Orion Pad Abort 1 Flight Test

Ground and Flight Operations

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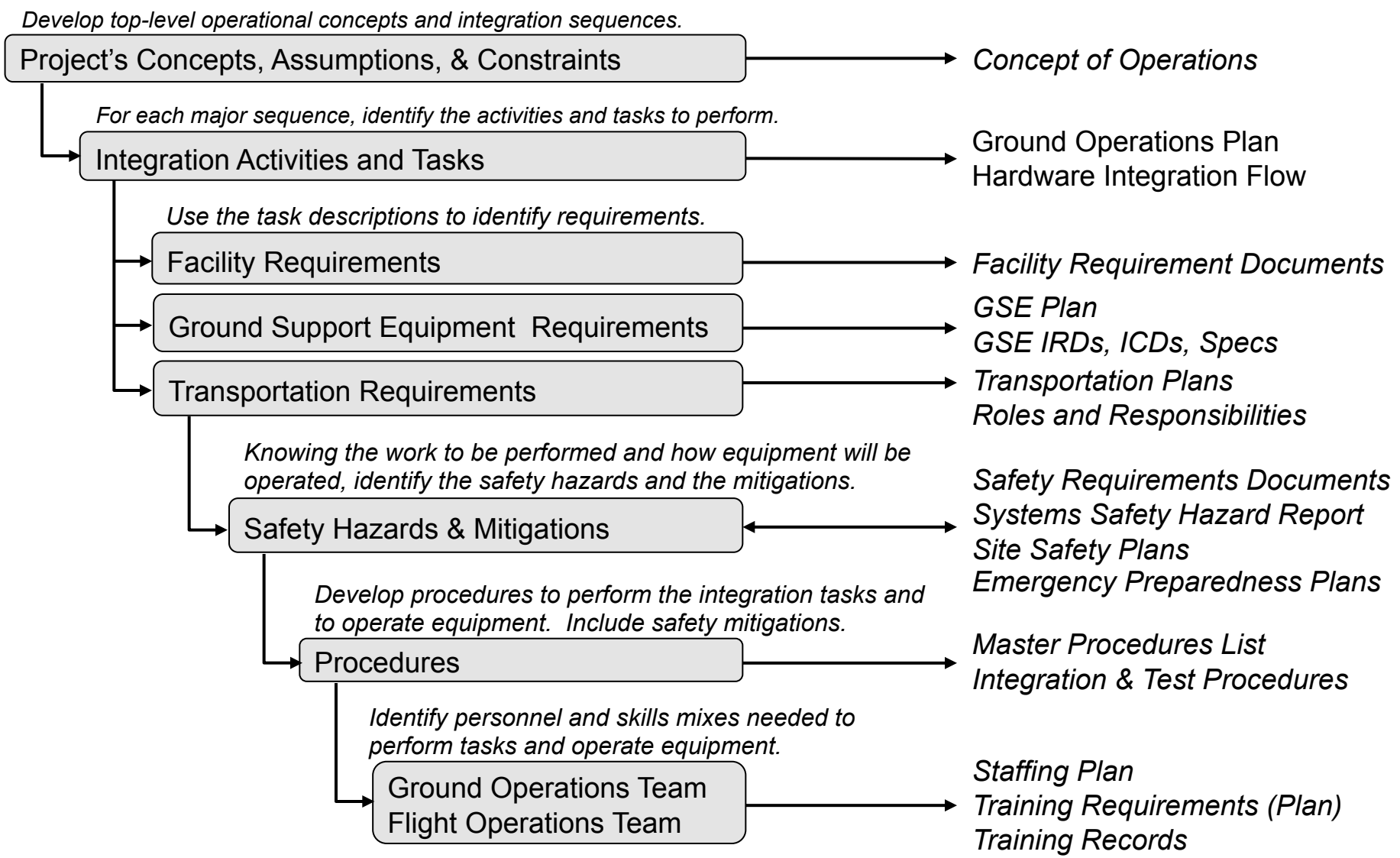
The Operations Team with the PA-1 Test Vehicle

Presentation Overview

- Operational Planning
- Facilities Preparation
- Integration and Testing
- Flight Ops
- Other Challenges and Successes

OPERATIONAL PLANNING

Approach to Operational Planning



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

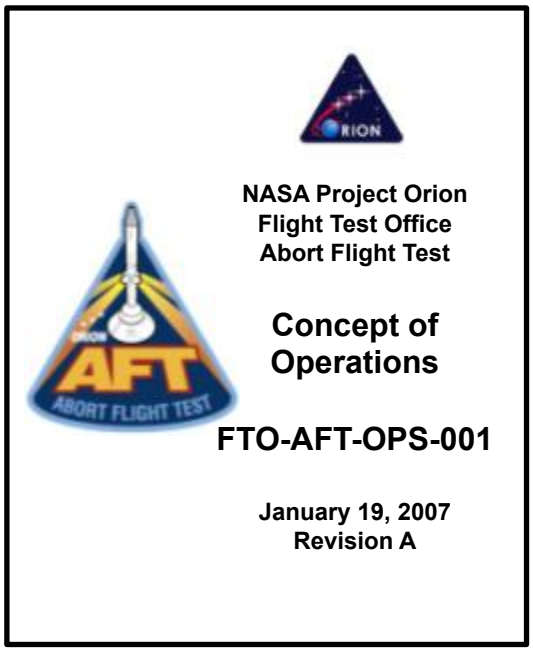
Considerations drove the Mission Operations Architecture

- Perform flight tests on an equipped test range
- Test range large enough to contain flight trajectories
- Use Mobile Launch Concept

