Orion Pad Abort 1 Flight Test

Ground and Flight Operations

Davis Hackenberg
Davis.L.Hackenberg@nasa.gov

Wayne Hicks
Wayne.Hicks@Zeltech.com

The Operations Team with the PA-1 Test Vehicle
Presentation Overview

• Operational Planning
• Facilities Preparation
• Integration and Testing
• Flight Ops
• Other Challenges and Successes
OPERATIONAL PLANNING
Approach to Operational Planning

**PROCESS**

- **Develop top-level operational concepts and integration sequences.**
  - Project’s Concepts, Assumptions, & Constraints
    - Concept of Operations
  - Integration Activities and Tasks
    - Ground Operations Plan
    - Hardware Integration Flow
  - Facility Requirements
    - Facility Requirement Documents
  - Ground Support Equipment Requirements
    - GSE Plan
    - GSE IRDs, ICDs, Specs
  - Transportation Requirements
    - Transportation Plans
    - Roles and Responsibilities
  - Safety Hazards & Mitigations
    - Safety Requirements Documents
    - Systems Safety Hazard Report
    - Site Safety Plans
    - Emergency Preparedness Plans
  - Procedures
    - Master Procedures List
    - Integration & Test Procedures
  - Ground Operations Team
  - Flight Operations Team
    - Staffing Plan
    - Training Requirements (Plan)
    - Training Records

**PRODUCTS**
Project’s overarching concepts, assumptions, & constraints drove the operational planning

**Operations Group Responsibilities**
- Plan for six flight tests:
  - Two (2) Pad Abort tests
  - Four (4) Ascent Abort tests
- Prepare the Test Vehicles
- Build the Launch Facilities
- Provide Mission Architecture to control test vehicle and to capture vehicle performance and aerodynamic data
- Perform the flight tests

**Mandates**
- Meet ambitious launch schedule
- Protect for late installation of long lead time and life-limited items
- Use aggressive test and verification approach

Considerations drove the Ground Operations planning
- Integrate the Test Vehicle in 2 phases to reduce time spent at launch site
- For PA-1:
  - Perform non-hazardous Crew Module integration at NASA Dryden Flight Research Center
  - Assemble Launch Abort System at Launch Site
  - Perform final hazardous processing at Launch Site

Considerations drove the Mission Operations Architecture
- Perform flight tests on an equipped test range
- Test range large enough to contain flight trajectories
- Use Mobile Launch Concept

Considerations drove the Launch Facilities
- Support both Pad Abort and Ascent Abort tests
- Provide integration areas for Launch Abort System, Crew Module, and Abort Test Booster.
- Launch Complex sited for hazardous ordnance processing and explosives operations
Contents
1. Organizational Roles and Responsibilities
2. Goals and Objectives
3. Abort Flight Test Scenarios
4. Test Vehicle Concepts
5. Ground Operations and Integration Flows
6. Flight Operations
7. Flight Operations for Ares Launch Opportunity
8. Training

Purpose
• Identifies organizational roles and responsibilities
• Describes the Test Vehicle, its components and the component functions, and the component providers.
• Described the top-level integrations flows and the integration locations.
• Describes the mission architecture and the roles for conducting the flight operations.
• Conveys top-level guidance from which to start developing requirements and specifications
Ground Operations Plan provided the detailed integration flows, activities, and task descriptions

Contents (Abbreviated Listing)
1. Roles and Responsibilities
3. Approach to Development
4. Ground Planning Documentation
5. Facilities
6. Ground Support Equipment
7. Initial Integration at Dryden Flight Research Center
8. Final Integration at WSMR
9. Pad Operations at WSMR
10. Recovery and Disposition Activities after Flight Test

Purpose
• Provides the detailed hardware integration flows.
• Assembly and integration tasks described in detail.
• Identifies personnel, facility, and equipment resources required to perform each task.
• Includes over 250 storyboards
• Task descriptions provide the starting point for developing procedures.
Over 250 Storyboards like this one used pictures to convey the integration sequences

<table>
<thead>
<tr>
<th>8.6.1 CM Mass Properties Test — Weight Determination</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Move CM to Test Location</strong></td>
</tr>
<tr>
<td>- Install CM vertical lifting fixture.</td>
</tr>
<tr>
<td>- Remove CM work stand.</td>
</tr>
<tr>
<td>- Configure CMTF for mobilizers.</td>
</tr>
<tr>
<td>- Move CM to test location</td>
</tr>
<tr>
<td><strong>2. Set Up for Test</strong></td>
</tr>
<tr>
<td>- Set up access control area.</td>
</tr>
<tr>
<td>- Configure test equipment.</td>
</tr>
<tr>
<td>- Prepare for critical lift operations.</td>
</tr>
<tr>
<td>- Roll in work stands</td>
</tr>
<tr>
<td>- Configure load cell and lifting slings for lifting</td>
</tr>
<tr>
<td>- Roll back work stands</td>
</tr>
<tr>
<td><strong>3. Conduct CM Weight Measurements</strong></td>
</tr>
<tr>
<td>- Take up the slack in the slings and ensure the</td>
</tr>
<tr>
<td>hook is centered over the CM.</td>
</tr>
<tr>
<td>- Start the data logger for the load cell.</td>
</tr>
<tr>
<td>- Lift CM into hover position over CMTF.</td>
</tr>
<tr>
<td>- Record CM weight.</td>
</tr>
<tr>
<td>- Stop data logger.</td>
</tr>
<tr>
<td>- Lower CM onto CMTF.</td>
</tr>
<tr>
<td>(Repeat per test procedure.)</td>
</tr>
<tr>
<td>(After last measurement!)</td>
</tr>
<tr>
<td>- Unhook load cell and slings from crane.</td>
</tr>
</tbody>
</table>

