Crew Module Overview

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49th AIAA Aerospace Sciences Meeting

Orion Pad Abort 1 Flight Test

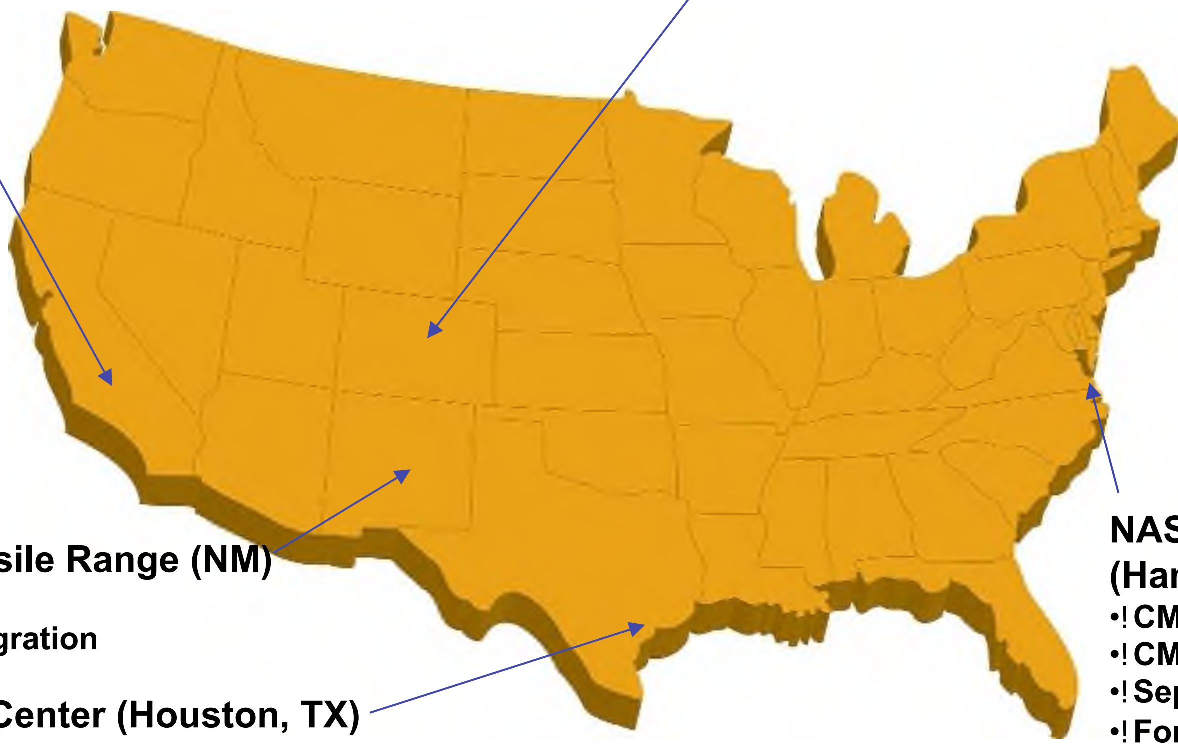
January 4-7 2011

PA-1 Launch Configuration

CM Integration Locations

Dryden Flight Research Center (Edwards, CA)
- DFI
- CM Integration
- Ground Tests
- Operations
- MOF
- Secondary Structures

Lockheed Martin (Denver, CO)
- Avionics
- MGSE / EGSE
- Secondary Structures
- Mechanisms

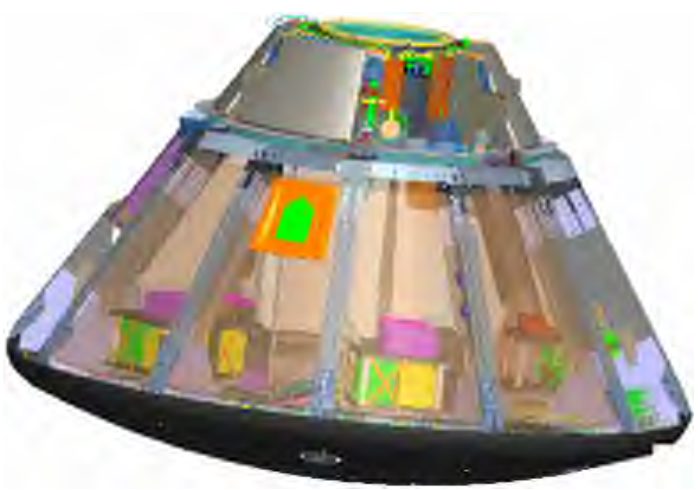


White Sand Missile Range (NM)
- Flight Tests
- Assembly & Integration

Johnson Space Center (Houston, TX)
- CEV Program Office
- Flight Test Office
- CPAS
- Pyrotechnics

NASA/LaRC (Hampton, VA)
- CM Primary Structure
- CM Pathfinder
- Sep Ring
- Forward Bay Cover
- MGSE

Crew Module Configuration



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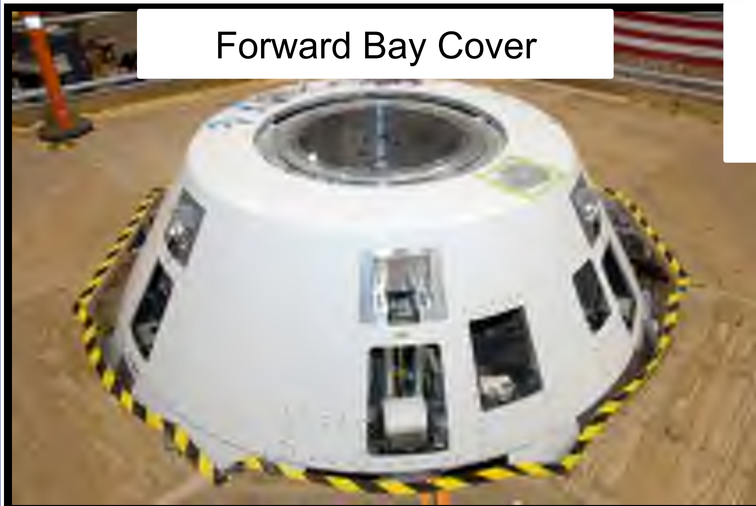
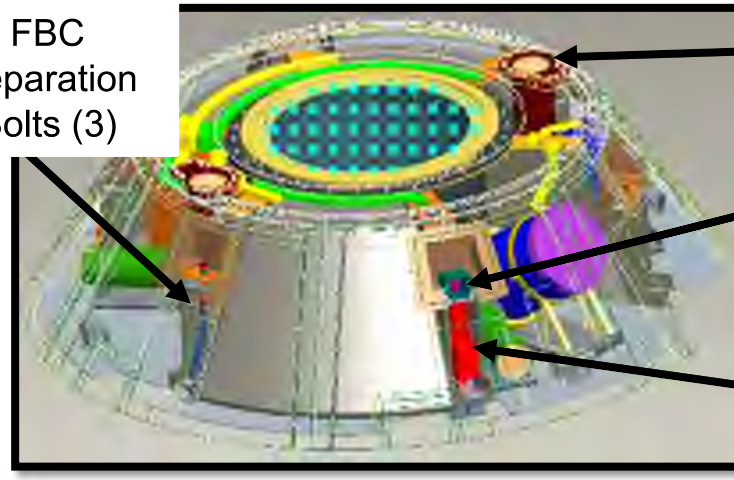
Forward Bay Cover (FBC) Jettison Mechanisms





