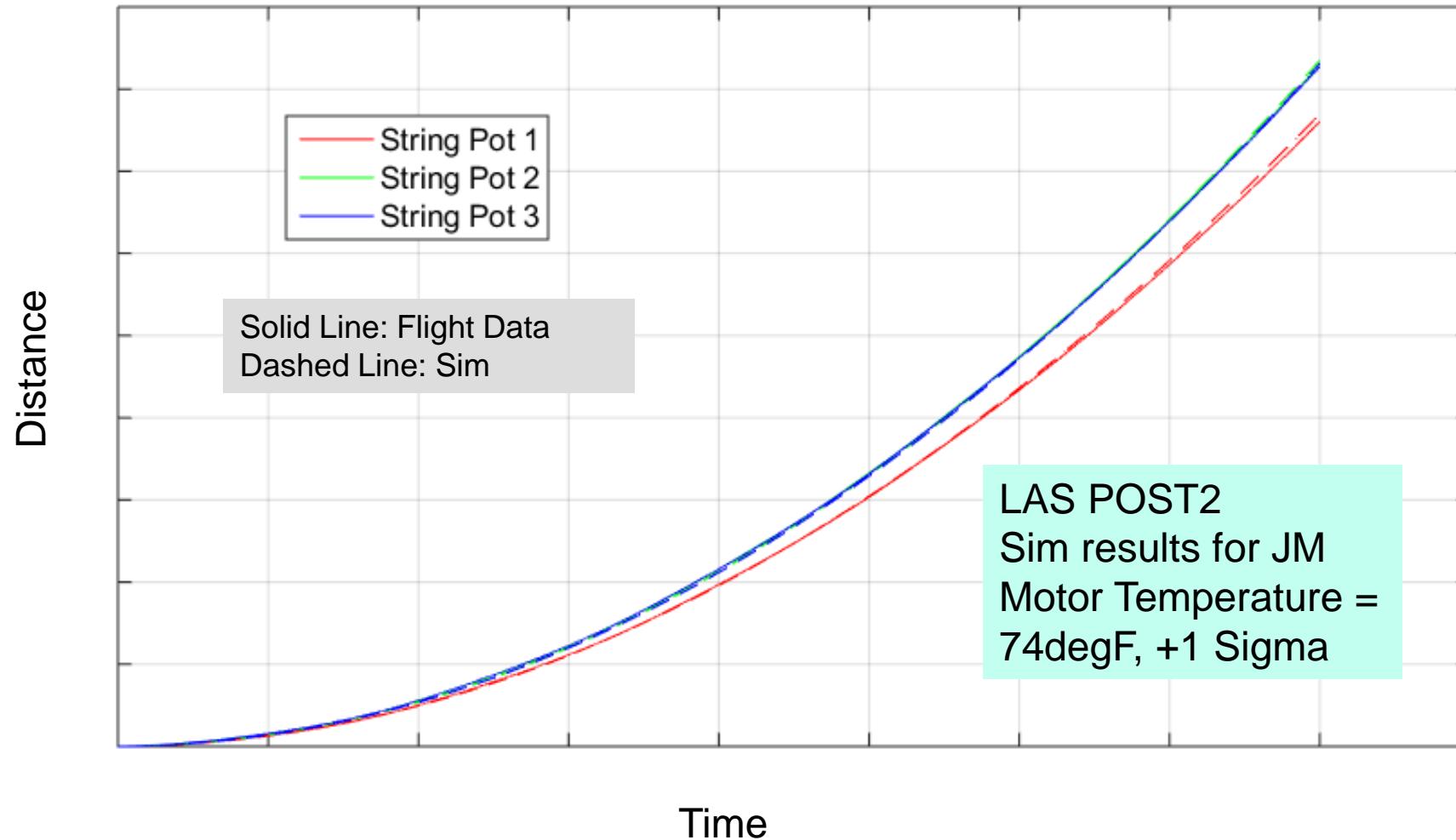


# LAS POST2 Simulation Architecture





# EFT-1 LAS Jettison Separation Data to LASO POST2 Simulation Comparison



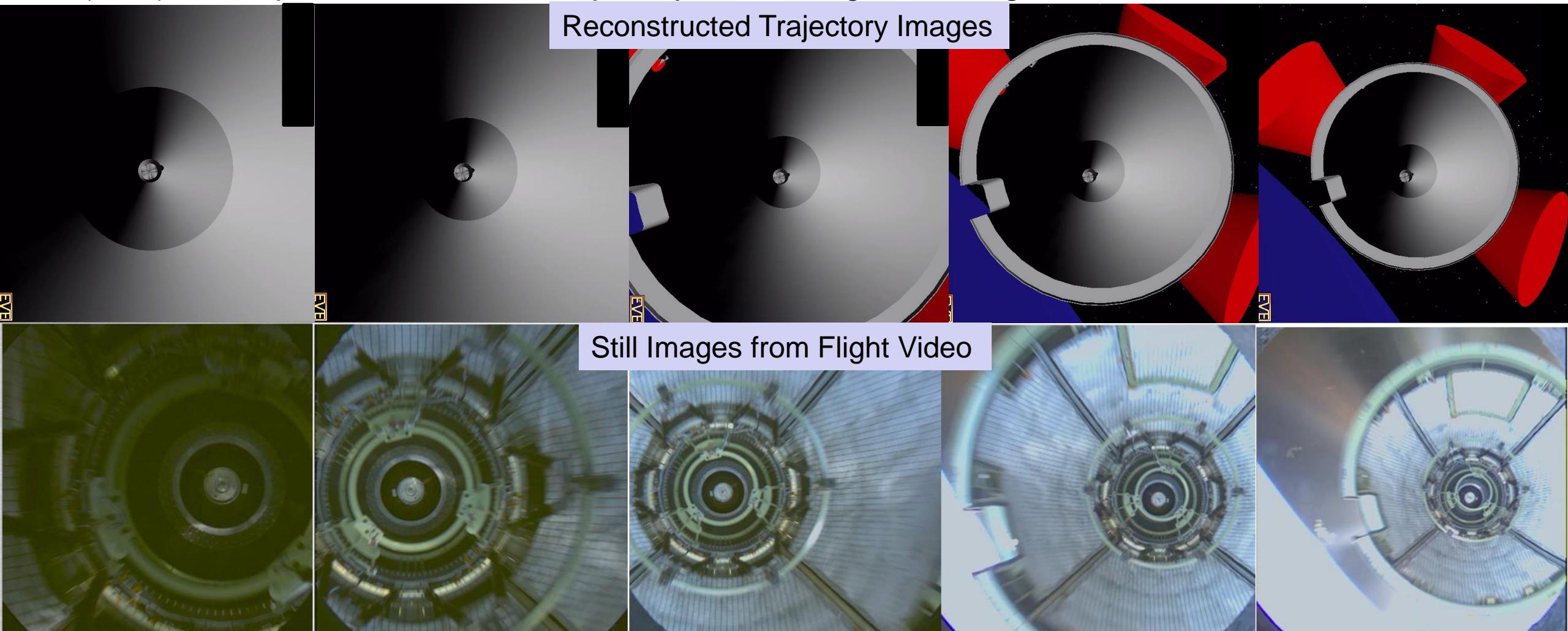
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# Trajectory Reconstruction vs Flight Imagery



- ◆ LASO POST2 jettison trajectories used as input into Engineering Visualization Environment (EVE) to compare reconstructed trajectory to still images from flight video



LAS jettison trajectory visualization consistent with flight video



## Concluding Remarks



- ♦ **Orion Multi-Purpose Crew Vehicle will serve as the next generation exploration vehicle**
  - Capable of transporting astronauts on a variety of expeditions beyond low Earth orbit
- ♦ **Exploration Flight Test -1 (EFT-1) successfully conducted December 2014**
  - Spacecraft orbit and re-entry test launched on Delta-VI Heavy
  - A suite of developmental flight instrumentation provided data on spacecraft subsystems and separation events
  - Data used to verify the function of the jettison motor to separate the Launch Abort System from the crew module
- ♦ **Conducted comparison of EFT-1 LAS jettison separation flight data with POST2 Non-linear 6-Degree-of-Freedom trajectory simulation results**
  - Analysis results show LAS jettison trajectory consistent with pre-flight analysis
    - Performance slightly higher than predicted
  - Met all LAS jettison flight test objectives
- ♦ **Next Orion flight test (Exploration Mission-1 (EM-1)) planned for 2018**
  - Launching on Space Launch System (SLS) from KSC