Considerations drove the Launch Faciltiies

- 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

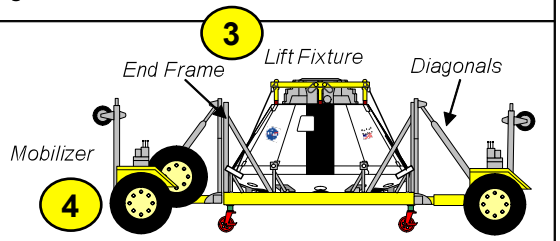
Purpose

- 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

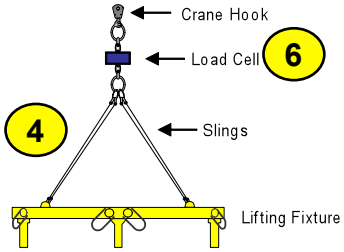
8.6.1 CM Mass Properties Test -- Weight Determination

1. Move CM to Test Location
- ☐ Install CM vertical lifting fixture.
- ☐ Remove CM work stand.
- ☐ Configure CMTF for mobilizers.
- ☐ Move CM to test location



Reconfigure Integration Stand as the Transporter.

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

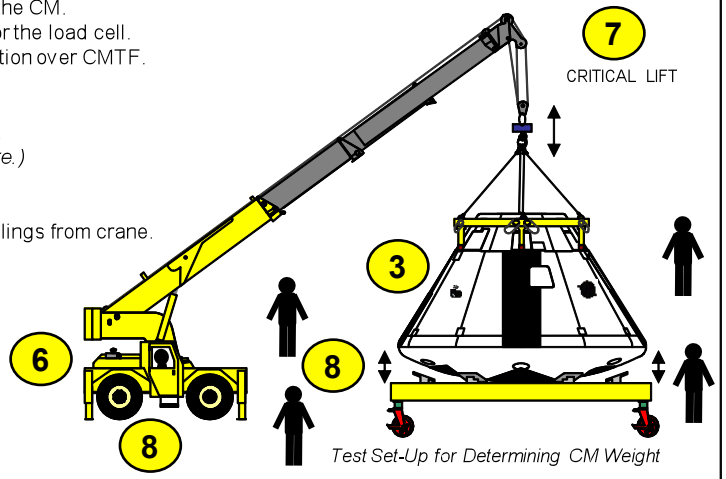


Lifting Configuration for Load Cell and Lifting Fixture

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.)

(After last measurement):
- ☐ Unhook load cell and slings from crane.



Test Set-Up for Determining CM Weight

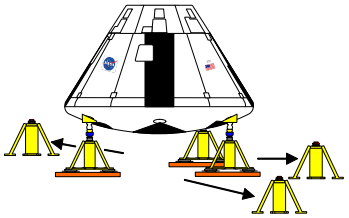
1. Each operation linked to Integration Flow
2. Activity Sequence includes detailed task descriptions
3. Flight Hardware clearly shown
   - Crew Module (in this example)
4. Ground Support Equipment:
   - Crew Module Transporter
   - Crew Module Lift Fixture
5. Facility Resources can be identified:
   - 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

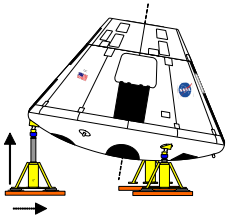
Storyboard

8.6.2 CM Mass Properties Test – Center of Gravity Determination (page 2 of 3)

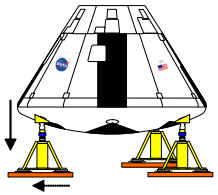
For first measurement set:



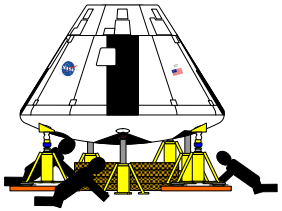
8. *Retract and remove safety jacks.*



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.

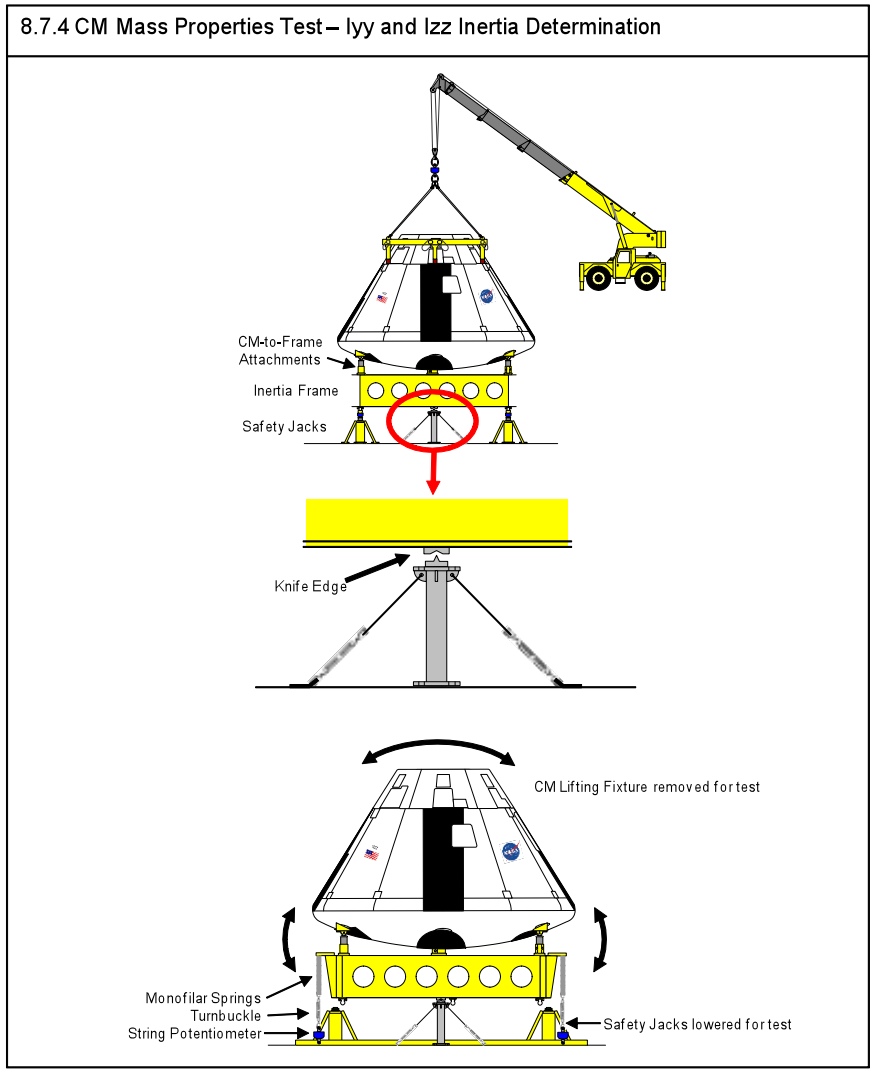
For second measurement set:
Repeat Steps 8 through 11 using the 120-degree jack as the apex jack.

