Orion Pad Abort 1 Flight Test
Ground and Flight Operations

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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**

1. **Project’s Concepts, Assumptions, & Constraints**
   - Develop top-level operational concepts and integration sequences.

2. **Integration Activities and Tasks**
   - For each major sequence, identify the activities and tasks to perform.

3. **Facility Requirements**
   - Use the task descriptions to identify requirements.

4. **Ground Support Equipment Requirements**

5. **Transportation Requirements**

6. **Safety Hazards & Mitigations**
   - Knowing the work to be performed and how equipment will be operated, identify the safety hazards and the mitigations.

7. **Procedures**
   - Develop procedures to perform the integration tasks and to operate equipment. Include safety mitigations.

8. **Ground Operations Team**
   - Identify personnel and skills mixes needed to perform tasks and operate equipment.

**Products**

1. **Concept of Operations**

2. **Ground Operations Plan**

3. **Hardware Integration Flow**

4. **Facility Requirement Documents**

5. **GSE Plan**

6. **GSE IRDs, ICDs, Specs**

7. **Transportation Plans**

8. **Roles and Responsibilities**

9. **Safety Requirements Documents**

10. **Systems Safety Hazard Report**

11. **Site Safety Plans**

12. **Emergency Preparedness Plans**

13. **Master Procedures List**

14. **Integration & Test Procedures**

15. **Staffing Plan**

16. **Training Requirements (Plan)**

17. **Training Records**
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
Concept of Operations Document established top level vehicle, ground, and flight operations concepts

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

### 8.6.1 CM Mass Properties Test—Weight Determination

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
</table>
| **1. Move CM to Test Location** | - Install CM vertical lifting fixture.  
- Remove CM work stand.  
- Configure CMTF for mobilizers.  
- Move CM to test location. |
| **2. Set Up for Test** | - Set up access control area.  
- Configure test equipment.  
- Prepare for critical lift operations.  
- Roll in work stands.  
- Configure load cell and lifting slings for lifting.  
- Roll back work stands. |
| **3. Conduct CM Weight Measurements** | - Take up the slack in the slings and ensure the hook is centered over the CM.  
- Start the data logger for the load cell.  
- Lift CM into hover position over CMTF.  
- Record CM weight.  
- Stop data logger.  
- Lower CM onto CMTF.  
(Repeat per test procedure.) |
| **4. Reconfigure Integration Stand as the Transporter** |
| **5. Load Cell and Lifting Fixture** |
| **6. Critical Lift** |

### Facility Equipment and placements:
- Mobile Crane
- Load Cell

### Procedures
- Convert Integration Stand to Transporter
- Transport Crew Module
- Critical Lift Pre-Task Planning
- CM Weight Determination Procedure
- “Critical Lift” involves hazardous ops

### Personnel
- Task Team Leader
- Safety Lead
- QA Lead
- Lift Manager
- Tug Operator
- Mobilizer Operators
- Crane Operator
- Mechanics
Storyboards were good predictors of actual operations

**Storyboard**

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.

**Actual**

Repeat Steps 8 through 11 using the 120-degree jack as the apex jack.

Repeat Steps 8 through 11 using the 240-degree jack as the apex jack.
8.7.4 CM Mass Properties Test – Iyy and Izz Inertia Determination

Storyboard

CM-to-Frame Attachments
Inertia Frame
Safety Jacks
Knife Edge

CM Lifting Fixture removed for test

Monoaxial Springs
Turnbuckle
String Potentiometer
Safety Jacks lowered for test

Actual
Swim Lanes were another tool used to plan resources, verifications, and prerequisites.

