Ares I Operability Overview

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MSFC/EO01
4/29/09
Vehicle and Ops Concept Overviews

What does operability mean to the Ares I Project?
   ± Goal of Operability
     □ Affordability
     □ Availability
     □ Safety

What is the Ares Project doing to influence operability into the flight hardware designs?
   ± Organization and Relationships
   ± Key Driving Requirements
   ± Ares Design Features and Relation to Ground Operations

How do we measure Ares I Project success in infusing operability?
   ± Ops Analysis & Integration tools
     □ DES
     □ Timeline
     □ Logistics Analysis
     □ Ground Support Equipment
     □ Benchmarking
Vehicle and Operations Concept Overviews
Stack Integration

- 2M lb gross liftoff weight
- 328 ft in length
- NASA-led

Upper Stage

- 305k lb LOX/LH₂ stage
- 18 ft diameter
- Aluminum-Lithium (Al-Li) structures
- Interstage
- Reaction Control System (RCS) / roll control for First Stage flight
- Primary Ares I avionics system
- NASA Design / Boeing Production
Operability is the combination of inherent design characteristics that determine both availability and affordability.
Ares Projects Office Design for Operations Manager:
The purpose of the Ares Design for Operations Manager (DOM) is to develop the philosophy and approach for design for operability, ensure that the approach is consistent with the Constellation approach, and assure the approach is communicated/implemented for the Ares Project.

The Ares DOM resides in VI with a direct communication line to the Ares Project Office Manager. The DOM works through the forums identified in this SEMP to accomplish this effort. VI WBS 5.2.5 is the primary team responsible in VI for executing the design for operations approach and philosophy. This philosophy will be documented in the Ares I Integrated Vehicle Design Definition Document, CxP 72070.

The DOM has a primary interface to the Constellation DOM and will have a designated counterpart in each Ares Element Project Office and a primary DOM counterpart in the MSFC Engineering Directorate.

Operations & Supportability Team (OST):
is established to provide a multilateral forum to manage operations integration planning, logistics support, and supportability engineering across all Ares organizations. The OST supports Ares design and development by providing operability analysis that influences the Ares vehicle for optimizing efficiencies and life cycle cost.
7.1 Operational Factors
Operational Factors include specialty engineering disciplines that influence the operational use of the system by providing operational quality features in the design. These factors for Ares include: Safety and Reliability, Operations and Support, and Safety & Quality Assurance.

7.1.1 Safety & Reliability
Safety & Reliability engineering is the incorporation and integration of safety, reliability and maintainability, in the flight hardware design to obtain a safe and reliable system.

Responsibilities
VI CSR (WBS 5.2.7 / QD / EV92) is responsible for ensuring that Safety & Reliability requirements are assessed, established and integrated into the system design. This function is facilitated by the CSRT.
VI O&S (WBS 5.2.5 / EO) is responsible for the definition and documentation of GS human factors through participation in the CARD and human system interface requirements development activities. The other WBS and Element offices are responsible for ensuring that operability is addressed and incorporated in to the respective product designs.
Figure 18 - Ares Product Teams, Technical Panels and Working Groups
How is the Ares I Project Ensuring an Operable Design?
Ares I Operability

Affordable
- reduce recurring cost in available $ for development of NASA programs
- **Ares I Recurring Cost Requirement**

Available
- launch on need driven by 2-launch solution. Reliable, easy to process and maintain
- **Launch Availability, System Readiness, Timeline & Maintenance Requirements**

Safe
- affordable and available without compromising safety
- **LOM and LOC requirements**
## Ares I System Requirements Document - KDR Summary

<table>
<thead>
<tr>
<th>KDR Section</th>
<th>Elaboration of TBR/TBD</th>
<th>TPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 R.EA1066</td>
<td>Launch Availability (excluding weather) Ares I shall have a probability of launch of not less than 98 ((TBR-001-939%)), exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.</td>
<td>Y</td>
</tr>
<tr>
<td>2 Changed to TPM</td>
<td>System readiness not less than 85% with confidence level of 95% TBR.CLV.134.1 - not less than 85% TBR.CLV.134.2 - Confidence Level of 95%</td>
<td>Y</td>
</tr>
<tr>
<td>3 R.EA6089</td>
<td>Ares I Minimum Mission Interval-Threshold Ares I shall support two launches within a 45 calendar day interval, measured from the launch of the first mission to the launch of the second mission.</td>
<td>Y</td>
</tr>
<tr>
<td>4 CLV.274</td>
<td>Ares I Maintenance Downtime for Failed LRU The Ares I shall have a Mean Maintenance Downtime (MDT) of 40 hours with a confidence level of 90% due to failed line replaceable units (LRU). This requirement addresses maintenance activities performed at the Pad or VAB. This requirement includes fault detection and isolation, Mean time to repair (MTTR), support equipment setup and removal time (SEST), and the re-test time of the vehicle sub-system, segment or element to ensure that the vehicle is restored to operational condition.</td>
<td>Y</td>
</tr>
<tr>
<td>5 R.CLV.224</td>
<td>Ares I Production Cost Ares I shall have a maximum threshold annual production cost of $XXXM (five flights/year), with an objective (goal) of $XXXM (five flights/year).</td>
<td>Y</td>
</tr>
</tbody>
</table>
Access Point Concepts - GOP

