Ares I Operability Overview

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MSFC/EO01
4/29/09

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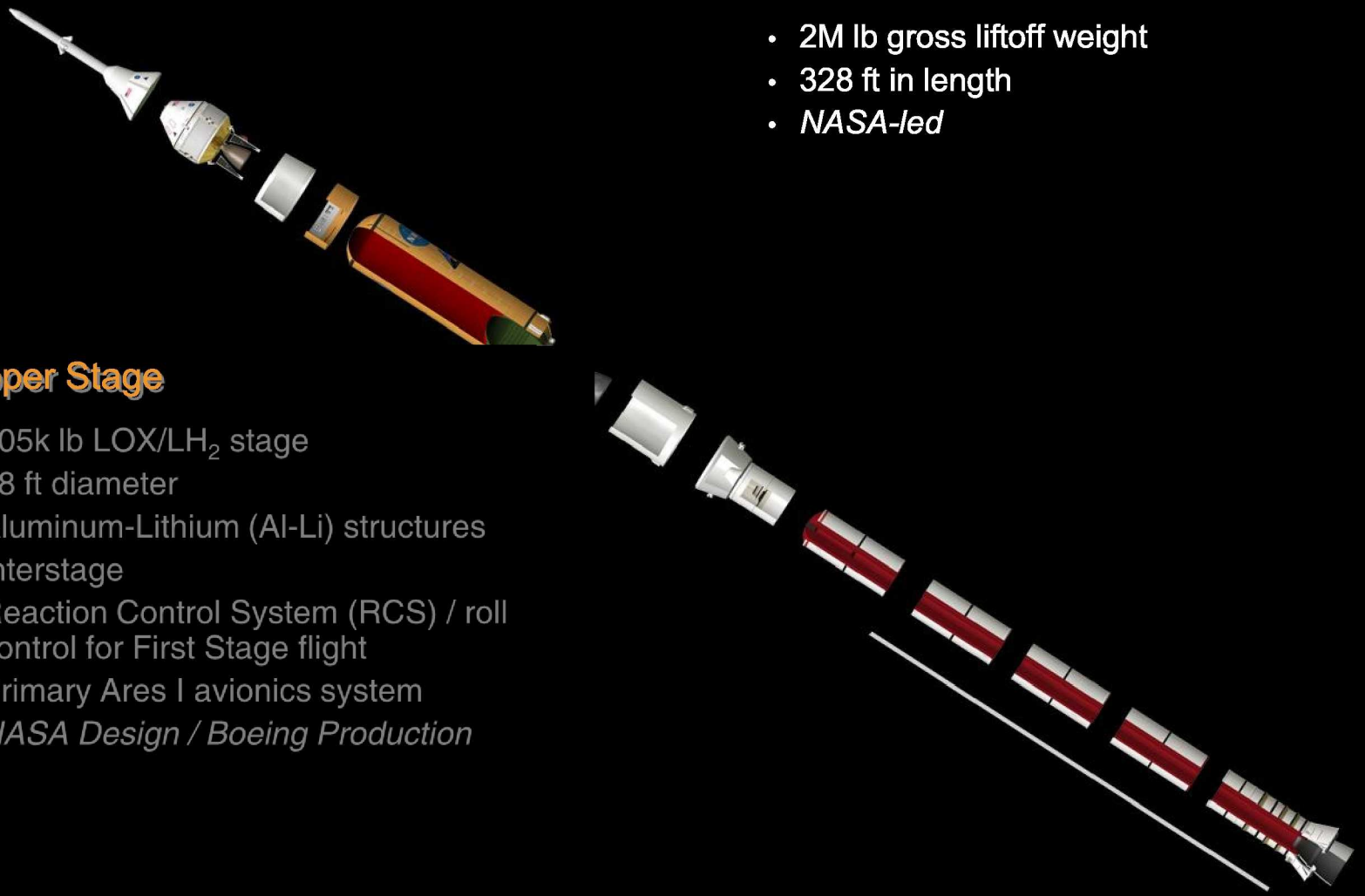
    - Ground Support Equipment
    - Benchmarking