8.2.4 CM Setup in Shuttle Hangar

<table>
<thead>
<tr>
<th>SEQUENCES</th>
<th>REQUIRE LSIT OPS</th>
<th>REQUIRE LSIT OPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receive CM in Shuttle Hangar</td>
<td>Convert CMTF into Integration Stand</td>
<td>Prepare CM for CM Integration</td>
</tr>
<tr>
<td>✅ Position CM under overhead bridge crane</td>
<td>✅ Prepare for LT operations</td>
<td>✅ Remove CM hatch</td>
</tr>
<tr>
<td>✅ Position CM under overhead bridge crane</td>
<td>✅ Remove CM &amp; frames</td>
<td>✅ Remove Panels 2 &amp; 5</td>
</tr>
<tr>
<td>✅ Position CM on casters</td>
<td>✅ Remove tie-downs</td>
<td>✅ CM Hatch Removal</td>
</tr>
<tr>
<td>✅ Remove mobilization</td>
<td>✅ Remove tripods &amp; tie-down hardpoints</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PROCEDURES</th>
<th>TUG (DFRC)</th>
<th>CM Lower Work Platform Panels</th>
</tr>
</thead>
<tbody>
<tr>
<td>FTO-AFT-OPS-1004</td>
<td>DFRC local transportation</td>
<td>B1 Work Stands</td>
</tr>
<tr>
<td>Work Order: E16640</td>
<td></td>
<td>Access Platform</td>
</tr>
<tr>
<td>FTO-AFT-OPS-1006</td>
<td>Removal of Panels 2 &amp; 5, Tripods &amp; Tie-Downs</td>
<td>CM Temporary Floor Panels</td>
</tr>
<tr>
<td>Work Order: E16643</td>
<td>Installation and Removal of CMTF End Frames and Diagonals</td>
<td>CM Lift Fixture Installation and Removal</td>
</tr>
<tr>
<td>Work Order: E16639</td>
<td>Lower Work Platform Panel Installation and Load Test</td>
<td></td>
</tr>
<tr>
<td>Work Order: E16640</td>
<td>CM Hatch Removal</td>
<td></td>
</tr>
<tr>
<td>Work Order: E16641</td>
<td>Drawing: 1247018 Skin Assembly</td>
<td></td>
</tr>
<tr>
<td>Work Order: E16642</td>
<td>Removal of Panels 2 &amp; 5, Tripods &amp; Tie-Downs</td>
<td></td>
</tr>
<tr>
<td>Work Order: E16643</td>
<td>Drawing: 1247018 Skin Assembly</td>
<td></td>
</tr>
<tr>
<td>Work Order: E16644</td>
<td>Temporary Floor Panel Installation and Load Test</td>
<td></td>
</tr>
<tr>
<td>Work Order: E16656</td>
<td>DFRC Lift Fixture Installation and Removal</td>
<td></td>
</tr>
<tr>
<td>Work Order: E16662</td>
<td>DFRC Lift Fixture Installation and Removal</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>PERSONNEL</th>
<th>Crane - PM &amp; equipment certification on file</th>
</tr>
</thead>
<tbody>
<tr>
<td>DFRC lug operator</td>
<td>Lead Test: CM Lower Work Platform Panels to 1,000 lbs</td>
</tr>
<tr>
<td>DFRC Crew (Spotters)</td>
<td>(2 people) x 2 SF = 1,000 lbs</td>
</tr>
<tr>
<td>DFRC lift operator</td>
<td>Lead Test: CM Lift Floor Panels to 1,000 lbs</td>
</tr>
<tr>
<td>DFRC Crew (Spotters)</td>
<td>(3 people) x 3 SF = 900 lbs</td>
</tr>
<tr>
<td>LARC Representative</td>
<td>Overhead Crane - PM &amp; Lift Carts on file</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>VERIFY</th>
<th>PRE-REQS</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM Temporary Floor Panels</td>
<td>Shuttle Hangar prepped for arrival</td>
</tr>
<tr>
<td>CM Lift Fixture Stands and Shackles</td>
<td>Tugs &amp; Cranes - PM &amp; Certs on file</td>
</tr>
<tr>
<td>CM Lift Fixture Storage Container</td>
<td>Lead Test: CM Lift Floor Panels to 1,000 lbs</td>
</tr>
<tr>
<td>Forklift</td>
<td>(3 people) x 2 SF = 600 lbs</td>
</tr>
<tr>
<td>Overhead Bridge Crane</td>
<td>Overhead Crane - PM &amp; Lift Carts on file</td>
</tr>
<tr>
<td></td>
<td>CM Lift Fixture - Correct Assy, Cert, and load tags on Slings and Shackles</td>
</tr>
</tbody>
</table>
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
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
Pad Operations included stacking the Test Vehicle and performing final tests and launch preparations.

Test Vehicle stacked onto Launch Pad

Crew Module being stacked onto Launch Pad

Launch Abort System being stacked onto Crew Module

Measuring Stack Straightness with Laser Scans

Thermal Cover installed
FLIGHT OPERATIONS
PLANNING AND EXECUTION
Flight Ops Challenges

• Mobile Control Room Architecture
• Launch Team Training
• Range Assets
Mobile Operations - WSMR Mission Architecture

Test Vehicles
(Launch Pad LC-32E)

Range Assets
S-Band TM Downlinks (RF)
- FTA DFI (15 Mbps)
- FTA DFI (5 Mbps)

- ATB HSS (3 Mbps)
- ATB DFI (5 Mbps)

- UHF C2 Uplink (RF)

- Radar Tracks (RF)
  - FBC (skin)
  - LAS (skin)
  - CM (Beacon)
  - ATB FT9

- Flight Termination (RF)
  - ATB FT9

- Optics

Launch Services Pad Interfaces

- FTA Umbilical Copper

- WSMR Fiber Backbones
  (TSN-SONET and TSN-HF)

Remote Technical Support Team

- WSTF
- NISP
- EDL (Houston)

- Cox RCC (Bldg 335)
  (range safety, technical support, and mission management team)