Upperstage Access

1st Stage Access

IU Access
Instrument Unit (IU) Design Overview

**Overall Dimensions:**
- 216.5 inch Dia. OML
- 86 inch Length

Avionics Plate (10)

Forward viewing Camera (2)

S Band Antenna (4)

Aft viewing Camera (2)

C Band Antenna (4)

Vent with Rain Shield (4)

Access Door

Purge Manifold

Umbilical Panel

LH2 Vent Valve

AL-Li Flange (2)

CEV I/F Panel (2)

Cable Tray

UHF Antenna (2)

AL-Li Barrel Panels (4)

Systems Tunnel Fairing & Bulkhead (Hidden)

**All component locations are notional and subject to change**
Supportability Challenges

- Providing the Capability for J2X to Perform Maintenance on the Stacked Vehicle
- Designing Internal Access GSE (platforms, etc.) to perform maintenance on stacked vehicle
- Providing Proper Number of Access Doors / Hatches to Support Integrated Vehicle Maintenance

Ares IL&S Team Integrating Design for Maintainability and Supportability with US/J2X/Human Factors/S&MA and GOP
US Ares I Mockup for Operability Evaluations

Figure 12-40  Instrument Unit Assembly
First Stage- Frustum Access

Frustum Access Door

± Currently there is no requirement for a door
  □ Access to the J2-X throat plug
  □ J2-X purge

± If FS moves ahead with an access door, there will be a minimum 500 lb mass impact to the Frustum.
How does the Ares I Project Measure Operability?
Document #: APO-1022

Document Title: System Readiness and Launch Probability Assessment Report

Purpose:
- Present the approach and procedure used when evaluating the Ares I design against the System Readiness Technical Performance Metric (TPM) and Launch Probability requirement.
- Discuss and describe the input data and ground rules and assumptions used in the analysis.
- Provide System Readiness and Launch Probability assessment.
- Provide Recommendations.

Scope: Ares ADAC-2B design configuration as defined by AMD-006
The System Readiness TPM was levied on the Ares vehicle by the Ares Project to ensure the vehicle design has the ability to meet the defined launch date with a certain probability.

The Ares I System Readiness measures that Ares I can be stacked and ready for "decision to load cryogenic propellants" in 34.8 calendar days 85% of the time.

System Readiness starts with stacking First Stage onto the Mobile Launcher and ends at "decision to load cryogenic propellants".

System Readiness is measured against 34.8 calendar days which is the Ares' allocation of the 45 calendar day minimum mission interval requirement and the critical path processing time requirement.

System Readiness TPM takes into consideration the interactions of nominal processing, off-nominal processing, work/holiday scheduling, and resource loading.
Objectives:

- Develop a useable model that accurately simulates the process flow of the Ares I by simulating the major vehicle components.
- Simulate the following processes: Manufacturing operations, Pre-launch operations, Post-launch/refurbishment operations, Component Transportation, and Resource Utilization (personnel, ground support equipment, and facilities).

Inputs:

- Nominal Tasks ± Ares I Reference Timeline.
- Off-Nominal Operations:
  - Probability that a failure will occur.
  - Once a failure has occurred, identification of which failure occurred.
  - Off-Nominal operations required to get back to nominal operations. This returns model to the point at which the failure occurred.
Ares I System Readiness: Process Flow

Ares I Timeline

Off-Nominal Analysis

The Availability

Model Outputs

Design Push Back

Analysis

Requirements Met

Reliability

S&MA

Sensitivities

Marshall Space Flight Center

National Aeronautics and Space Administration
Ares I System Readiness: Results

Marshall Space Flight Center

SDR to PDR Check Point:
- Achieved System Readiness (SR) decreased from 45% to 10%.
- Shift in the SR curve is due to increasing the fidelity of the timeline.

PDR Check Point to PDR:
- Achieved System Readiness increased from 10% to 75%.
- The shift in the System Readiness curve is due to four factors:
  - Updates to the Ares I Reference Timeline.
  - Re-allocation of the 45 calendar days. Ares I allocation went from 38 to 34.8 calendar days.
  - The baseline work schedule at KSC is 3 shifts a day, 6 days a week.
  - Incorporated in the KSC holiday schedule.
<table>
<thead>
<tr>
<th>TPM</th>
<th>Design Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ares I shall have a system readiness not less than 85% at a Confidence Level of 95%.</td>
<td>Watch</td>
</tr>
</tbody>
</table>
Ares I Launch Probability: Traceability

- CxP Probability of Crew Launch requirement (CA0123) is the probability of achieving launch timelines to support Lunar DRM, and is driving case for Ares I ground reliability & maintainability.