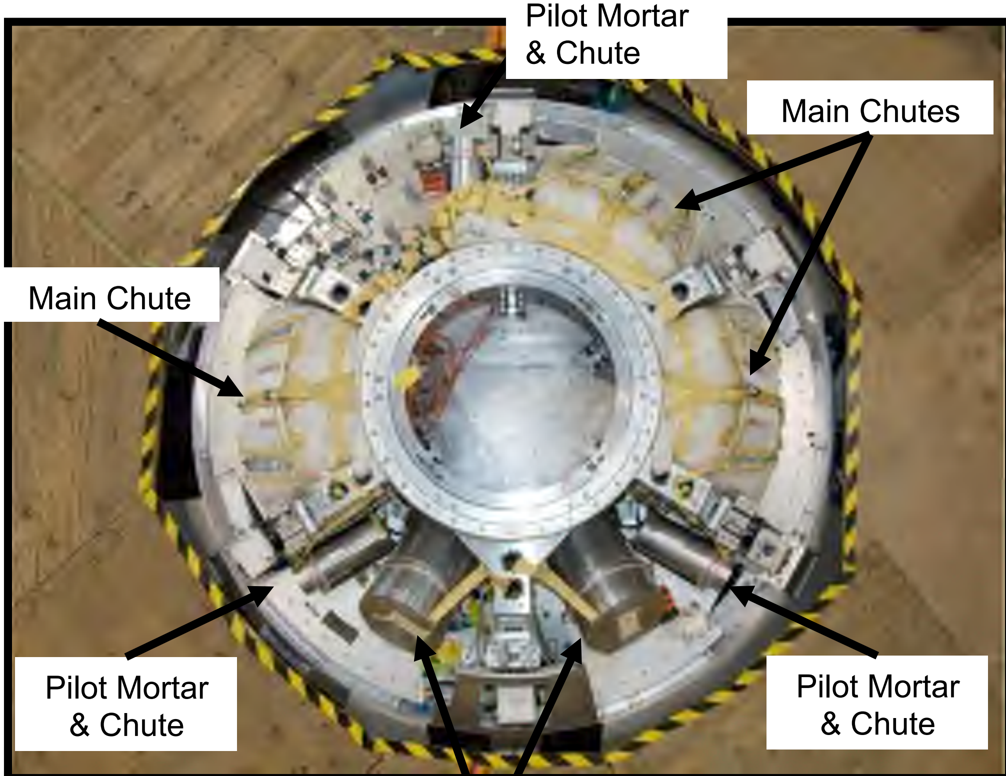
- FBC Jettison Mechanisms provide the structural connections between the CM gussets and provide the mechanism by which separation occurs
- Consists of 2 chute mortars, 3 Separation Bolts, and 3 Thrusters

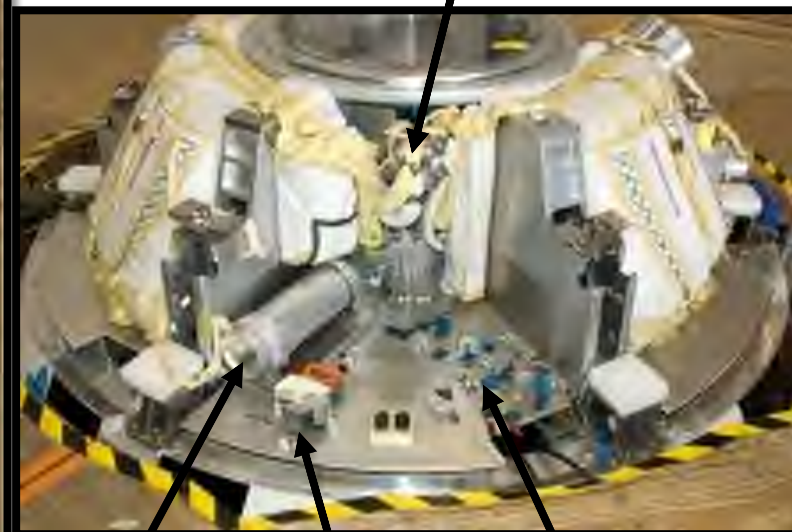
Separation Bolt

Thruster

Parachute

Forward Bay and Chutes





- Forward bay contains the CPAS Gen I chutes, the Forward Bay Cover R&R Mechanisms, and CM-LAS electrical Separation Connectors

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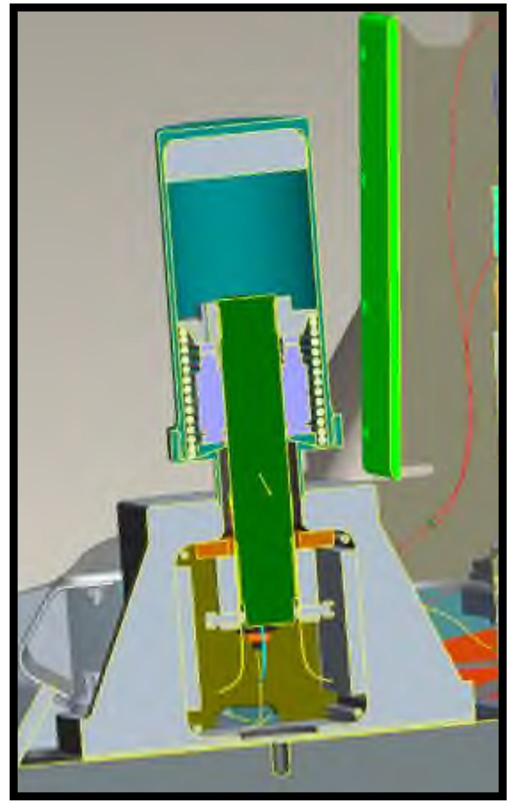
LAS Retention & Release (R&R) System

Six Separation Locations



- LAS R&R system provides the structural connection between the CM and the LAS and the mechanism by which separation occurs
- 6 LAS R&R mechanisms mounted above the 6 primary longerons
- Each mechanism consists of frangible nuts (with containment) holding pre-tensioned studs from the LAS side, initiated with 2 booster cartridges each

Adapter Cone to CM Mate

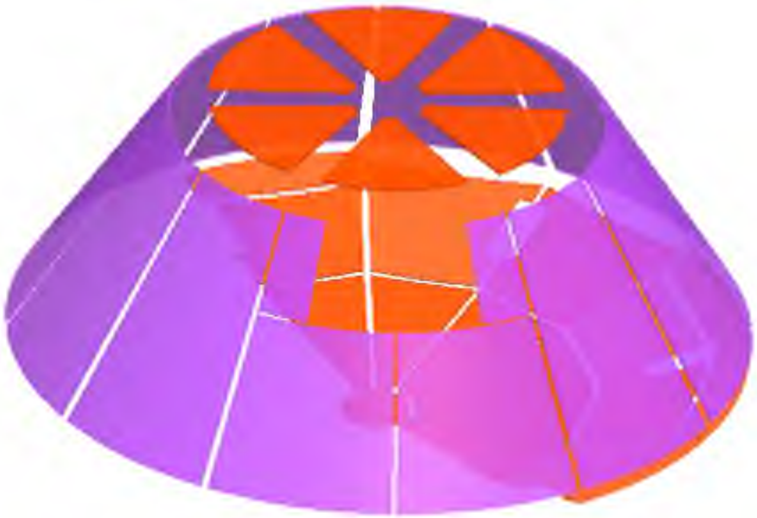
Alignment pins are used to facilitate installation

(shown with no aero close-out installed)

LAS to CM Separation Connectors

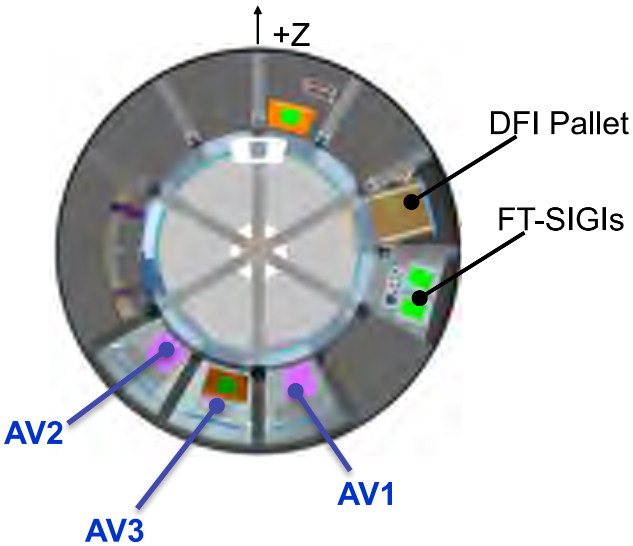
•! Provides signal pass-through between LAS and CM (eg. ACM command, LAS DFI), and trigger signal for DFI High Speed Camera