For third measurement set:
Repeat Steps 8 through 11 using the 240-degree jack as the apex jack.

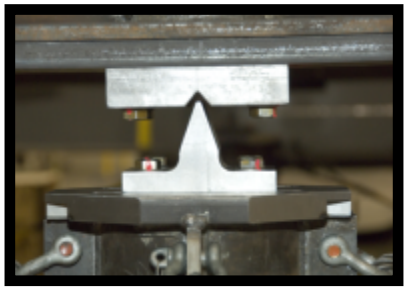
Actual

Storyboard for the Crew Module Iyy Inertia Test

Storyboard



Actual

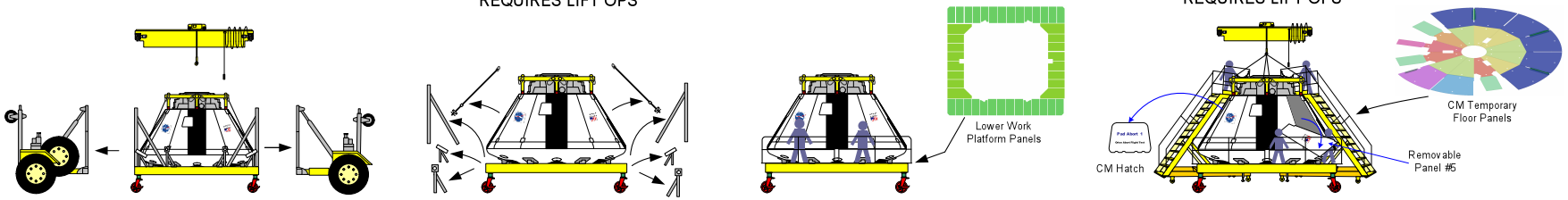


Swim Lanes were another tool used to plan resources, verifications, and prerequisites

DFRC Initial Integration

8.2.4 CM Setup in Shuttle Hangar

April 1 — Apr 4



	Receive CM in Shuttle Hangar	Convert CMTF into Integration Stand		Prepare CM for CM Integration	
SEQUENCES	❑ Position CM under overhead bridge crane ❑ Orient CM to +Z North ❑ Lower CM onto casters ❑ Remove mobilizers ❑ Establish grounds	❑ Prepare for Lift Operations ❑ Remove CMTF end frames ❑ Remove tie-downs ❑ Remove tripods and tie-down hardpoints	❑ Install lower work platform panels onto CM Integration Stand	❑ Remove CM hatch ❑ Remove Panels #2 and #5 ❑ Remove #2 and #5 composite shoulder panels and aluminum supports ❑ Rig interior lighting and utility power	❑ Install CM temporary floor panels ❑ Prepare for Lift Operations ❑ Remove CM Lifting Fixture
PROCEDURES	FTO-AFT-OPS-1004: DFRC FTA Local Transportation Work Order: E15855 CM Grounding Reference: OMM CM Grounding Cable Assy PN# 948956030215 -501	Work Order: E15840 Removal of Panels 2&5, Tripods & Tie-Downs FTO-AFT-OPS-1005: Installation and Removal of CMTF End Frames and Diagonals	Work Order: E15853 Lower Work Platform Panel Installation and Load Test	Work Order: E15839 CM Hatch Removal Drawing: 1247018 Skin Assembly Work Order E15840: Removal of Panels 2&5, Tripods & Tie-Downs Drawing: 1247018 Skin Assembly	Work Order: E15852 Temporary Floor Panel Installation and Load Test Drawing: AFT-50009 Temporary Floor Panels Reference: Powerpoint File "Temp Floors – 4-2-08" FTO-AFT-OPS-1006: CM Lift Fixture Installation and Removal
GSE	Tug (DFRC) Mobilizers (LaRC) Grounding Straps (LM)	Broderson Crane (DFRC) Lifting Straps Tag Lines Flat Bed Truck (transport goal posts to storage) B1 Work Stands Access Platforms	CM Lower Work Platform Panels	B1 Work Stands Access Platform	CM Temporary Floor Panels CM Lift Fixture Slings and Shackles CM Lift Fixture Storage Container Forklift Overhead Bridge Crane
PERSONNEL	DFRC tug operator DFRC Crew (Spotters) Mobilizer operators LaRC Representative	DFRC crane operator Ops Lead Crew Chief Crew (Optional) Safety Lead	Crew Chief Crew QA Lead (Optional) Safety Lead (Optional) Panel Provider Representative	DFRC crane operator Ops Lead Crew Chief Crew QA Lead (Optional) Safety Lead	DFRC Lift Supervisoer DFRC Overhead crane operator Ops Lead Crew Chief Crew QA Lead (Optional) Safety Lead
VERIFY		Crane – PM & equipment certification on file Lift Straps – Cert & Load tags	Load Test: CM Lower Work Platform Panels to 1,000 lbs (2 people) x 2 SF = 1,000 lbs		Load Test: CM Floor Panels to 1,000 lbs (2 people) x 2 SF = 1,000 lbs Overhead Crane – PM & Lift Certs on file CM Lift Fixture– Correct Assy, Cert, and load tags on Slings and Shackles
PRE-REQS	Shuttle Hangar prepped for arrival Tugs & Cranes – PM & Certs on file				

