Crew Module Overview

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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

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

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

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

Video Camera

+Z

DFI Cameras (Crew Tunnel)

High Speed Film Camera
## PA-1 DFI Parameter Summary

<table>
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<tr>
<th>Sensor Type Summary</th>
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<td>Accelerometer</td>
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<th>Module Meas. Summary</th>
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<td>CM</td>
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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
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
Ixx Inertia 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
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
Project Orion Abort Flight Test

DFI Film and Video Cameras
3 Full Mains
Post Launch Fly-By and Survey

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