Acoustic Blankets



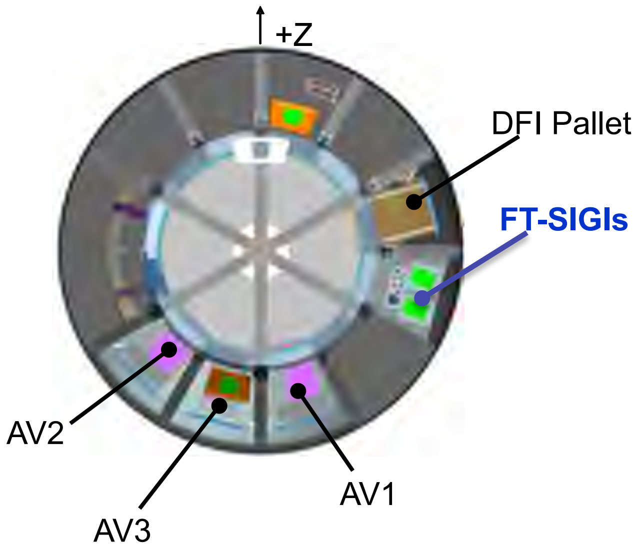
- Acoustic blankets are used to attenuate the acoustic levels the avionics and DFI systems experience during the flight
- The blankets line the walls of the CM, cover all of the forward bulkhead, and half of the heat shield

Avionics and Avionics Pallets



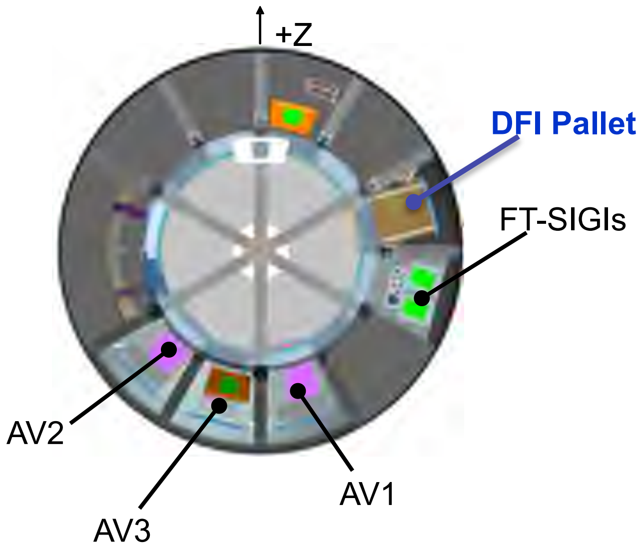
- Avionics system is a palletized design with dedicated racks and structurally dampened pallets
- Avionics is a dual-string system with redundancy allowing for continuous operation in the case of a primary system failure

SIGI and SIGI Pallets



- FT-SIGIs provide outputs of linear acceleration, linear and angular velocity, position, attitude (roll, pitch and true heading) and attitude rate, altitude, and body angular rates
- The FT-SIGIs are floor mounted and isolated separate from the avionics pallets
- Rotated to prevent acceleration clipping

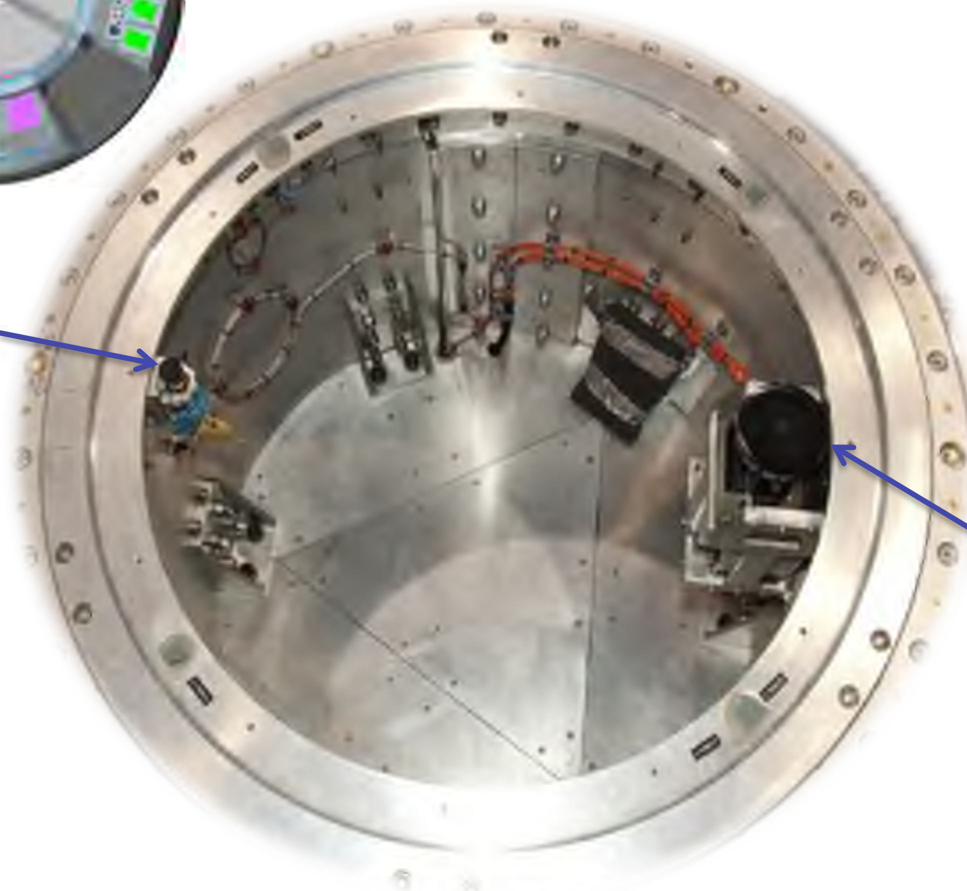
DFI and DFI Pallet



- The DFI subsystem is a distributed system that collects video and data in the LAS and CM and transmits all collected data for recording, encoding and downlinking

DFI Cameras


+Z
DFI Cameras (Crew Tunnel)


Video Camera
High Speed Film Camera

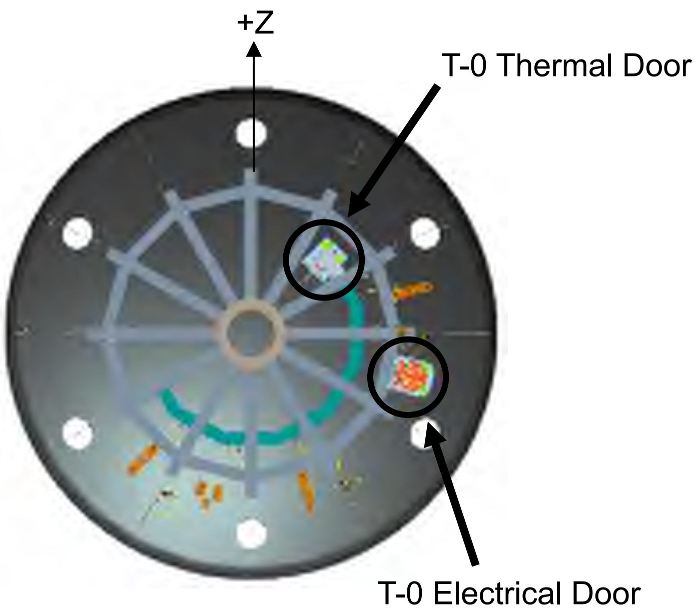
PA-1 DFI Parameter Summary

Sensor Type Summary	QTY
Accelerometer	43
Calorimeter	33
Current	4
Mic./ Diff. Press	61
Static Press.	134
Pressure	10
RTD	6
Status	56
Strain Gage	105
TC	157
Voltage	76
Time	6
Video	1
Total Count	**692**