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

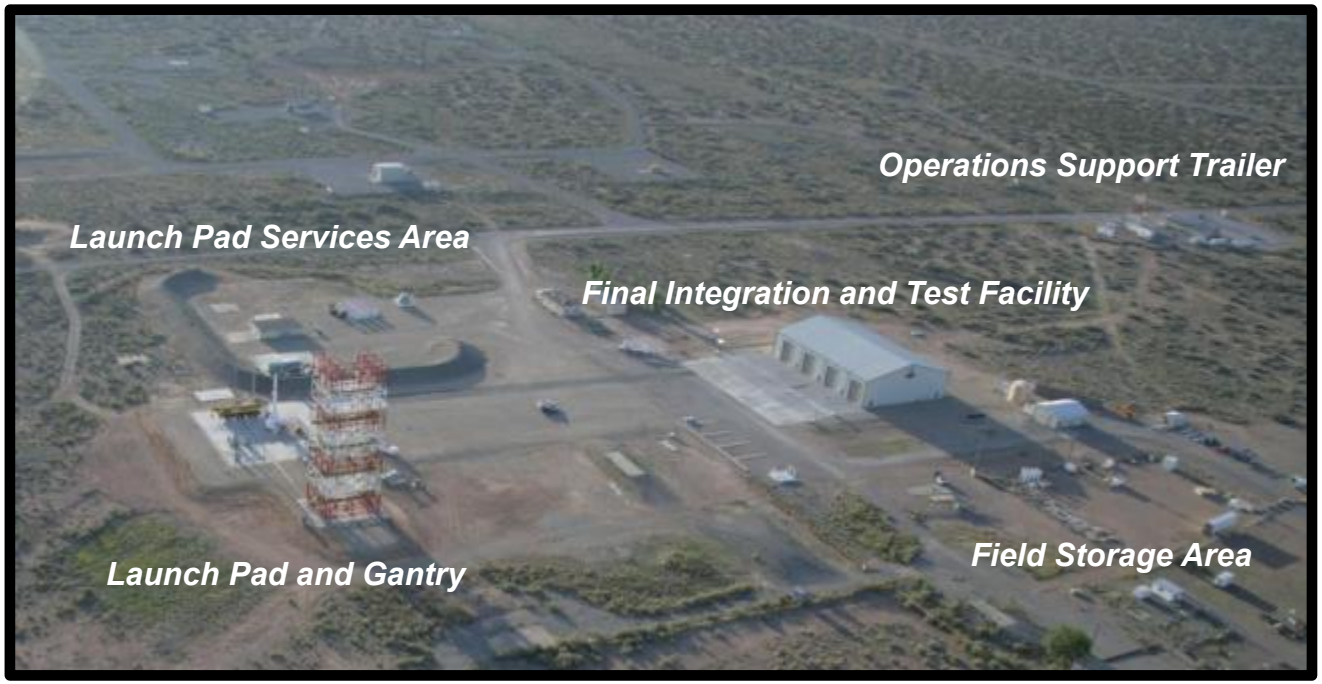


PA-1 Vehicle on Launch Pad and FITF

Launch Pad and Gantry

Final Integration and Test Facility (FITF)

Integration Bays inside FITF



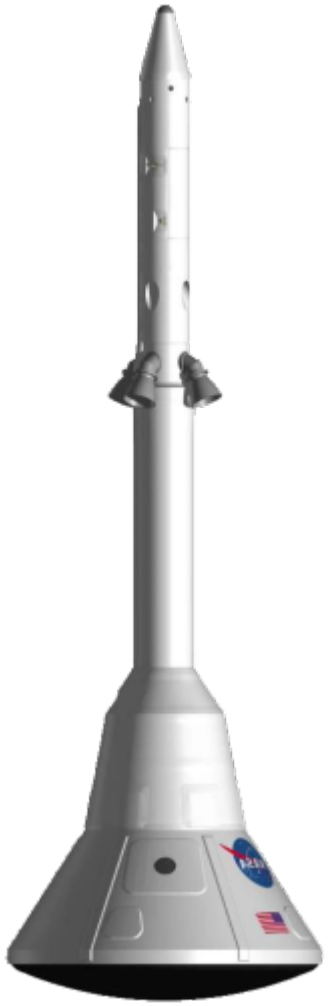
Aerial View of Orion Launch Complex 32 East

LC-32 East

Operations Support Trailer

INTEGRATION AND TESTING

Test Vehicle assembly, integration, and testing occurred in two phases



CM Delivery → DFI Sensors → Structures & Mechs → Harness & Pallets → Functional Tests → Fwd Bay Fitchecks → Mass Properties → RF Range Tests → Ship to WSMR

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

Phase II:
Final Integration occurred at the White Sands Missile Range

LAS Delivery → Structural Mates → Functional Tests

CM Delivery → Functional Tests → CM/SR Mate

Fwd Bay Integration → Integrated Electrical Tests → Stacking → Pad Tests → Flight Test → Recovery