Vehicle and Operations Concept Overviews

Stack Integration

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



Upper Stage

- 305k lb LOX/LH_2 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*

Current Ares I Ops Concept

Marshall Space Flight Center

MSFC Ares I Responsibility

KSC Ground Operations Responsibility

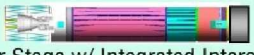
Note: Conceptual Ground Ops Flow–Official Flow Owned by Ground Ops Project


Engine Assembly & Test–SSC


J–2X Components


Nozzle Extension


Michoud Assembly Facility


Upper Stage w/ Integrated Interstage, J–2X, and Instrument Unit


Barge


Aft Segment


FWD & Center Segments

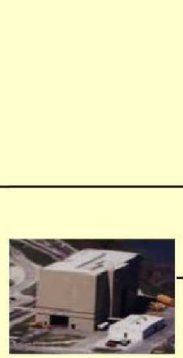

Aft Exit Cone


FWD Frustum & Conical Aeroshell


First Delivery FWD Skirt & Skirt Extension (Trade)


ARF


PRF


RPSF

Aft Skirt

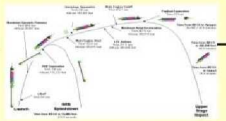
FWD Frustum & Skirts & Conical Aeroshell


Vehicle Assembly Building


Transfer to Pad


Launch Pad


Post Launch Mobile Launcher Refurbishment


Ascent Operations (Responsibility of Mission Ops Project)


Recovered CM


First Stage


First Stage Recovery

Note: During DDT&E Phase (including three 5-segment flight tests), MSFC Exploration Launch Projects' First Stage Office will manage PRF, ARF, and RPSF operations. For steady state operations, MSFC First Stage Office will be responsible for sustaining engineering for PRF, ARF, and RPSF operations.

Recovered First Stage Booster Hardware (Trade)


Disassembly Hangar AF


FWD & Center Segments


Aft Segment


Rail Transport Utah Facility

Recovered First Stage Segments


Parachutes

FWD Skirt & Skirt Extension

Aft Skirt

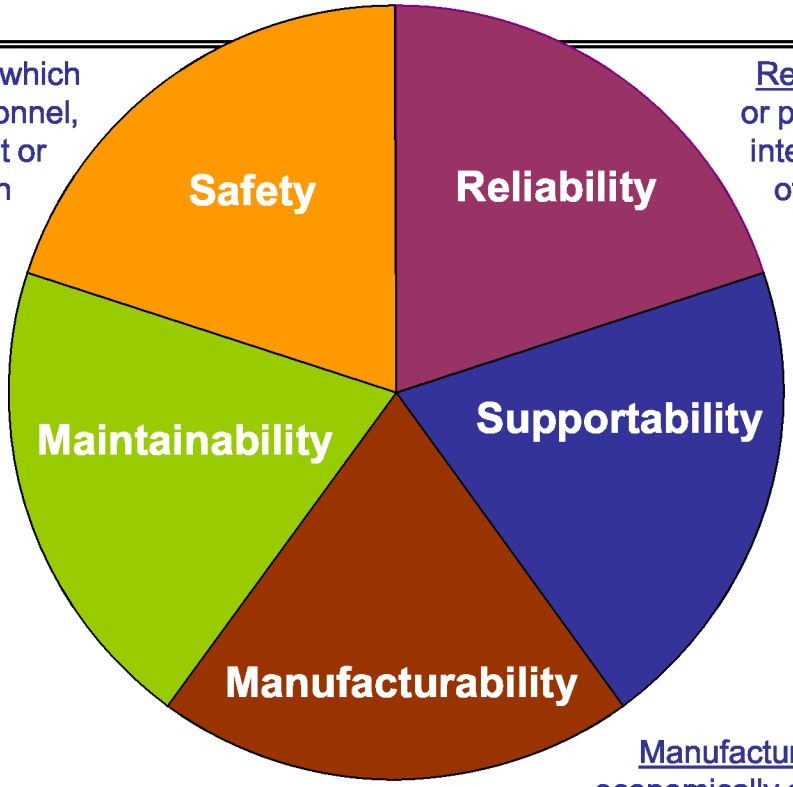
Ares I Operational Flow

What Does Operability Mean to the Ares I Project?