Meas. Summary by Sub-System	QTY
CPAS	16
Orbital Structures	56
Aero-Thermal	294
Thermal	45
Structures	30
SD-Mics	61
SD-Shock	2
SD-Vibe	26
LAS, AM	19
LAS, JM	15
LAS, ACM	19
DFI	109
Total Count	**692**

Module Meas. Summary	QTY
CM	278
LAS	414
TOTAL	**692**

T-0 Doors



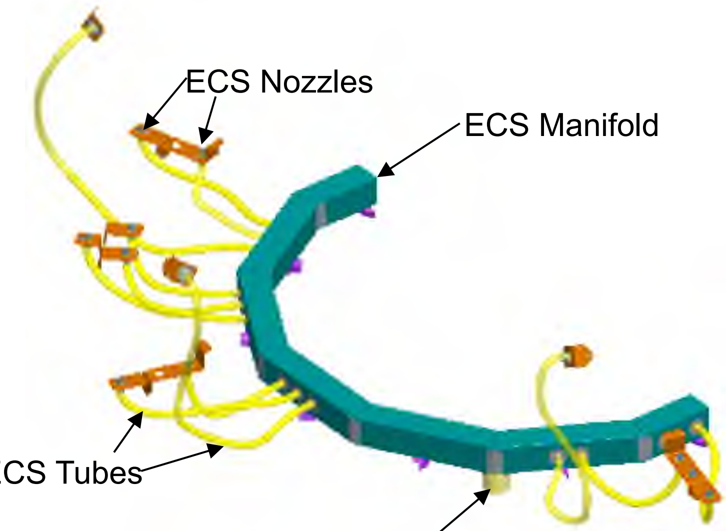
T-0 Electrical Door

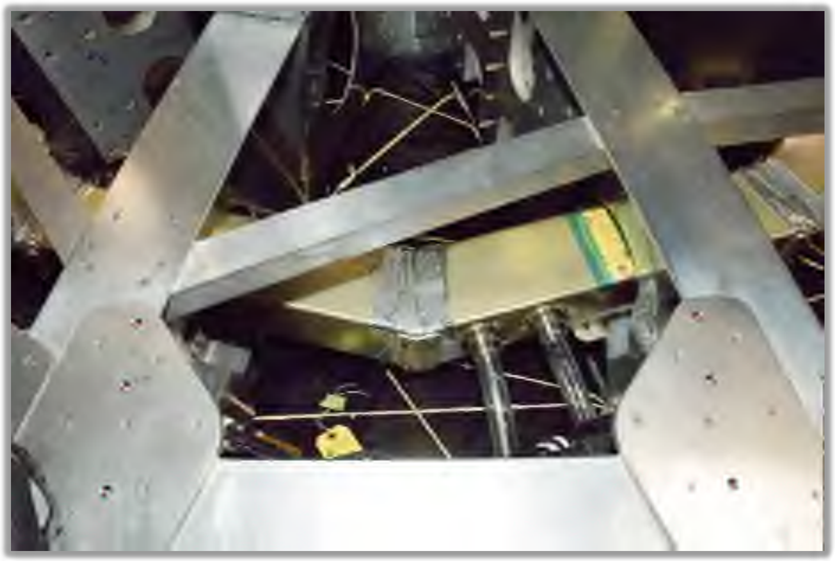
T-0 Thermal Door

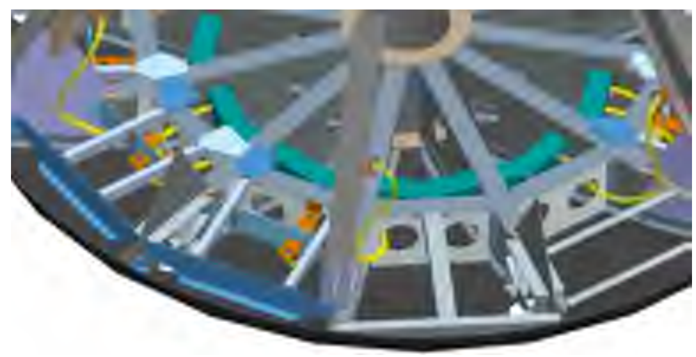
- T-0 doors are located on the heatshield, one for thermal conditioning, and one for electrical disconnect
- Each closes at liftoff and latches to maintain the CM OML

Thermal Control System Overview

- Thermal Control for PA-1 vehicle accomplished in two ways:
  - Active control until launch through Environmental Control System (ECS) which provides direct chilled air cooling
  - Passive control through heat sinks for up to ½ hour after ECS disconnect
- ECS consists of T-0 inlet through heatshield, a main distribution manifold, and nozzle delivery