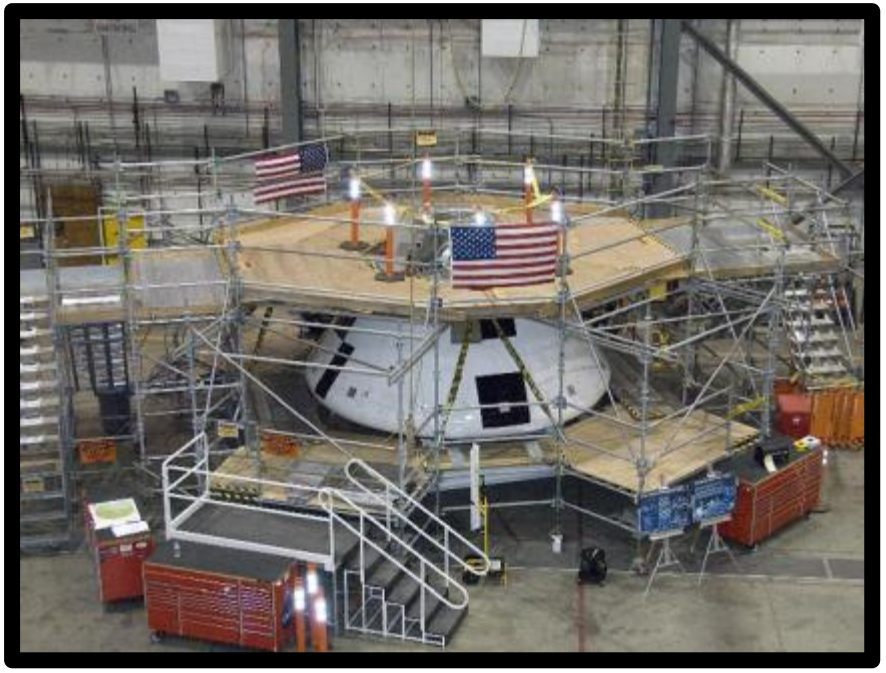
Crew Module was outfitted with sensors, avionics, and mechanisms at NASA Dryden