- CxP Probability of Crew Launch decomposes into several Ares requirements that collectively serve to limit the likelihood of not being able to launch Ares I after Ares V has launched.
  - Ares I Launch Probability (EA1066) ± probability that Ares I launch attempt is not scrubbed due to hardware/software failure.
  - Ares I System Maintainability (EA6203) ± given that Ares I failure occurred, probability that Ares I can be repaired to support follow on launch opportunity within 72 hours of the failed launch attempt.
  - Ares I Launch Probability Due to Natural Environments (EA1068) ± probability that Ares I launch attempt is not scrubbed due to weather.

- Ares I Launch Probability is the probability that Ares I does not experience a hardware/software failure during the time period from start of tanking to launch that would result in a launch scrub.
  - Launch Probability is the reliability of the Ares I hardware/software that must function during the specified prelaunch time period for a successful launch.

- Launch Probability has been suballocated to the Elements to serve as reliability design requirement.
Launch Probability Assessment is based on initial preliminary analyses provided by each of the Elements.

- **First Stage**
  - Launch Probability: 0.993
  - Pre-requirement: 0.9985
  - Similarity to RSRB: 2%
  - Prelaunch reliability logic model

- **Upper Stage**
  - Launch Probability: 0.993
  - Pre-requirement: 0.9716
  - Pre-requirement value: 0.969
  - Prediction: 0.9986
  - Logic model
  - Similarity to SSME: 2%

- **Upper Stage Engine**
  - Launch Probability: 0.993
  - Pre-requirement: 0.9986
  - Similarity to RSRB: 2%
  - Prelaunch reliability logic model

**Shuttle Launch Delay 1981-2008**

**Similarity to RSRB**

**Launch delay history**

**Prelaunch reliability logic model**

**Similarity to SSME**

**Launch delay history**
<table>
<thead>
<tr>
<th>Requirement</th>
<th>Design Compliance</th>
</tr>
</thead>
<tbody>
<tr>
<td>R.EA1066</td>
<td>Watch</td>
</tr>
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</table>

Ares I shall have a probability of launch of not less than 98 (TBR-001-939)% exclusive of weather, during the period beginning with the decision to load cryogenic propellants and ending with the close of the day-of-launch window for the initial planned attempt.
Ares I Ground Operations Data Book

- Document #: CxP 72224
- Document Title: Ares I Ground Operations Data Book
- Purpose: Capture supporting data intended to enable implementation of the CxP Integrated Timeline
- Scope: Ground processing of the Ares I vehicle elements at KSC required for vehicle integration, checkout, and launch
Ares I GODB Overview

1. Captures Ares I Reference Timeline
2. Timeline Overview maps Ares I Reference timeline and CxP Integrated Timeline
3. Ground Operations / Task oriented perspective to Ares I documentation
4. Holding place for ground operations requirements until they move to ICDs, Specs, Drawings, etc.
5. Captures Off-nominal analysis

FIGURE D2.8-1 OFF-NOMINAL DATA EXAMPLE

An off-nominal event is modeled as three separate rolled-up activities: Ground operations required to prepare for the conduct of maintenance activity, maintenance activity, and ground operations required to close-out maintenance and re-enter the nominal flow. Ground operations activities are characteristic “buckets” based on the state of the launch vehicle at a particular time during the nominal flow. This takes into account state information such as the status of a segment or stage being stacked; pre- or post-offload; accessibility to spaces, commodities (presurant, hypergolic and cryogenic fluid) status; crew location; etc. Maintenance activity includes installation and removal of internal access Ground Support Equipment (GSE), actual removal and replacement of the LRU, and component/system retest/certification. Maintenance activity tends to be LRU specific rather than amenable to being placed into characteristic buckets, largely because retest/certification needs and policies are unknown and vary considerably among the LRU. Internal access GSE design has not been finalized and off-nominal test and handling GSE requirements are unknown at this time.

Current estimates of the probabilities of an off-nominal event occurring are based on the launch probability requirement, allocated equally to the LRU within each Element, rather than on time-dependent distributions. This is because it is expected that design engineers will meet the requirements for system performance to meet the launch
Ares I Reference Timeline

Ares I Integrated Mission Timeline (CxP 72071)

Analysis Tool

- Verify the design is meeting O&S requirements
  - Critical Path Processing Time
  - System Readiness
  - Launch Probability
  - Flight Rate

- Determine sensitivities

- Identify support equipment requirements (Location, timing, quantity, etc.)

- Identify access requirements between vehicle and ground (VAB, ML, Pad)

- Supports Analysis of corrective maintenance processes
  - Where in the flow can a failure be detected?
  - What tasks are required to restore nominal operations?

- Supports Analysis of processes for Human Factors
  - Does the design allow enough room to perform the required operations?
  - Do HF constraints require sequential operations?

Ascent 50 Minutes
### Requirement

R.EA.6089 Launch Interval back to back within 45 Days

Ares I shall provide the capability for back to back launches within 45 days measured from the launch of the first integrated stack to the launch of the second integrated stack.

### Design Compliance

**WATCH**

- Current assessment indicates this requirement can be achieved with 24 x 7 operations.
- Can not be achieved with 6 day workweek.

