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
Notional Ascent Abort Scenarios

1. FTV Ignition
2. FTV Boost
3. LAV Reorientation
4. LAS Jettison
5. CM Recovery Sequences
6. Landing

- High Altitude Abort
- Max Q Power-on Tumble Abort
- Max Q Abort
- Transonic Abort
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

- Ares V - Heavy Lift Launch Vehicle
- Orion - Crew Exploration Vehicle
- Earth Departure Stage
- Lunar Lander
- Ares I - Crew Launch Vehicle
Launch Abort System (LAS) and Crew Module (CM)
Abort Motor Test Firing
Jettison Motor Firing
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

- Telemetry, video, timing distribution, and processing equipment racks (7)
- LM Command, Control, and Monitoring System racks - not shown (3.5)
- Video Monitors (4)
- Workstation displays (21)
- Intercom panels (18)
WSMR Tracking Optics

Bill Site has wide FOV camera and 2 mounts total

Dee Site has wide FOV camera

CM
LAS
FBC
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
Lessons Learned (continued)

Proposed wind placard table, not the actual table used for launch

<table>
<thead>
<tr>
<th>Altitude Above WGS-84 Reference Ellipsoid (ft)</th>
<th>4000</th>
<th>4500</th>
<th>5000</th>
<th>5500</th>
<th>6000</th>
<th>6500</th>
<th>7000</th>
<th>7500</th>
<th>8000</th>
<th>8500</th>
<th>9000</th>
<th>9500</th>
<th>10000</th>
<th>10500</th>
<th>11000</th>
</tr>
</thead>
</table>
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
• 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
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
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
  - Meteorology 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

The image shows a graph with the x-axis labeled "Longitude (deg)" ranging from -106.415 to -106.37, and the y-axis labeled "Latitude (deg)" ranging from 32.405 to 32.44. The graph includes several lines representing different data sets:

- iCERT Runs
- Nom Run
- BET Data

The data points are spread across the graph, indicating the ground track over a specific area and period.
Winds blowing from West to the East
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?