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

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

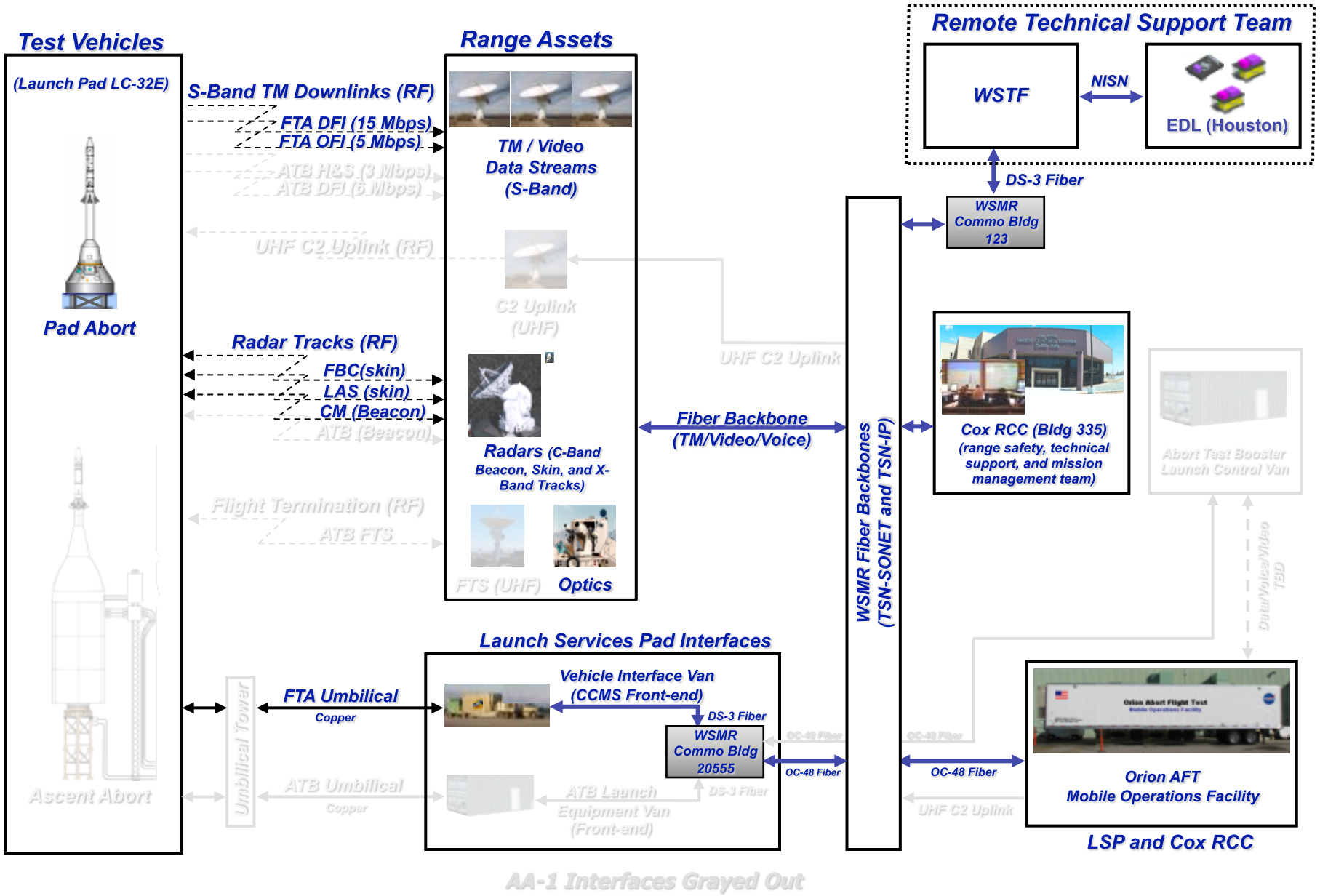
Thermal Cover installed

FLIGHT OPERATIONS PLANNING AND EXECUTION

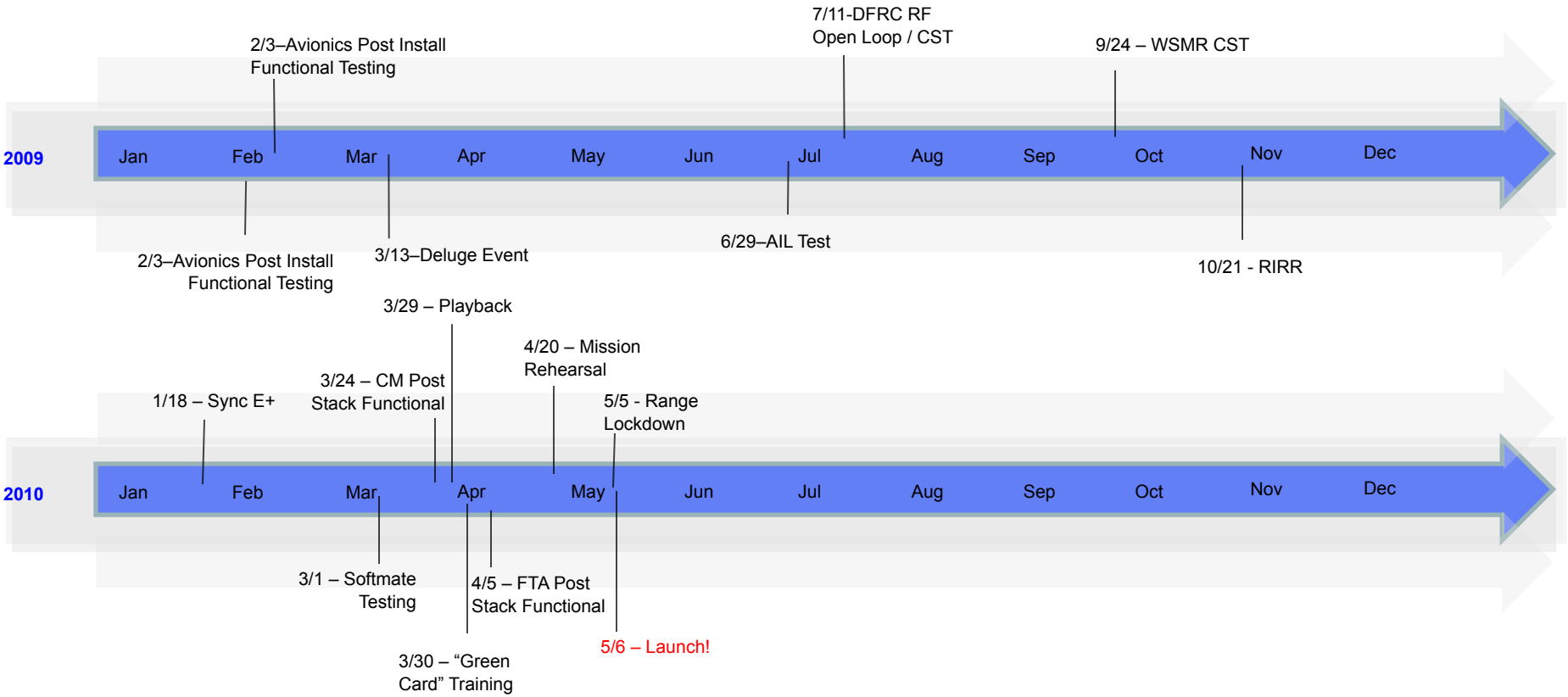
Flight Ops Challenges

- Mobile Control Room Architecture
- Launch Team Training
- Range Assets

Mobile Operations - WSMR Mission Architecture



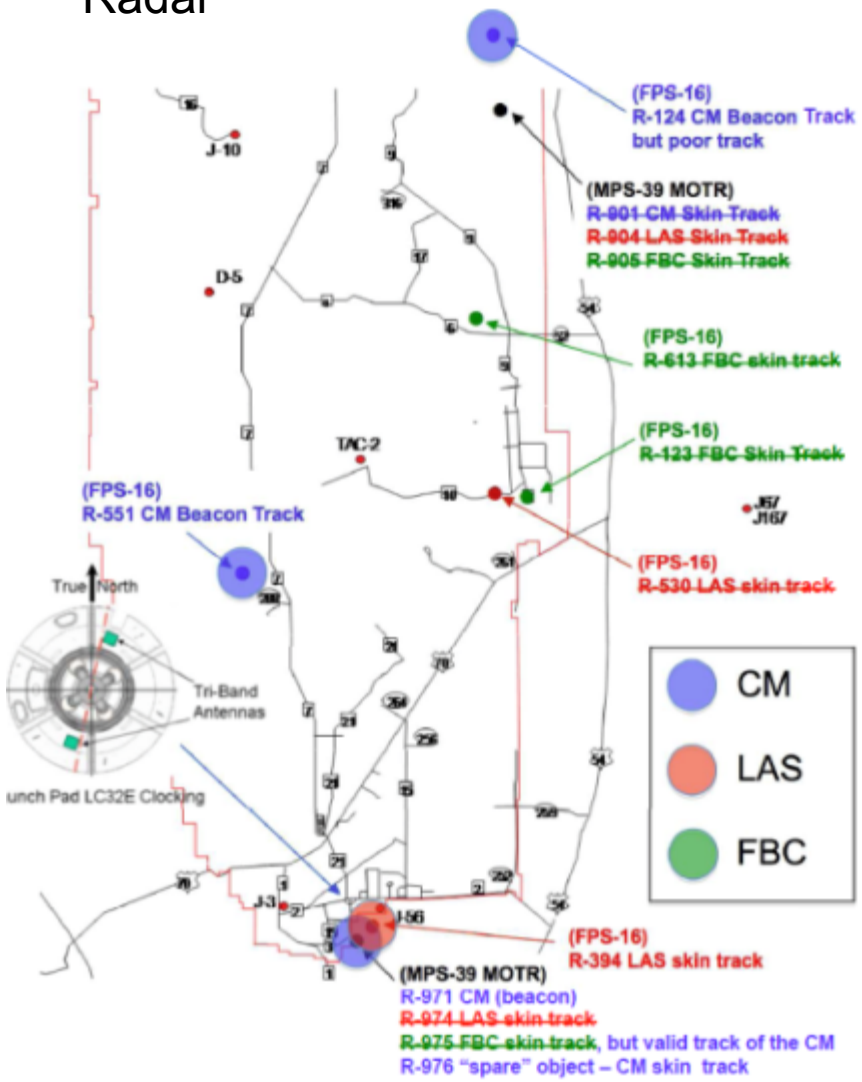
Launch Team Training



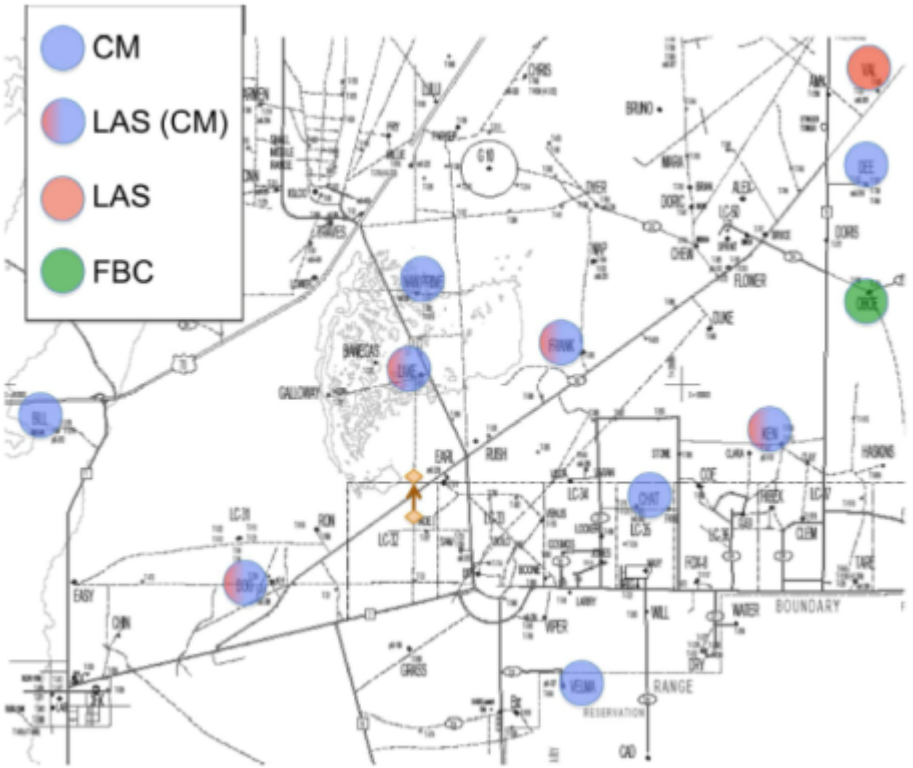