![Ares I/Orion Total Online Cycle Time](chart)

**Forward Plan:**

- Use the Ground Operations Analysis List (GOAL) to pursue opportunities for improvement.
- Work with Level II IGOWG to monitor changes affecting this requirement.
# Critical Path Opportunities List

<table>
<thead>
<tr>
<th>CARD, Rev C REQUIREMENT (Critical Path Hours)</th>
<th>Current CRITICAL PATH</th>
<th>POTENTIAL TIMELINE IMPACTS</th>
<th>THREAT / OPPORTUNITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start of Ares I First Stage Stacking to Ready for Upper Stage Mate (225 hours)</td>
<td>FS = 240 (+15 hours)</td>
<td>FS Off-Line Stacking Options</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simplify Joint Closeout</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Simplify Aft Skirt close out design</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fwd Skirt purge until T-O</td>
<td></td>
</tr>
<tr>
<td></td>
<td>US = 32 (+1 hours)</td>
<td>Remove J2X Engine throat plug before US mate</td>
<td>Study Underway</td>
</tr>
<tr>
<td>Ready For Upper Stage Mate to Ready for Integrated Orion Spacecraft Stacking Preps (31 hours)</td>
<td></td>
<td>Reduce time required for internal access GSE</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Reduce Inspections</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lift &amp; Mate US to FS bolt and torque operations</td>
<td>Threat</td>
</tr>
<tr>
<td>Ready for Integrated Orion Spacecraft Stacking Preps to Ready for First Stage Systems Tunnel LSC Installation (80 hours)</td>
<td>Ares = 0&lt;br&gt;Orion = 90&lt;br&gt;GS = 0&lt;br&gt;Total = 90 (+10 hours)</td>
<td>ARES I activities are in parallel, any changes could impact the critical path</td>
<td>Threat</td>
</tr>
<tr>
<td>Ready for First Stage Systems Tunnel LSC Installation to Rollout Preps Complete (209 hours)</td>
<td>Ares = 145&lt;br&gt;Orion = 32&lt;br&gt;GS = 14&lt;br&gt;Total = 191 (-18 hours)</td>
<td>Reduce Functional &amp; Integrated Testing</td>
<td>Opportunity</td>
</tr>
<tr>
<td>Rollout Preps Complete to Orion/Ares I Launch (112 hours)</td>
<td>Ares = 46&lt;br&gt;Orion = 12&lt;br&gt;GS = 59&lt;br&gt;Total = 117.5 (+ 5.5 hours)</td>
<td>Reduce activities required during Pad Processing operations</td>
<td>Opportunity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>PAD Interface Zone (+ 30 degrees)</td>
<td>Threat US Can Not Meet</td>
</tr>
</tbody>
</table>
Document #: CxP 72077

Document Title: Ares I Logistics Support Analysis (LSA) Report

Purpose: The purpose of the LSA Report is to document in-process LSA tasks for the Ares I PDR. These LSA tasks are designed to document design requirements, influence design, and benchmark quantitative support system alternatives and reduce maintenance costs.

Scope: The LSA Report provides results of in-process LSA activities for Ares I PDR as well as documentation of LRUs and associated data parameters as required by CLV.EA6203. Current LSA activities include:

- Off-nominal Timeline Analysis
- VAB vs. Pad Trade
- Supportability Assessments
- LSA Record database
- Front End Analyses (Use Study, Comparative Analyses, Supportability Design Factors)
- Ares I Support System Alternatives Determination
- Ground Operations Contingency Analysis
- Maintenance Engineering Analysis (MEA)
- Supportability Requirements
- Line Replaceable Unit (LRU) Candidates
- Limited Life Components Candidates
Consecutive Launch Attempts Described

Legend

- X = scrubbed Ares V Attempt
- ✓ = Launched Ares V
- ✗ = tanked/scrubbed Ares I due to Ares V launch scrub

Ares I must tank for each attempt of the Ares V plus for each of its own attempts after a successful Ares V launch leading to a potential for 7 consecutive tankings of the Ares I before the missed TLI window.

4 consecutive Ares V attempts

New (CA-XXXX-PO)

6 Days

7 consecutive Ares I tankings

(CA-0125-PO)

TLI 1

TLI 2
Burn-down Plan
R.EA6203 - Maintainability

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Design Compliance</th>
</tr>
</thead>
</table>
| R.EA6203 - Maintainability Requirement | ♦ The results of off-nominal analysis of the Pad vs. VAB LRU trade indicate less than 0% of the repairs due to LRU failures can be repaired within 24 hours, less than 5% within 48 hours and less than 56% of LRUs within 72 hours.  
♦ The Initial results of the the Integrated Stack Contingency Analysis indicate less than 0% of the repairs due to LRU failures can be repaired within 24 hours, less than 0% within 48 hours and less than 56% of LRUs within 72 hours.  
♦ Forward Work:  
♦ Conduct a follow-up Ares I Maintenance Engineering Analysis (MEA) with KSC to increase the fidelity of the off-nominal timeline.  
♦ Coordinate with Level III projects (Ground Ops and Orion) and Level II (Supportability Operability and Affordability (SOA) Group) in conducting an Integrated Off-nominal Timeline analysis to identify vehicle design and ground operations push-back areas and increase the fidelity of the Integrate Vehicle off-nominal timeline.  
♦ Perform an Ares I integrated analysis of candidate line replaceable units (LRUs) to determine what percentage are pad replaceable units (PRUs).  
♦ Coordinate with Level III projects and Level II (SOA) to prepare changes to Level II Maintainability Requirement.  
♦ Prepare and coordinate CR to add Maintainability reqs Mean Maintenance Downtime (MDT), Mean time to Repair (MTTR), Support Equipment Set-up and removal time (SEST). These are the derived Ares I system requirements that will be used to measure if Ares I is meeting the allocated level II maintainability requirement. |