- Abort Test Booster Launch Control Van

- Orion AFT Mobile Operations Facility

AA-1 Interfaces Grayed Out
Launch Team Training

• 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
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
- Begin Execution
- Final 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

2008
- 1/21–AV1,2,3 Pallet Installs
- 2/3–Avionics Post Install Functional Testing
- 3/30 – Pyro Summit
- 6/4- Avionics Sync D
- 6/16–FB Thrusters and Sep Bolts
- 7/11-FBC Arrives at DFRC from LaRC
- 7/11-RF Open Loop / CST
- 8/16–FB Thrusters and Sep Bolts
- 9/15–Avionics Harness Install
- 9/24 - CST
- 10/3–Mass Properties Testing
- 11/30 – CM Pyro Integration
- 12/1–Install Reworked Avionics Harnesses
- 12/3–Avionics Post Ship Functional Testing

2009
- 1/7 – CM Pyro Installs Complete
- 2/3–Avionics Post Install Functional Testing
- 3/30 – Pyro Summit
- 4/28 – Final BWIR
- 4/4 - LAS Stack
- 4/14 – Final Pyro Connections
- 5/6 – Launch!

2010
- 3/22 – CM Stack
- 4/28 – Final BWIR
- 4/4 - LAS Stack
- 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
Questions?
BACK-UP
# Off Nominal Procedures Overview

## Countdown Milestones

<table>
<thead>
<tr>
<th>Power On Prelaunch</th>
<th>Emergency Call</th>
<th>Emergency Call</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Pause / Hold</strong></td>
<td><strong>Kill</strong></td>
<td></td>
</tr>
<tr>
<td>• Parameter - Load</td>
<td>• Hold and evaluate</td>
<td></td>
</tr>
<tr>
<td>• SIGIs - On</td>
<td>• Monitor system health and status</td>
<td></td>
</tr>
<tr>
<td>• Avionics - POST</td>
<td>• Consider –</td>
<td></td>
</tr>
<tr>
<td>• DFI - On</td>
<td>• RF – Off</td>
<td></td>
</tr>
<tr>
<td>• LAS RDAUs - On</td>
<td>• Monitor system health and status</td>
<td></td>
</tr>
<tr>
<td>• OFI RF - On</td>
<td>• Consider –</td>
<td></td>
</tr>
<tr>
<td>• DFI RF - On</td>
<td>• OFI / DFI RF – Off</td>
<td></td>
</tr>
<tr>
<td>• SIGIs – Start Alignment</td>
<td>• FDRs – Stop Recording</td>
<td></td>
</tr>
<tr>
<td>• Transfer to Internal then back to External Power</td>
<td>• Transfer To External Power</td>
<td></td>
</tr>
<tr>
<td>• ACM - On</td>
<td></td>
<td>ACM Vulnerable 6 min window</td>
</tr>
</tbody>
</table>

## LAS BIT

| • LAS S/As - Arm/Safe Checkout | • ACM 140vdc on for pintle checks | • Hold and evaluate |
| • Reset Counter | • 7 min to fully discharge power hybrid | • Monitor system health and status |
| • Reset Time | • Consider – | • Consider – |
| • FDRs – Start Recording | • OFI / DFI RF – Off |   • RF – Off |
| • Transfer to Internal Power | • FDRs – Stop Recording | • Transfer To External Power |
| • PEC Power - On | • ACM Vulnerable |                |
| • LAS S/As - Arm |                |                |

## Abort Enable

| • PECs charged | • MSS | • ACM Vulnerable |
| • LAS Rdy Mode (ACM 140 vdc – ON) |   • Hold Fire Control – select Hold |    |
| • SIGIs – NAV Mode | • S/A Safe Cmd – select Rotate to Safe Position | Kill |
| • Hold and assess situation | • Vehicle still powered but in Launch Safe Mode | Kill |
| • Team decision | • Recycle SIGI, reset T-0, try again | Kill |
| • Abort Scrub, cancel for the day |                |                |

## Abort Execute

| • Parameter - Load | • MSS | • ACM Vulnerable |
| • SIGIs - On       |   • Hold Fire Control – select Hold |    |
| • Avionics - POST  | • S/A Safe Cmd – select Rotate to Safe Position | Kill |
| • DFI - On         | • Vehicle still powered but in Launch Safe Mode | Kill |
| • LAS RDAUs - On   | • Team decision | Kill |
| • OFI RF - On      | • Recycle SIGI, reset T-0, try again | Kill |
| • DFI RF - On      | • Abort Scrub, cancel for the day | Kill |
| • SIGIs – Start Alignment |                |                |
| • Transfer to Internal then back to External Power |                |                |
| • ACM - On         |                |                |
PA-1 Communications Plan
Version 4-10-10

WSMR Assets
- Telemetry
- Comm
- Radar
- Video
- Range Safety
- Recovery

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
- B1830

Mission Support

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#

Mobile Operations Facility (MOF)

Vehicle Integration Van (VIV)