- **In addition to Training on timeline in the 1.5 months prior to launch**
  - **3 Table Top Reviews (TTR) with the entire team**
  - **2 Emergency/Contingency Procedure simulation trainings**
  - **2 PAO rehearsals**
  - **3 Test Specific TTR's and Emergency procedure planning**
  - **Mishap Response 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

Radar



Camera's



A FEW KEY CHALLENGES AND SUCCESSES

The Project overcame many challenges

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

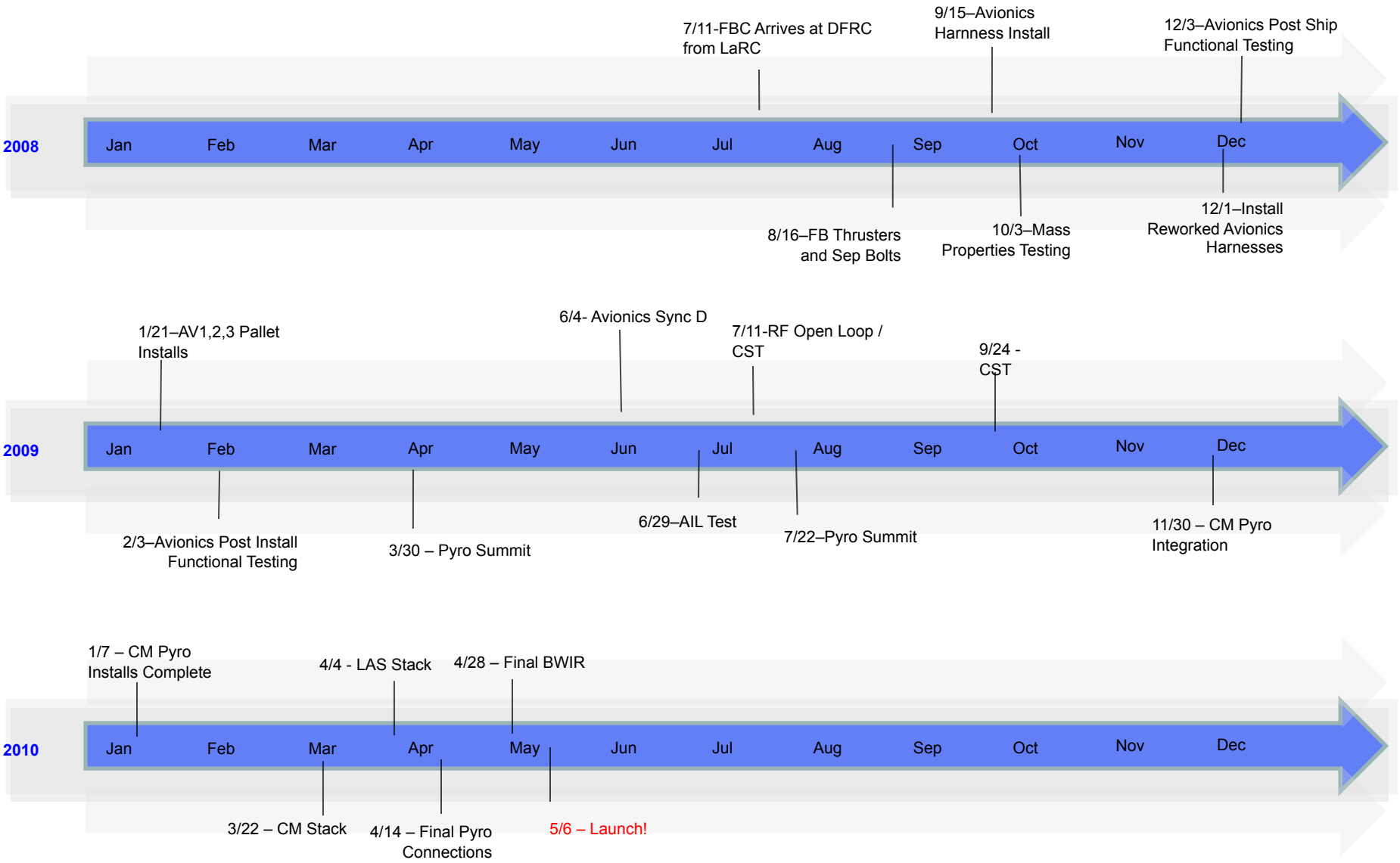
Challenges:

- 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



Recovery

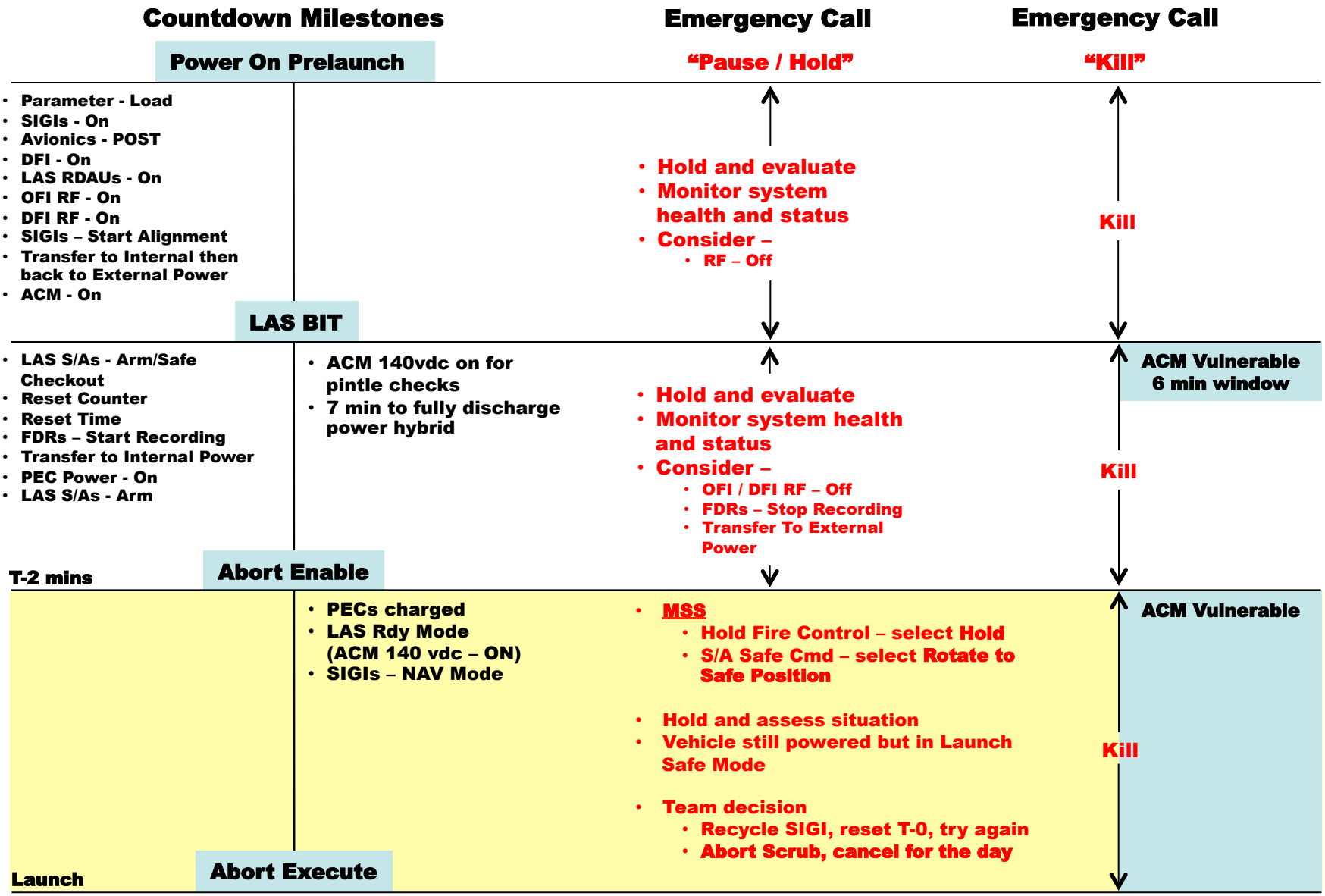
1. Receive Post-Landing Assessment from MOF (Scorecard)
2. Deploy to LZ staging Point
3. UXB sweep for UXO
4. Assess hazards preventing safe approach
5. Approach and Safe
6. Repeat 4&5 according to Hazard Analysis
7. Transport to LC32 or other destination

NOTE: Photo document entire process

Questions?

BACK-UP

Off Nominal Procedures Overview



PA-1 Communications Plan
Version 4-10-10