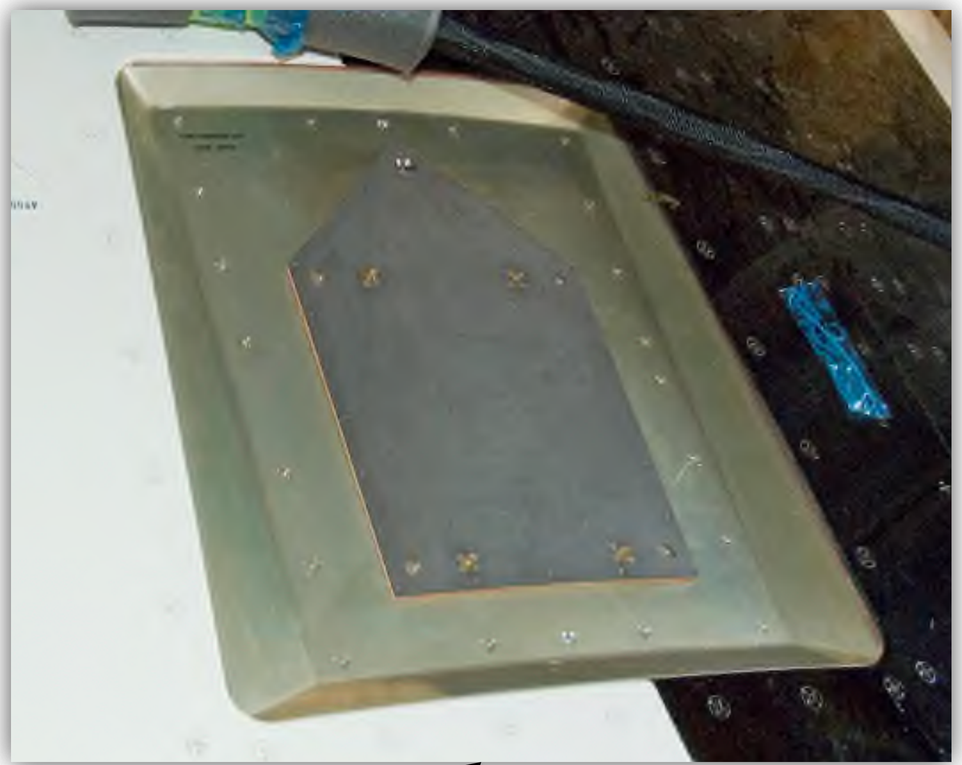




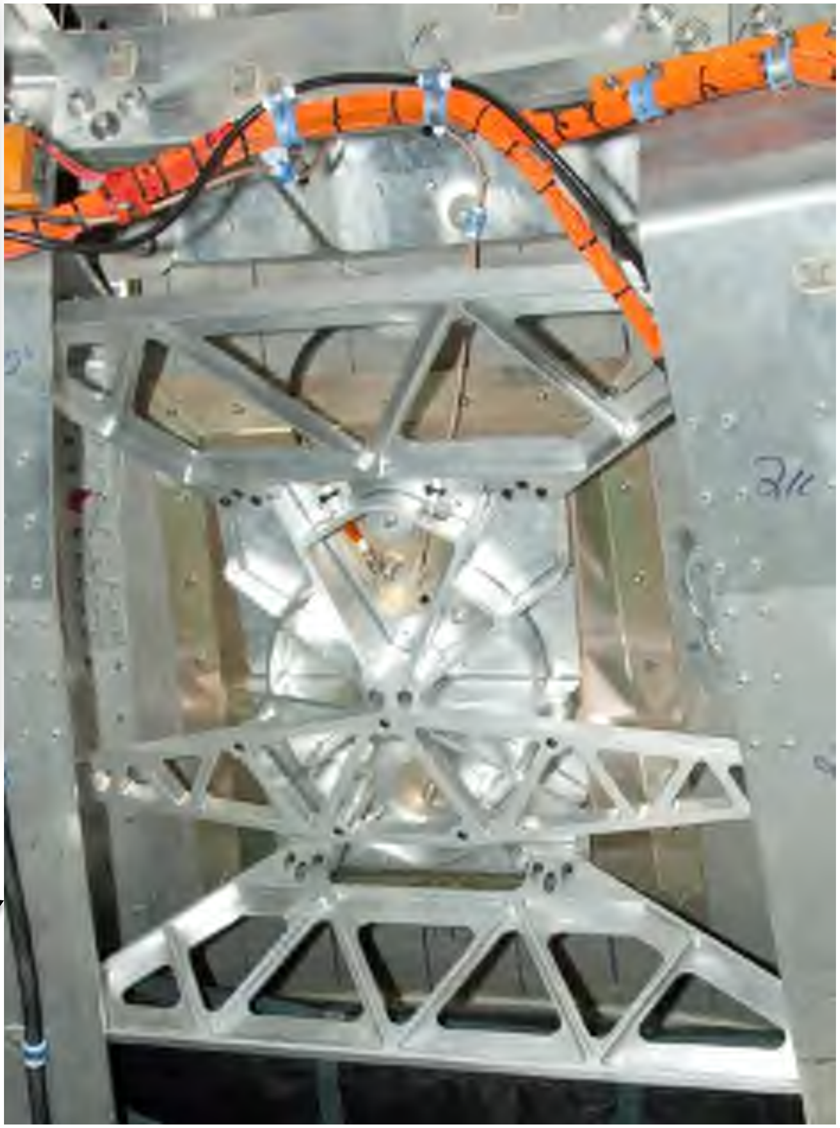


ECS Integrated in Boilerplate Structure

Antenna & Antenna Mounting Bracket

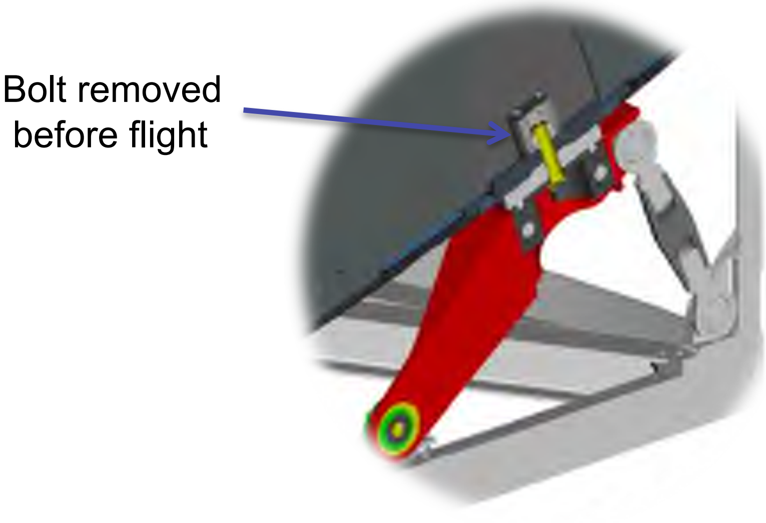


External View



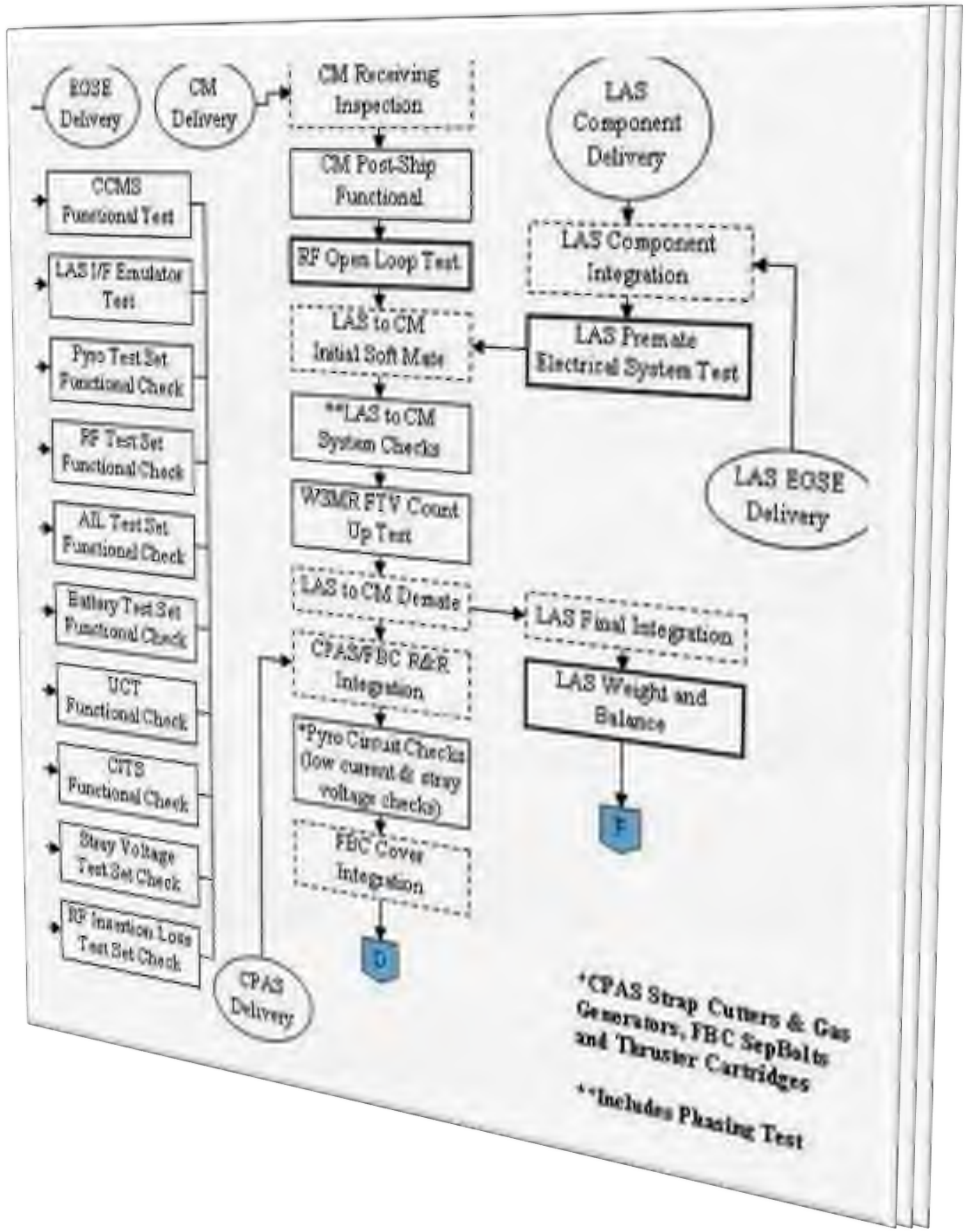
Internal View

CM to SepRing Structural Attachment



- Provides interface between CM and Sep Ring
- Sep Ring is mounted to launch stool

