Orion Abort Flight Test

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Recent Abort Flight Test Events

- Pad Abort 1 flight test occurred on 6 May 2010 from White Sands Missile Range in New Mexico
Abort Flight Test

- Orion’s Launch Abort System (LAS) provides an emergency escape system for the crew

- Abort Flight Test Objectives:
  - Provide adequate testing to demonstrate proper performance and function of the LAS throughout the required flight envelope
  - Validate key abort models
    - LAS performance and functionality
    - Parachute system performance and functionality
    - Separation aerodynamics
    - Separation mechanism performance
  - Pathfinder for Orion system integration and ground operations procedures
**Orion Spacecraft Overview**

- **Crew Module**
  - Provides safe habitat for crew
  - Allows reentry and landing as a stand alone module
  - ISS “lifeboat” capability

- **Launch Abort System**
  - Safely removes the crew from launch vehicle in an emergency
  - Protects crew module from atmospheric loads and heating
  - Jettisons after successful pad operations and first stage flight

- **Service Module**
  - Supports crew module from launch through separation
  - Accommodates unpressurized cargo or mission science equipment

- **Spacecraft Adapter**
  - Provides connection to launch vehicle
  - Protects Service Module components
Components of Program Constellation
Launch Abort System (LAS) and Crew Module (CM)
Jettison Motor Firing

ORION
LAUNCH ABORT SYSTEM
JETTISON MOTOR
DEMONSTRATION MOTOR #2 (DM-2)
JULY 17, 2008

Project Orion: Flight Test Office
Attitude Control Motor Firing
PA-1 test at White Sands was designed to fly a due North trajectory, At KSC, the pad abort trajectory ‘dog-legs’ towards the ocean
Launch Abort Vehicle (LAV) Controller Info

- For PA-1, LAV controller was developed by Orbital-Dulles
  - PID controller, had heritage from Pegasus
  - On-board gain scheduling based on mass properties changes
  - Roll-yaw coupling (p-beta) which used a yaw command to dampen roll rates
  - Timer-based guidance
    - 0-2 seconds; open-loop pitch-over to get downrange; commanded pitch & yaw
    - 2-10 seconds; downrange guidance; commanded alpha & beta
    - 10-21 seconds; reorientation guidance; commanded alpha & beta
    - All commands turned into attitude rate commands in FSW before they were passed to the ACM controller
Mobile Operations Facility (MOF) Overview

- Chute Installation
- Acoustic Blanket Installation

- Chutes
- Acoustic Blankets

- Intercom panels (18)

- Telemetry, video, timing distribution, and processing equipment racks (7)

- Video Monitors (4)

- Workstation displays (21)

- LM Command, Control, and Monitoring System racks - not shown (3.5)

- Intercom panels (18)
Bill Site has wide FOV camera and 2 mounts total

Dee Site has wide FOV camera
Footage from various video sites

- PA-1 Compilation video
**Personal Experiences / Lessons Learned**

- **Launch Fever, noun:** An unwillingness to miss an important deadline despite known problems.
  - High speed film camera in crew module
  - SIGI-2 issues
  - ACM controller issues
  - Coyote

- **Managing emotions associated with the launch**
  - Went through various failure scenarios
    - Tip-over risk
    - High vibration associated with the initial pull-away
    - Risk of loss of controller authority with jet interaction
    - Risk of parachute failure
  - Stress near T-0
    - Coping techniques

- **Estimating probability of mission success**
  - 81 unique PA-1 related risks
Lessons Learned (continued)

• Project pace & travel (4 years)
• Number of different organizations involved – always complicated
  – Flight Test Office was the responsible flight test organization
  – On some level, you needed to be Al Haig-like
• Lessons Learned take awhile to process, then recognize & identify
  – Project collected Lessons Learned just after launch
  – Lessons Learned in wind placard story
Lessons Learned – wind placards story