1. Each operation linked to Integration Flow
2. Activity Sequence includes detailed task descriptions
3. Flight Hardware clearly shown
   - Crew Module (in this example)
4. Ground Support Equipment:
   - Crew Module Transporter
   - Crew Module Lift Fixture
5. Facility Resources can be identified:
   - Aircraft Integration Facility
6. Facility Equipment and placements:
   - Mobile Crane
   - Load Cell
7. Procedures
   - Convert Integration Stand to Transporter
   - Transport Crew Module
   - Critical Lift Pre-Task Planning
   - CM Weight Determination Procedure
   - “Critical Lift” involves hazardous ops
8. Personnel
   - Task Team Leader
   - Safety Lead
   - QA Lead
   - Lift Manager
   - Tug Operator
   - Mobilizer Operators
   - Crane Operator
   - Mechanics
Storyboards were good predictors of actual operations

For first measurement set:

8. Retract and remove safety jacks.
9. Activate air bearing pallets; Start data loggers; Raise apex jack.
10. Record weights; Lower apex jack; stop data loggers.
11. After measurements sets are obtained, reset safety jacks under CM.

Repeat Steps 9 and 10 as needed to obtain first measurement set.

For second measurement set:
Repeat Steps 8 through 11 using the 120-degree jack as the apex jack.

For third measurement set:
Repeat Steps 8 through 11 using the 240-degree jack as the apex jack.
Storyboard for the Crew Module Iyy Inertia Test

Storyboard

8.7.4 CM Mass Properties Test – Iyy and Izz Inertia Determination

Actual
Swim Lanes were another tool used to plan resources, verifications, and prerequisites.
FACILITIES PREPARATION
Facilities Description

- Facility Requirements Document (FRD) used to document launch complex requirements and to initiate design effort
- Construction of LC-32E facilities commenced on October 1, 2007
  - Final Integration and Test Facility (FITF)
  - Launch Pad
  - Launch Services Pad
  - Operations Support Trailer (OST)
- Construction of FITF complete in April 2008
- Construction of Launch Pad complete in August 2008
PA-1 Vehicle on Launch Pad and FITF

Launch Pad and Gantry

Final Integration and Test Facility (FITF)

Integration Bays inside FITF

Launch Pad Services Area

Operations Support Trailer

Aerial View of Orion Launch Complex 32 East

LC-32 East

Field Storage Area

Operations Support Trailer
INTEGRATION AND TESTING
Test Vehicle assembly, integration, and testing occurred in two phases

Phase I:
Crew Module integrated initially at Dryden Flight Research Center

Phase II:
Final Integration occurred at the White Sands Missile Range
Crew Module was outfitted with sensors, avionics, and mechanisms at NASA Dryden

CM Arrival via C-17

Painted w/Test Pattern

Avionics Pallets and Harnesses Installed

Installing Sensors and Cameras

Crew Module being integrated in Shuttle Hangar at NASA Dryden Flight Research Center

CM Functional and RF Tests

Mass Properties Tests
Launch Abort System was assembled and checked at the launch site

Motor Roll Transfer onto integration trailer
Adapter Cone placement
Structural Mates
LAS Functional Tests

LAS being prepared in the Final Integration and Test Facility
LAS Ready for Roll-Out
Integrated electrical tests verified Crew Module and Launch Abort System interfaces

Crew Module Forward Bay Integration

Setting up cameras to monitor Phasing Test

Attitude Control Motor Functional Test

Crew Module / Launch Abort System Soft Mate Testing
Pad Operations included stacking the Test Vehicle and performing final tests and launch preparations.
FLIGHT OPERATIONS
PLANNING AND EXECUTION
Flight Ops Challenges

• Mobile Control Room Architecture
• Launch Team Training
• Range Assets
Mobile Operations - WSMR Mission Architecture
• In addition to Training on timeline in the 1.5 months prior to launch
  • 3 Table Top Reviews (TTR) with the entire team
  • 2 Emergency/Contingency Procedure simulation trainings
  • 2 PAO rehearsals
  • 3 Test Specific TTR’s and Emergency procedure planning
  • Mishap Response Planning
  • Recovery Ops dry-run