Test, Test Some More, Re-test



LaRC Primary Structures Testing

PA-1 CM Workmanship Test

PA-1 SepRing Workmanship Test

Weight and CG Measurement

Ixx Inertia Measurement

Project Orion Abort Flight Test

Iyy and Izz Inertia Measurement

PA-1 Acoustic Test

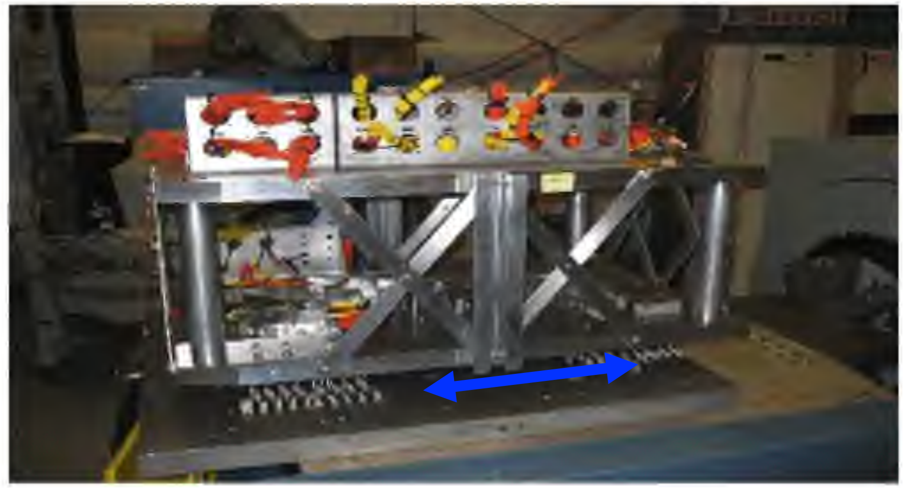
- Goal: Provide guidance for the analysis results for equipment on CM forward bulkhead and transfer functions between acoustic excitation and vibration response
- Value: Improve accuracy of Mid & High Frequency environment predictions

PA-1 Shaker Test

- Goal:
  - Identify global damping values for Loads Models
  - Provide Transfer Functions between interface environments and component vibration response
- Value:
  - Use test to scale environments and generate component loads; reduce model uncertainty factors
  - Identified unexpected damping at lower frequencies
    - Could not exercise CM at high levels
    - Highly isolated subassemblies

DFI Pallet Developmental Vibration Testing

- The Engineering Development DFI pallet was subjected to many acceptance level tests
- Tests were conducted in all axis