- Surprised at how ‘basic’ things became issues that grew quickly out of control (the ‘how-did-we-get-here?’ phenomenon)*
  - Wind placards were an example of this
    - Early on, LM Mission Analysis group identified an issue with the winds modeling in GRAM-99 with the WSMR RRA (wasn’t consistent with weather balloon data, RRA data from the 1980’s)
    - FTO agreed to go with the WSMR RRA from GRAM-2007 put into GRAM-99, our concern was that the weather balloon data hadn’t been blessed by the Air Force organization (AFCCC) that certifies RRAs
    - Using this RRA caused the LM Mission Analysis group to develop placards that were very restrictive, and it became a lot of work to get these placards expanded to reasonable operational levels
    - Control room operations were down to a minimal staff (due to MOF size), support personnel were available, but communication was sometimes spotty

* Still working to define all the lessons learned here
Proposed wind placard table, not the actual table used for launch.
Weather go/no-go call plan progression

- Plan A: GNC & Dryden meteorologist would make the call
- Plan B: at their request, involved LM Mission Analysis personnel in weather center; GNC & Dryden MET still make the call
- Plan C: Senior Ops helps GNC in control room when complex placards are developed; GNC, Dryden MET, Sr. Ops, FTA lead make the call once we see data from weather center
- Plan D: As placard issue becomes more complex & controversial, the decision gets pushed up to the Mission Management Team (MMT is Orion PM & his support staff)
  - Used 5 weather balloons on day of launch
  - Had 924 MHz profiler next to launch site
  - Flying in the windiest part of the year for White Sands (March - May)
  - 4 day launch window (Thursday – Sunday); can’t go the following week due to another higher priority program’s launch
  - Day before the launch, briefing MMT on weather-101
Lessons Learned (continued)

• After all that, balloon data showed that we were go for flight, but from the Ops recovery team and then from flight data, we learned that we were flying in 3-sigma GRAM winds that day.
Lessons Learned (continued)

- Wind Placards
  - Don’t involve people in the process who don’t have decision making authority; or if you do involve them, make sure they have associated with them a decision maker who has authority
  - During flight operations, a data or analysis briefing needs to come with a recommendation (ties back to authority)
    - At earlier stages of the project, analysts tend to show you all the data, so decisions can be collectively made by the team – this isn’t useful or productive during operations
  - Additional LLs in work
Altitude Time History from flight

Apogee was 10,386.0 feet (geodetic)
CM downrange was 6907.5 feet (SIGI measured)
Total flight time was 134.4 seconds
PA-1 Flight Test Ground Track
Post-flight data comparisons to simulation

- ANTARES simulation runs done using post-flight updated simulation models for
  - Abort Motor thrust profile from flight
  - Attitude Control Motor thrust profile from flight
  - Meterology day-of-flight atmospheric model
  - Mass Properties
  - Parachutes (higher fidelity models incorporated)
- Still waiting for day-of-flight aerodynamic models to come in
  - Possible that drag is not as high as pre-flight aero models predict?
Flight Data compared to dispersed simulation runs
Ground Track

![Ground Track Diagram]
Winds blowing from West to the East
6 May 2010 – 6:09am local time
What is next for Orion & Abort Flight Test

• Orion program management has decided to pursue OFT-1 as the next flight test
  – Test is mainly an entry test, with only a nominal LAS jettison
  – OFT-1 is a un-crewed orbital test (no docking with space station)
  – FT-2 (Orion-2) is the first crewed flight test on the manifest

• AA-2 is currently being considered as a follow on test in between OFT-1 and FT-2 (Orion-1 & Orion-2)
  – AA-2 is a transonic abort (LAS abort occurs as vehicle passes through Mach 1, about 40 seconds into the ascent)
  – Would test the production LAV controller
  – Would be performed with an abort test booster (ATB)
    • Currently SR 118 Peacekeeper motor
  – Currently performing a trade study on the AA-2 launch site location

• Production launch vehicle determination expected by Oct 31
Wrap-Up

- **Ops candid commentary during flight**
  - Includes helicopter chase video

- Questions/Comments?