• Incorporation of training around launch timeframe is difficult and required full commitment from the entire project
WSMR Tracking Assets Used for PA-1

Radar

Camera’s
A FEW KEY CHALLENGES AND SUCCESSES
The Project overcame many challenges

- Flight Test Organization
- Ops and Vehicle Planning
- Unforeseen Events
- Re-plan and Coordinate
- Schedule Pressures
- Final Execution
- Begin Execution
Coordination and Resources

• Coordination and planning of resources was difficult due to a constantly changing schedule
• Keeping all parties involved at all times during integration phases allowed for extra support during surges – A representative for people at the test location proved extremely useful
• Running 2 shifts the final month prior to launch included engineering and technician support from all project locations.
• Daily Ops tag-up helped improved situational awareness in all time zones
• Utilization of the entire teams knowledge and skills was essential in meeting the aggressive launch date that was planned 2 months prior
Pathfinder and Risk Reduction Operations

- Conducted for all operations that involved pyrotechnics, including integration and lifts. (In plan)
- Fit checks (opportunity based)
- Conducted (as time allowed) for Day-of-Flight Operations and other key issues such as integration with WSMR (opportunity based)

Challenges:
- Required significant planning and dedication by the entire team.
- Scheduling around other required activities was difficult
- Timing of operations not ideal relative to other project activities such as acceptance testing
- Developing SOP’s

Successes
- Personnel safety maximized for all operations
- Procedures released on time and conducted with minimal red-lines.
- Risk Reduction – changes and issues were identified early
- Confidence in operations allowed them to easily be performed on night shift
- Finished operations ahead of schedule!!!
Pathfinder Ops - Pyrotechnics Integration Timeline

- **7/11**: FBC Arrives at DFRC from LaRC
- **9/15**: Avionics Harness Install
- **12/3**: Avionics Post Ship Functional Testing
- **8/16**: FB Thrusters and Sep Bolts
- **10/3**: Mass Properties Testing
- **12/1**: Install Reworked Avionics Harnesses
- **1/21**: AV1,2,3 Pallet Installs
- **6/4**: Avionics Sync D
- **6/29**: AIL Test
- **7/11**: RF Open Loop / CST
- **7/22**: Pyro Summit
- **9/15**: Avionics Harness Install
- **9/24**: CST
- **11/30**: CM Pyro Integration
- **1/7**: CM Pyro Installs Complete
- **4/4**: LAS Stack
- **4/28**: Final BWIR
- **3/22**: CM Stack
- **4/14**: Final Pyro Connections
- **5/6**: Launch!
Recovery

1. Receive Post-Landing Assessment from MOF (Scorecard)
2. Deploy to LZ staging Point
3. UXB sweep for UXO
4. Assess hazards preventing safe approach
5. Approach and Safe
6. Repeat 4&5 according to Hazard Analysis
7. Transport to LC32 or other destination

NOTE: Photo document entire process
BACK-UP
## Off Nominal Procedures Overview

### Countdown Milestones

**Power On Prelaunch**
- Parameter - Load
- SIGIs - On
- Avionics - POST
- DFI - On
- LAS RDAUs - On
- OFI RF - On
- DFI RF - On
- SIGIs – Start Alignment
- Transfer to Internal then back to External Power
- ACM - On

**LAS BIT**
- LAS S/As - Arm/Safe
- Checkout
- Reset Counter
- Reset Time
- FDRs – Start Recording
- Transfer to Internal Power
- PEC Power - On
- LAS S/As - Arm

**Abort Enable**
- PECs charged
- LAS Rdy Mode (ACM 140 vdc – ON)
- SIGIs – NAV Mode

**T-2 mins**

**Abort Execute**

### Emergency Call

**“Pause / Hold”**
- Hold and evaluate
- Monitor system health and status
- Consider –
  - RF – Off

**“Kill”**
- Hold and evaluate
- Monitor system health and status
- Consider –
  - OFI / DFI RF – Off
  - FDRs – Stop Recording
  - Transfer To External Power

### Emergency Call

- Kill
- ACM Vulnerable 6 min window

- Kill
- ACM Vulnerable
PA-1 Communications Plan
Version 4-10-10

WSMR Cox RCC
- Range Controller
- UXB
- Orion AFT Mission Engineering Rooms
- Orion AFT Mission Management Team
- Orion AFT Mission Support Room
- Orion AFT EDL-Houston

Test Director

MOF
- NASA Meteorology
- Recovery
- Ground Ops Lead / NASA Safety

Mission Support
- Cell Phones UHF Trunk Radios
- Belt Packs

Comm Nets
- Mission Net
- System Net
- Data Net
- Comm Net
- WSMR Cmd/ISO Net
- UXB Recovery Net
- Support Net (Telecon)
- MMT to TD Phone
- Dashed segments signify Receive-Only

OCDF Access Code: ________
VIP Rm Access Code: ________
Support Net: 866-916-4201 5709324#