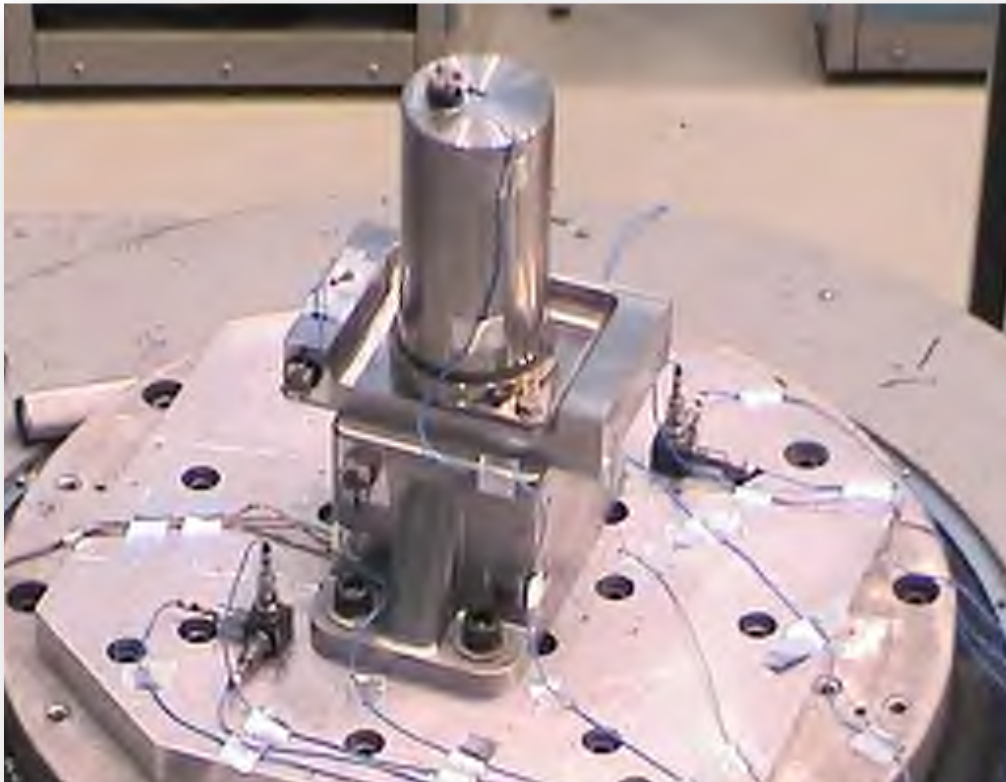


Longitudinal (Shear) Direction

Vertical (Axial) Direction

Transverse Roll Direction

LAS R & R Component Level Vibration Testing



LAS R&R Assembly on Vibration Table

Super Nut

Frangible Nut

Range Integration Tests

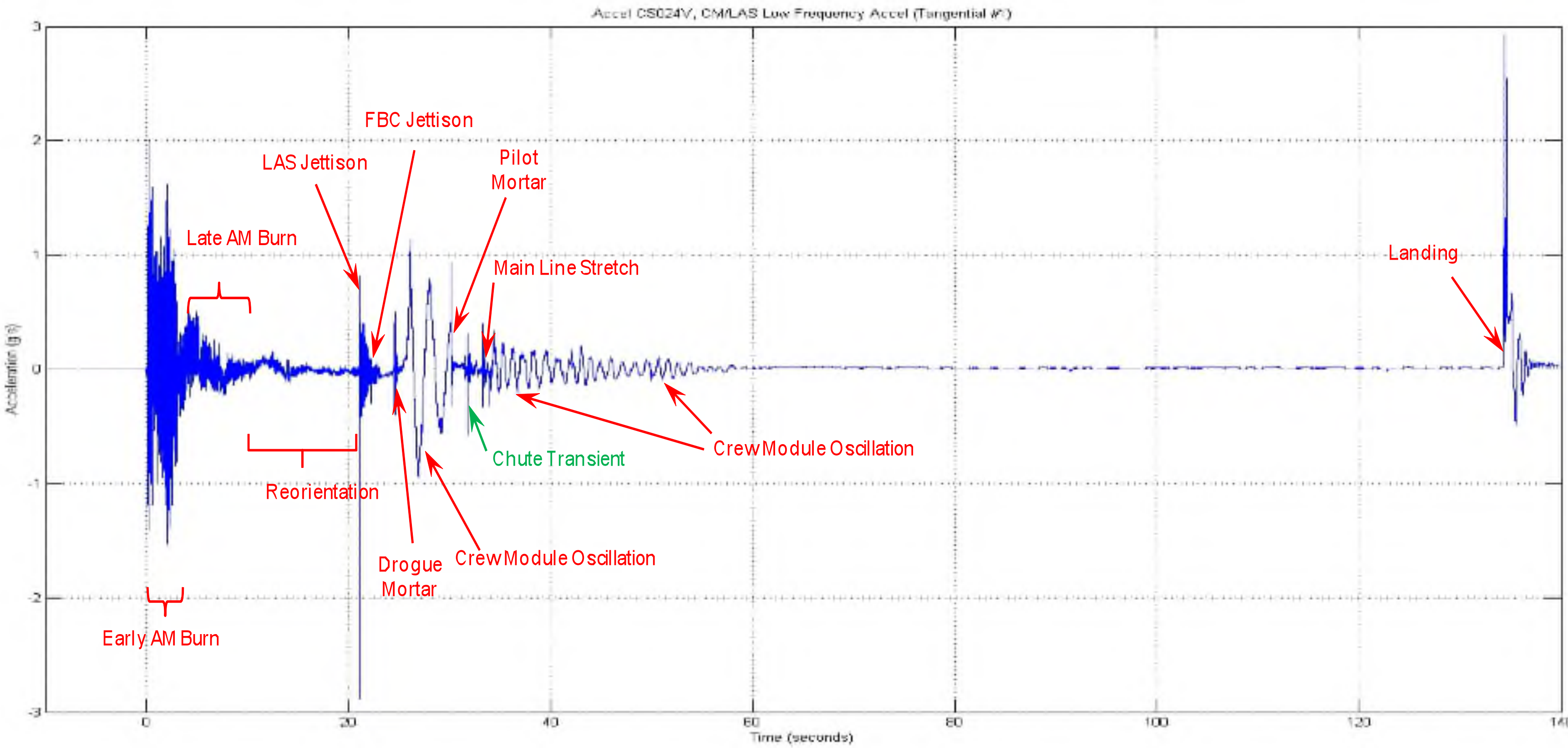
Mobile Operations Facility

Softmate, Phasing, & Count Down-Up Tests

How did it turn out?

Nominal Event Timeline

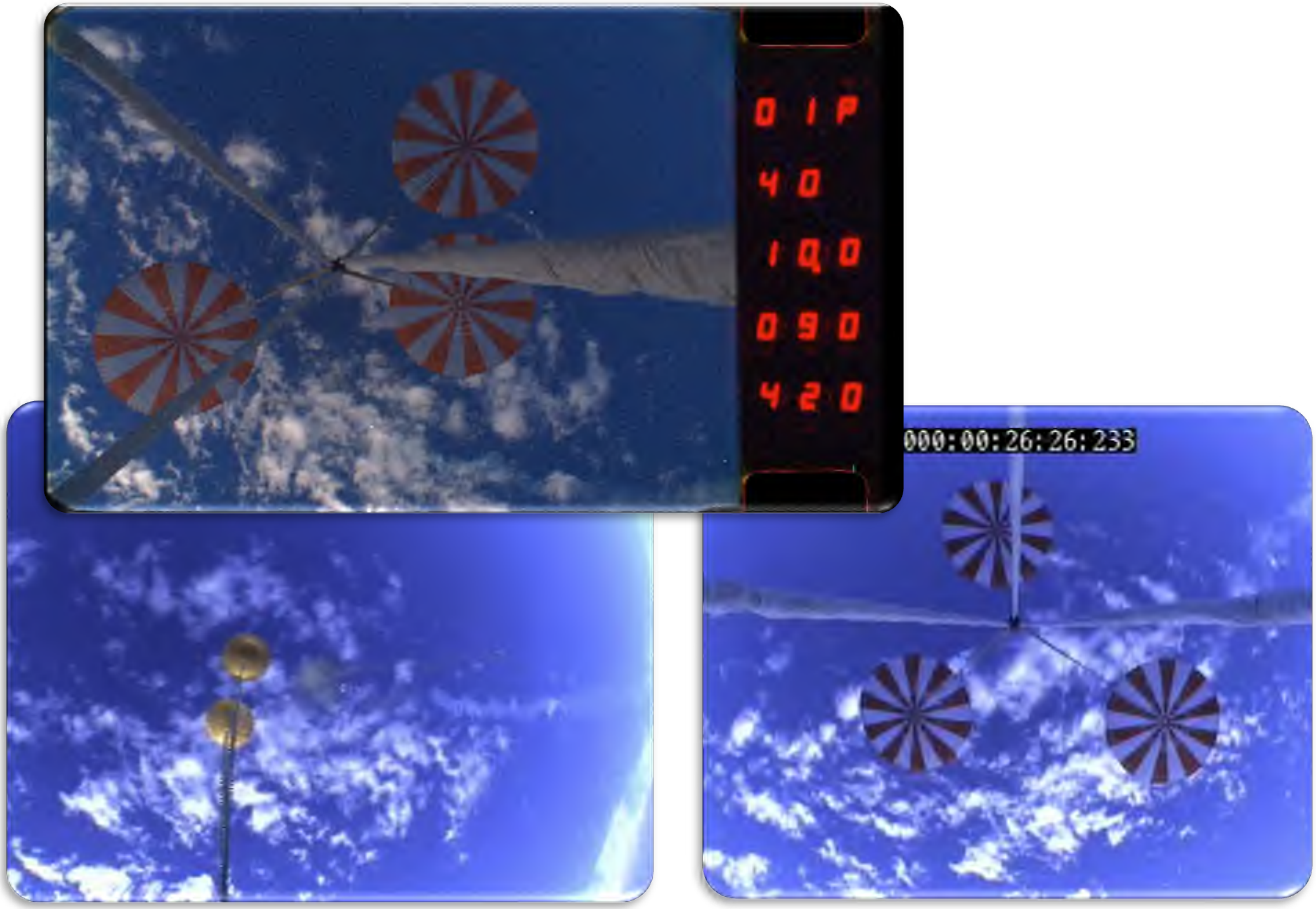
- All CM events occur per timeline
- Unexpected chute transient at time of confluence deployment