Ares I systems failures identified after decision to load cryogenic propellants, with a likelihood of occurrence greater than (TBD-001-1500)% that would result in a scrubbed launch, shall be maintainable as follows:

a. No less than 45% (TBR-001-1413) can be remedied to support a launch attempt within one day.

b. No less than 65% (TBR-001-1414) can be remedied to support a launch attempt within two days.

c. No less than 70% (TBR-001-1415) can be remedied to support a launch attempt within three days.
Interstage Internal Access

Interstage Mock-up

♦ Characterize design driven human actions and postures
♦ Simulate procedures

Interstage HFE Modeling (Conceptual)

♦ Determine LRU access
♦ Simulate the large-scale integrated environment
♦ Define dynamic human operational envelop
♦ Measure physical performance attributes

Physical Modeling
Performance, Analysis & Design
Demonstrator (PADD) Facility

Virtual Human Modeling
Delmia V5 Digital Human Modeling with Human Task Simulation and Human Builder Solutions
Platform Access Locations

VAB

LAS Interstage
CM to LAS Interface
SM T-0 Umbilicals
US-SA Interface

LAS Interstage

GSE to support repair of TPS on Upper stage undefined

Cryo Loading Umbilicals
Field-Joint Interstage to 1st Stage
FS Frustum

FS Field Joint 5
FS Field Joint 4
FS Field Joint 3
FS Field Joint 2
FS Field Joint 1

First Stage Aft Access
First Stage Forward Access

Pad

CEV Crew Access
CEV SM Access
CLV IU Access
ACCESS #6
ACCESS #5
ACCESS #4

FS Field Joint 5
FS Field Joint 4
FS Field Joint 3
FS Field Joint 2
FS Field Joint 1

First Stage Aft Access
First Stage Aft Access

ACCESS #3
ACCESS #2
ACCESS #1

Upper Stage Aft Access
CLV Interstage Access

FS Field Joint 1

No Frustum Door Access at the Pad

Mobile Launcher Platform

National
Ares I GSE Plan

- **Document #:** CxP 72218
- **Document Title:** Ares I Ground Support Equipment (GSE) Plan
- **Purpose:**
  - Defines the GSE Policies & Responsibilities
  - Defines the GSE Working Groups
  - Establish the process for GSE Certification
  - Establish the process for the development of the Acceptance Data Package for the GSE
  - Provides the Ares I GSE matrix
- **Scope:** CxP 72218 defines the overall planning and GSE organizational responsibilities for The Ares I Elements as they are integrated at KSC into a final Ares I Configuration.
IU Internal Access (IA) GSE concept

Foam Wedges concept

♦ Provides small lightweight modular elements for handling
♦ Utilizes proven method of IA GSE (Shuttle ET program)
The Ares/KSC GSE Working Group (GWG) is the primary vehicle to integrate the GSE efforts of the Ares Elements and coordinate those efforts with KSC.

- The GWG is co-chaired by Ares and KSC
- Membership includes all Element Project offices, and Contractors
- Holds quarterly face to face meetings
- Promotes commonality
- Encourages cooperation
- Facilitates the development of Internal Access (IA) GSE for shared volumes
Document #: APO - 1029

Document Title: Ares I Operability Assessment Report (OAR) 20% complete

Purpose:
- Captures ongoing operability analysis, solution sets, and lessons learned during the Ares 1 design activities as well as recommendations and a forward plan for the next design phase
- Utilized for operable design solutions/recommendations
- Operability snapshots for comparative analysis as the vehicle matures
- Actionable items that have identified analysis activities and tracking thereof
- Document Benchmarking activities (for PDR, status is included as supporting document)

Scope: Provide a documented ledger of multiple operability assessments supporting Project Milestones
**OAT Activities Status**

- **Actions ±** The OAT is working toward the full resolution of this item thru additions and/or enhancements to normal forward work.

- **Tracking & Forward Work ±** The OAT is working toward the full resolution of these items thru normal working group activities and forward work. Technical Community agrees with forward plan. Work is in scope.

