Crew Module Overview

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Orion Pad Abort 1 Flight Test
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PA-1 Launch Configuration

- Launch Abort System (LAS)
- Adapter Cone
- Crew Module (CM)
- Separation Ring (SR)
- Launch Stool
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

- Forward Bay Cover
- CPAS Components
- Forward Bay Floor, Gussets & Crew Tunnel
- Pallets & Harness
- External Skins
- Forward Bay Bulkhead
- Longerons
- Heatshield Assembly
- Heatshield
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.
• Forward bay contains the CPAS Gen I chutes, the Forward Bay Cover R&R Mechanisms, and CM-LAS electrical Separation Connectors
LAS Retention & Release (R&R) System

• 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
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 (e.g., 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
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.
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.
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<th>Sensor Type Summary</th>
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<th>Module Meas. Summary</th>
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<td><strong>TOTAL</strong></td>
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T-0 Doors

- 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

![Diagram of ECS system]

ECS Inlet from T-0 Mechanism
ECS Nozzles
ECS Manifold
ECS Tubes
ECS Integrated in Boilerplate Structure
Antenna & Antenna Mounting Bracket

External View

Internal View
CM to SepRing Structural Attachment

- Bolt removed before flight
- 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
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
The Engineering Development DFI pallet was subjected to many acceptance level tests.
Tests were conducted in all axes:
- Vertical (Axial) Direction
- Transverse Roll Direction
- Longitudinal (Shear) 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

Project Orion Abort Flight Test
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

T-0 doors closed
LAS Jettison, FBC Jettison, and Drogue Deployment
DFI Film and Video Cameras
3 Full Mains
CM Recovery

Project Orion Abort Flight Test
Project Orion Abort Flight Test

Post Launch Fly-By and Survey

- VIV – well protected, no damage
- ECS Cart – well protected, no damage
- J-Box Shelter, no damage
- Abort Motor Plume Impingement
- NW Blast Shield – uprooted from concrete due to direct alignment of AM plume
- T-0 Umbilicals whipped against J-Box Shelter and thrown to one side
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