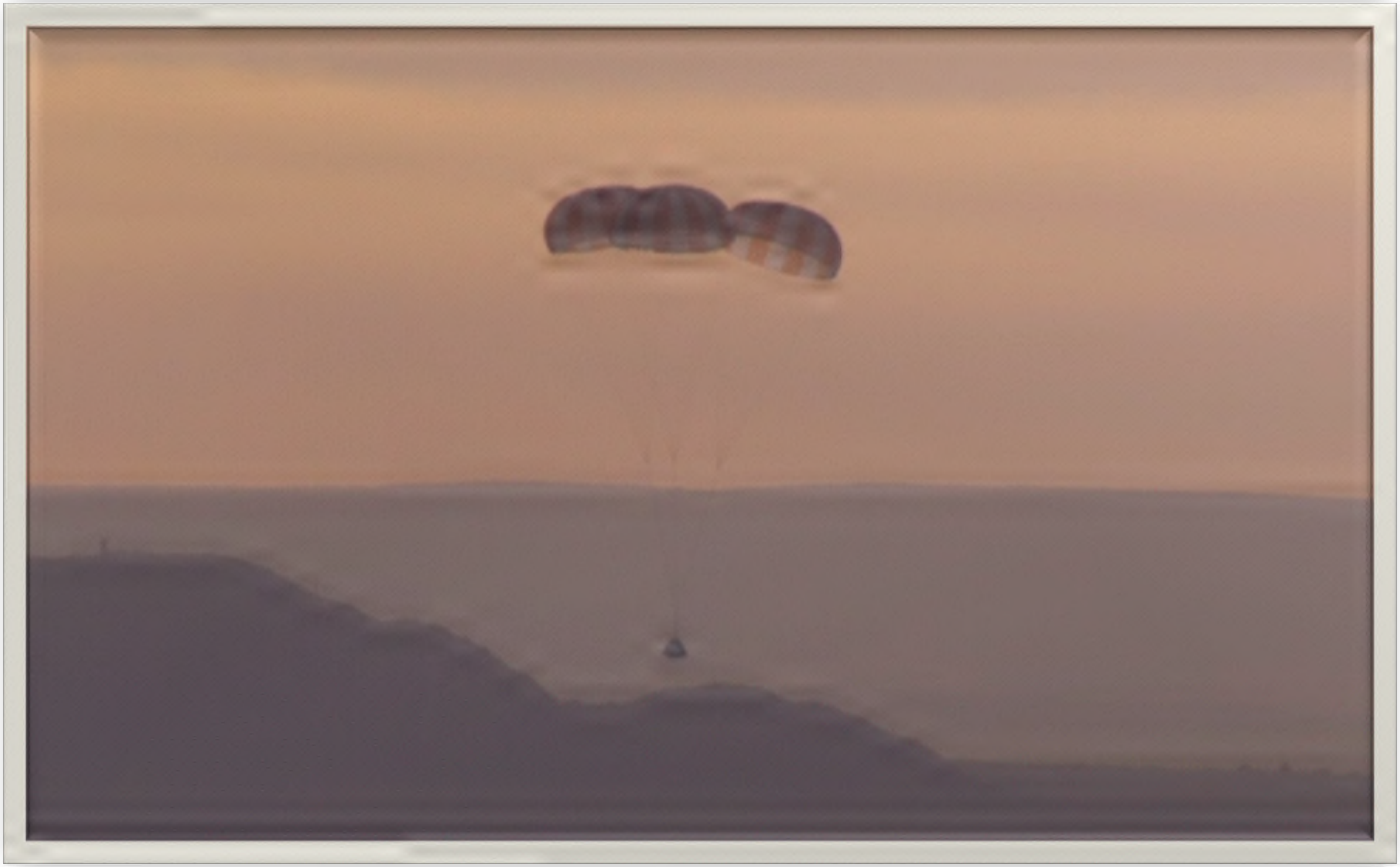
Reorientation Phase Complete

LAS Jettison, FBC Jettison, and Drogue Deployment

DFI Film and Video Cameras



3 Full Mains



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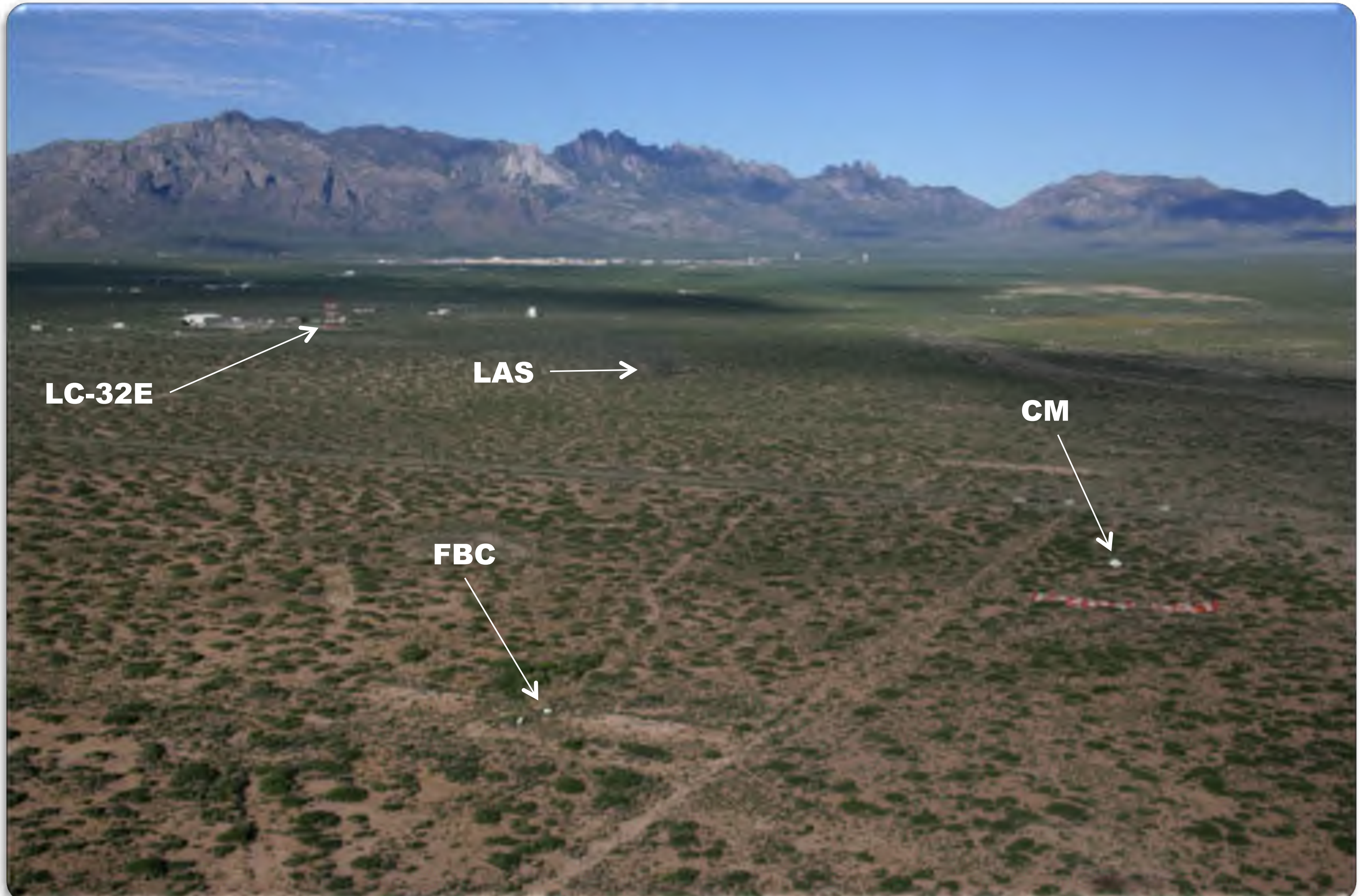
CM Recovery

Project Orion Abort Flight Test

Post Launch Fly-By and Survey

Post Landing



Qualitative Loads Assessment

- Flight results show acoustic loads were generally higher than predicted
  - Mean Predicted Environment (MPE) was not sufficiently high to cover loads for the P95/50 case (95% of flights with 50% confidence)
  - Data suggests that additional margin should have been included in MPEs to ensure flight environments did not exceed MPEs
    - Based on this one flight test case
- However, CM internal component vibration loads were generally lower than predicted
  - CM Zone 4 Forward Bay Floor
  - Example: Predicted Grms, axial: 45.9 Measured: 9.36
  - Note: Instrumentation quantity, sample rates, and locations not ideal to analyzing this problem
- Conclusion: Need better predictors for load transfer functions and dampening
  - Some hardware was likely over-designed and over-tested
  - Some hardware, such as the antennas mounted on the external skin, may have been under-designed
  - Additional conservatism on forcing functions may have been unworkable for some designs, such as the mechanisms

Final Thoughts

- Environmental specifications required minimum 1 minute duration random vibration test is all axis
  - Overly conservative given most severe loads are during Abort Motor burn which lasts < 5 seconds
  - Program later adapter 3-Tier approach for some LAS components
    - A load case is derived for each major phase of flight
    - Requires 3x load cases for every component or zone
  - What is the minimum test duration for a good acceptance test?
- More instrumentation bandwidth should be dedicated for recovering component loads post-flight
  - Need data to develop better models for structural damping and transfer functions to avoid unnecessary component over-design and over-test, or possible under-design
  - Over-test erodes flight margin
- Difficult to obtain useful data for component loads from flight vehicle tests
  - Can not achieve flight test levels
  - Need to be conservative with flight hardware installed
  - Managers need to weigh test risk vs. payback
- Consider taking more risk for similar, unmanned, developmental flight tests
  - Ground test and analysis only buy-down risk incrementally
  - Need to get to the flight test quickly for low cost
  - Need flight test data to create better models
  - Results in better, robust, cost-effective flight designs