- **Recommended Study Items ±** The OAT recommends, or anticipates recommending a

```
VSHFLDO\VWXG\WR\UHVROYH\WKL\LWHP\7KH\VWXG\LV\MXVWLILHG\E\D\&\FOH\EHQHILWV\6WXG\ZLOO\UHTXL\HDG\L\LR\DO\UHV\RFH\V\`
```
Historically, a likelihood of pre-launch contingency event includes more than just hardware failures.
OAT Identified Studies

Studies Proposed

- Optimization of Orion/Ares Flange Closeout
- Early Close-out of First Stage Forward Skirt
- Elimination/Consolidation of T-0 umbilicals
- Early Close-out of First Stage Aft Skirt
- Redesign of First Stage Aft Skirt

Status

- Study Denied
- Study Conditionally Approved
- Awaiting ROM Cost & Schedule
- Study Underway
- Items per Study

4/20/2009
Recommended Study 1

Study 1: Early Fwd Skirt Closeout

Related Inputs:

- Utilize Common (Lithium Ion) Batteries
- Eliminate late processing on the FTS system
  - S&A devices
  - External code loading
- Installation of Igniter Safe and Arm device in the RPSF
Goal was to discuss processes, procedures, and design solutions to improve operability of the launch vehicle

Ares I Project and MSFC Engineering met with designers and developers of the Ariane 5, Atlas V, Delta IV, and H-IIA

- Ariane 5 ± ESA / CNES / Arianespace
- Atlas V ± ULA / Lockheed
- Delta IV ± ULA / Boeing
- H-IIA - JAXA

Benchmarking process ± We sent questions ahead of time to allow them to pull in key personnel for the meeting and to formulate answers. The meetings were one or two days with each company / agency. Findings were to be identified that may need further discussion
Key Findings / Common threads:

- Sparing philosophy - Use part next in production line as spare
- Multiple access points to Instrument Unit / Interstage
- Testing was minimized and in some cases moved completely to the right. JAXA moved some to left
- Clean pad approach was pursued. All vehicles minimized pad activities
- Maximized repair capability at launch facilities to avoid shipping back to manufacturer
- Wet dress rehearsal was intended to be deleted but only JAXA has stopped performing Wet Dress Rehearsal (WDR)
- All vehicles evolved from previous versions
- Operability was impacted through chief engineer
- Other observations
  - H-II had common bulkhead but JAXA eliminated it and went with separate tanks for H-IIA to improve operability
  - Atlas also uses composite casings for SRB
  - Atlas V minimized health and status measurements to avoid complexity
  - All vehicles designed ground facilities to fit vehicle design whereas Ares is making vehicle design fit existing facilities
  - First stage umbilical connections (purges) through the ML post with Vehicle resting on post. Eliminated a T-0 connection.
  - Final report will contain more observations and recommendations
## Comparison to Ares

<table>
<thead>
<tr>
<th></th>
<th>Ares I</th>
<th>Ariane 5</th>
<th>Atlas 5</th>
<th>Delta IV</th>
<th>H II</th>
<th>STS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Access at Pad</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Time for Pad Ops</strong></td>
<td>7 days</td>
<td>1 day</td>
<td>9 hours</td>
<td>10 days</td>
<td>12 hours</td>
<td>1 Month</td>
</tr>
<tr>
<td><strong>Time to roll back</strong></td>
<td>4 + days</td>
<td>1 day</td>
<td>&lt;1 day</td>
<td>??</td>
<td>&lt;1 day</td>
<td>Varies</td>
</tr>
<tr>
<td>(rollback, repair, and</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>roll-out if problem</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>detected prior to</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tanking)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Upgraded design for</strong></td>
<td>New</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td><strong>operability</strong></td>
<td>design</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Access doors</strong></td>
<td>1 per</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
<td>Multiple</td>
</tr>
<tr>
<td><strong>volume</strong></td>
<td></td>
<td>(8)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wet dress rehearsal</strong></td>
<td>3 +2 No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>12 No</td>
<td>First flights, No</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Operability</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Access doors</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Volume</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wet dress rehearsal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Comparison to Ares

<table>
<thead>
<tr>
<th></th>
<th>Ares I</th>
<th>Ariane 5</th>
<th>Atlas 5</th>
<th>Delta IV</th>
<th>H II A</th>
<th>STS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Time to process</strong></td>
<td>40 + days</td>
<td></td>
<td></td>
<td>30 days</td>
<td></td>
<td>2 Months (VAB stacking)</td>
</tr>
<tr>
<td><strong>Multiple vehicle processing</strong></td>
<td>No</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Inventory of Spares</strong></td>
<td>TBD</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Number of people required in LCC (Front Room)</strong></td>
<td>Est. 100</td>
<td>30</td>
<td>~30</td>
<td>~30</td>
<td>20</td>
<td>~230</td>
</tr>
<tr>
<td><strong>Reduced testing at launch facility</strong></td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Backup
Ares I Operability Improvements post SRR

- Eliminated First Stage pyrotechnic hold-down
- Removed First Stage joint heaters
- Added First Stage frustum access door ± access in VAB
- Monopropellant commonality between US RCS, FS RoCS & HPU systems
- Reduced to 3 string avionics system ± 1 FT
- J-2X Nozzle Extension installed @MAF prior to shipment to KSC
Recurring Cost Discussion Points

- Ares committed to working to lower launch vehicle recurring cost

- Ares has set recurring cost requirements in our System Spec

- Allocated requirements to the hardware Elements

- We will be measuring as a TPM on a regular basis

- Utilized industry ideas, knowledge and capabilities to meet these requirements

- Agency Leadership appears committed to the goal of reduced ops costs

- Many challenges ahead
  - Measuring progress with confidence on a regular basis
  - NASA risk culture
  - Political

- Opportunities
# Ares I System Definition Review (SDR)

## Ares I Punch List Milestones

<table>
<thead>
<tr>
<th>Name</th>
<th>'07</th>
<th>'08</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ARES I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ground Systems</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CRs (CARD, IR...)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### ARES Punch List Baselined
- Ship to Integrate
  - US Nozzle Extension
  - US TVC Testing
- Pad Processing
  - US Cold He
- Pad LRUs
  - PAD/VAB LRU Trade
  - US/Engine Maintenance
  - US Storage
- Reduced Reliance on Ground Networks
  - ARES Ascent Communications
- Reduced Assembly Operations
  - FS Offline Stacking
  - VAB/ML Access/Platforms
  - (Frustum Access Door)
  - Stabilization and Damping
- Passive Rollout (To/From Pad)
  - J-2X Engine
  - Upper Stage IU

### Key Cx Decision Packages
- US Cold He
- ARES Ascent Comm.
- FS Offline Stacking
- Nozzle Extension and TVC
- Stabilization and Damping
- Initial VAB/ML Access Needs
- Passive Rollout (To/From Pad)

### ARES Feasibility Analysis/Trades
- Completed
  - US/J2 Offline Maintenance
  - US Storage
  - VAB/PAD Access
- ARES P/L Resync to PDR
  - VAB/PAD Access
  - Closeouts prior to rollout
  - Protective Covers Enclosures
  - Automated Diagnosis

Red = Ares I / GO Baseline Disconnect
Trade 1:
- Measure the impact of decreasing the US internal interstage GSE installation and removal time by 50%.
- Result: Achieved System Readiness is 85%.

Trade 2:
- Trade 2 built onto Trade 1.
- Measure the impact of decreasing the RoCS/ReCS powered-up testing prior to the IVT by 50%.
- Result: Achieved System Readiness is 85% (unchanged).

Trade 3:
- Measure the impact of a growth in the timeline due to unknown factors. All US task durations were increased by 10%.
- Result: Achieved System Readiness is 65%.
Ares I Timeline

Ares I Integrated Mission Timeline (CxP 72071)

Ares I Reference Timeline (CxP 72224)

CxP Integrated Timeline (GOTAR-03)

Ares I Flight Operations Data Book (CxP 72243)

ML Refurbish 5/21/2008

Launch 5/22/2008

T0 9.7 Days

Upper Stage Stacking

Orion Stacking

LSC & Systems Tunnel C/O

Launch 6/18/2008

Previous Launch

9.7 Days (T0-36.3 d)

VAB Integrated Ops

41.1 Days

Pad Ops

Launch

Countdown 26.5 Hours

Launch to US Disposal 50 Minutes

46 Days Launch to Launch (6 Day Work Week)
<table>
<thead>
<tr>
<th>Area 1 Ground Rules and Assumptions</th>
<th>Ao Model</th>
<th>FS</th>
<th>US</th>
<th>USE</th>
<th>VI</th>
<th>KSC GOP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. DAC-2 Configuration</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>2. DAC-2A Configuration</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>No open work -- no planned element assembly work after turnover to launch site</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>4. Single Barge</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>5. Single Mobile Launcher</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>6. Single Launch Pad</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>7. Single VA5 Stacking Cell</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>8. First Stage Stacked on Mobile Launcher</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>9. Non explosive hold down mechanism</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>10. US stack as soon as FS is physically ready</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Closeout work completed in parallel to other activities (except during actual lift or other hazardous clears)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>11. During Stacking: Only unpowered continuity and fluid leak checks as each element is stacked</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>12. After Stacking: End to end functional test occurs only after Areas/Orion are fully stacked and integrated</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>13. J-2X throat plug removed prior to stacking US -- No throat-plug for rollout or pad ops.</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>14. Pad testing of interfaces and functionality will only include items it is not possible to test in the VAB</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>15. Hyper Loading will be performed at the Pad</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Final closeout of the Instrument Unit, Interstage, Forward Skirt, and Aft Skirt performed at the launch pad (closeouts following hypergolic and ordnance loading)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>TBR</td>
</tr>
<tr>
<td>16. Final ordnance operations performed at the Pad</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>TBR</td>
</tr>
<tr>
<td>Launch countdown tasks and times are estimates under further development</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>TBR</td>
</tr>
<tr>
<td>17. Nominal activities are conducted 24 hours/5 days a week</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>Off-nominal activities are conducted 24 hours/7 days a week until the schedule is restored</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>TBR</td>
</tr>
<tr>
<td>18. No services during rollout</td>
<td>NO</td>
<td>YES</td>
<td>NO</td>
<td>NO</td>
<td>NO</td>
<td>YES</td>
</tr>
<tr>
<td>No “Remove before flight” items (Environmental Covers, etc. – does not include Safe &amp; Arm devices)</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>19. US RCS and FS RoCS use monopropellant hydrazine.</td>
<td>TBR</td>
<td>YES</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>20. Clean Pad (Rollback to VAB for repairs)</td>
<td>TBR</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>21. Parallel activities are not constrained by personnel resources</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>TBR</td>
</tr>
<tr>
<td>Parallel activities are not constrained by personnel resources</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>TBR</td>
</tr>
<tr>
<td>22. Tasks are not shift dependent</td>
<td>YES</td>
<td>NO</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>23. Field Joint heaters eliminated</td>
<td>YES</td>
<td>TBR</td>
<td>YES</td>
<td>TBR</td>
<td>YES</td>
<td>YES</td>
</tr>
<tr>
<td>24. Ground rules and assumptions</td>
<td>YES</td>
<td>TBR</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
<td>YES</td>
</tr>
</tbody>
</table>
### Forward Plan:

- Pursue opportunities for improvements from Ground Operations Analysis List (GOAL)
- Work opportunities/changes to the Critical Path requirements using the Ground Operations Timeline from GODB and GOTAG
- Review status of opportunities in Ares GOWG
## Ares I Critical Path Allocations For Ground Operations

<table>
<thead>
<tr>
<th>Ares I SRD Requirement R.EA6004</th>
<th>Threshold (Hours)</th>
<th>Objective (Hours)</th>
<th>Ares I Reference Timeline Assessment (Hours)</th>
<th>Allocation</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEGMENT 1 ML Refurbishment</td>
<td>170</td>
<td>142</td>
<td>177.5</td>
<td>GS</td>
</tr>
<tr>
<td>SEGMENT 2 ML Preps in VAB</td>
<td>52</td>
<td>43</td>
<td>54</td>
<td>Ares I, GS</td>
</tr>
<tr>
<td>SEGMENT 3 First Stage Stacking</td>
<td>225</td>
<td>189</td>
<td>240</td>
<td>Ares I, GS</td>
</tr>
<tr>
<td>SEGMENT 4 Upper Stage Stacking</td>
<td>31</td>
<td>26</td>
<td>32</td>
<td>Ares I, GS</td>
</tr>
<tr>
<td>SEGMENT 5 Orion CEV/LAS Installation</td>
<td>80</td>
<td>67</td>
<td>90</td>
<td>Orion, GS, EVA</td>
</tr>
<tr>
<td>SEGMENT 6 Integrated Vehicle Test &amp; Closeout</td>
<td>209</td>
<td>175</td>
<td>191</td>
<td>Orion, Ares I, GS, EVA</td>
</tr>
<tr>
<td>SEGMENT 7 Pad Operations</td>
<td>112</td>
<td>94</td>
<td>117.5</td>
<td>Orion, Ares I, GS, EVA</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>879</strong></td>
<td><strong>736</strong></td>
<td><strong>902</strong></td>
<td></td>
</tr>
</tbody>
</table>
Ares I SRD Cost Requirements

[R.CLV.224] Ares I Production Cost

Ares I shall have a maximum threshold annual production cost of $TBD (5 flights/year), with an objective (goal) of $TBD (5 flights/year).

[R.CLV.225] VI Production Support Cost

Vehicle Integration shall have a maximum threshold annual production cost of $39M ($07) (5 flights/year), with an objective (goal) of $38M ($07) (5 flights/year).

[R.FS.111] First Stage Production Cost

The First Stage shall have a maximum threshold annual cost of $615M ($07) (5 flights/year), with an objective (goal) of $587M ($07) (5 flights/year).

[R.US.214] Upper Stage Production Cost

The Upper Stage shall have a maximum threshold annual production cost of $TBD (5 flights/year), with an objective (goal) of $TBD (5 flights/year).


The J-2X Engine shall have a maximum threshold annual production cost of $201M ($07) (5 flights/year), with an objective (goal) of $189M ($07) (5 flights/year).
COOL Items
Marshall Space Flight Center

Priority 1
- Commodity Loading: Kevin Ingoldsby
- Hyper Loading: Kevin Ingoldsby
- Pad Interface Zone/Consolidated Access Points: Stan Rhodes
- Passive Rollout: Kevin Ingoldsby
- Reduce Cooling: Gordon Aaseng
- Reduced Reliance on Ground Network: Don Pearson
- Ship to Integrate: Stan Rhodes

Priority 2
- Automatic System Safing
- Closeout for Flight Prior to Rollout
- Internal Failure Diagnosis - In Flight
- Internal Failure Diagnosis - Launch Flow
- Launch Flow Direct Labor (cost trades)
- Mission Integration Production Template (OPM-manhours; Refine TBR times)
- Non-Intrusive Integrated Testing
- Onboard Consumables Management
- Real-Time Attitude Analysis
- Remove-Before-Flight Covers
- Test/Sim in the VAB

Priority 3
- Commonality of serviceable items
- CIL Retention Rationale
- Corrective Maintenance Time

All need compliance status/metrics at each design review
Priorities based on how soon they need to be worked to have positive program impact

Initial items primarily derived from Stretch Requirements, plus other top operability initiatives such as CIL Retention Rationale