Operability Defined

Safety: Freedom from conditions which can cause injury or death to personnel, damage to or loss of equipment or property or hazard to mission

Reliability: Probability that a system or product will satisfactorily perform its intended function for specified period of time under specified conditions



Maintainability: How easily or quickly a system is restored after scheduled /unscheduled interruption through failure or routine removal from service for maintenance

Supportability: Degree to which a system can be supported

Manufacturability: How easily and economically a product can be produced

Availability: Probability that a system or piece of equipment will operate satisfactorily at any point in time as required

Affordability: Determination that the Program life cycle cost is in consonance with the long-range investment & mission plans

Operability is the combination of inherent design characteristics that determine both availability and affordability

Ares I Operability Roles & Responsibilities

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.

Ares I Operability Roles & Responsibilities (Contd.)

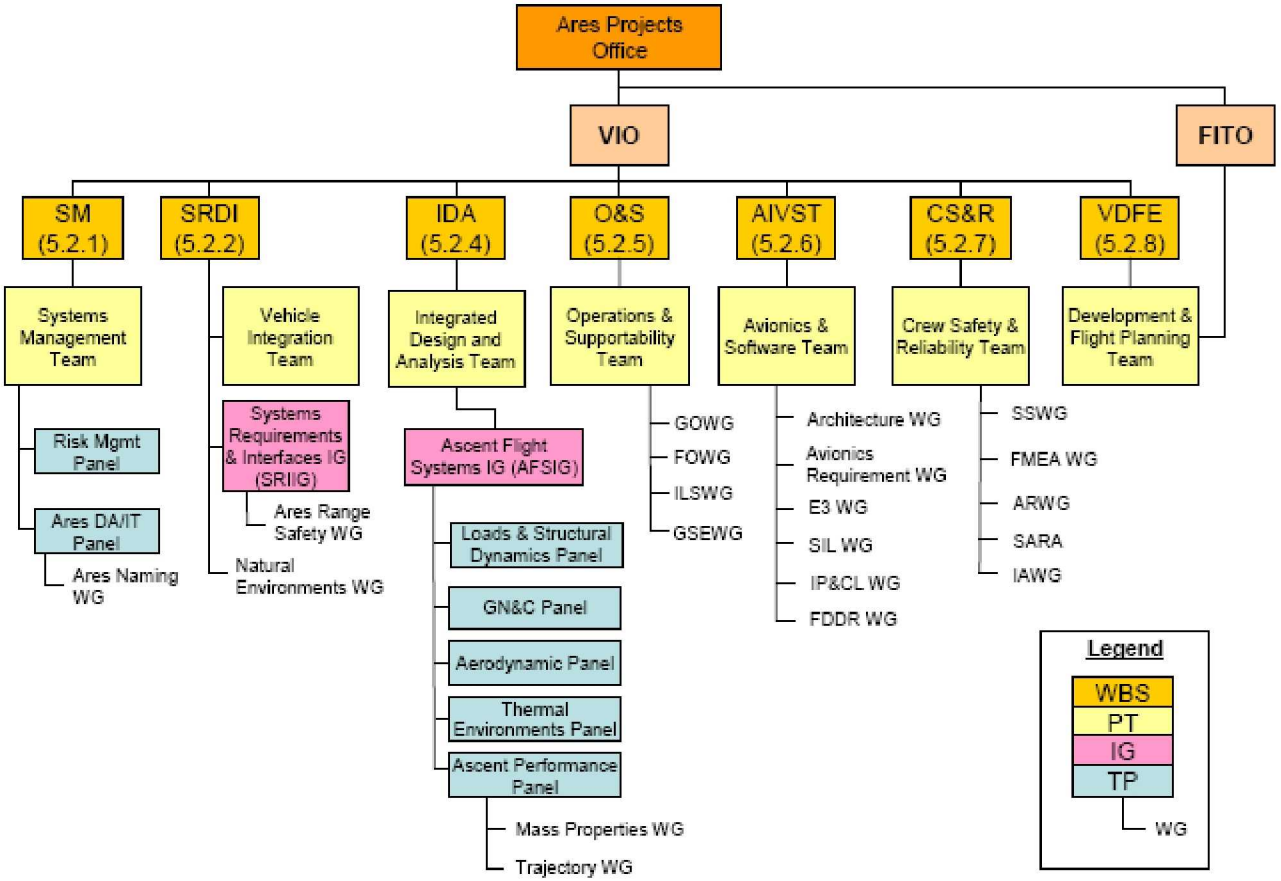


Figure 18 - Ares Product Teams, Technical Panels and Working Groups

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*

97 #Total SRD Rqmts
9 #KDRs

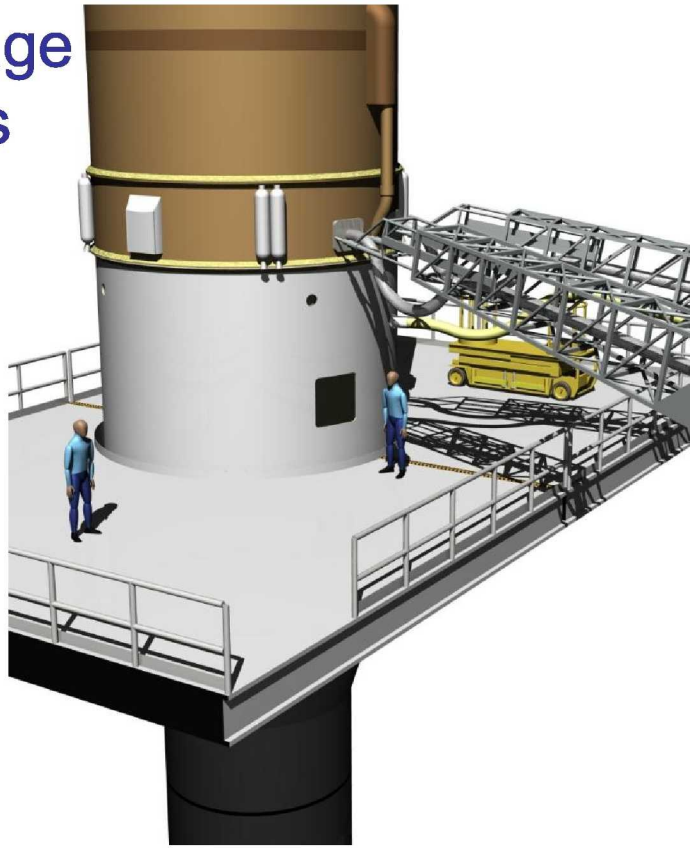
SRD Section 3.2 O&S Key Driving Requirements (KDRs)

	Top Level KDR		Elaboration of TBR/TBD	TPM
1	R.EA1066	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.	Y
2	Changed to TPM	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%	Y
3	R.EA6089	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.	Y
4	CLV.274	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 requirements 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.	Y
5	R.CLV.224	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).	Y

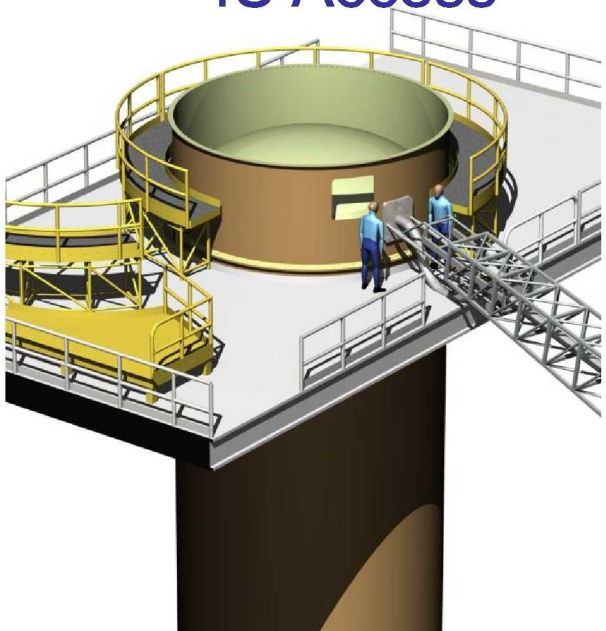
Access Point Concepts - GOP

1st Stage Access

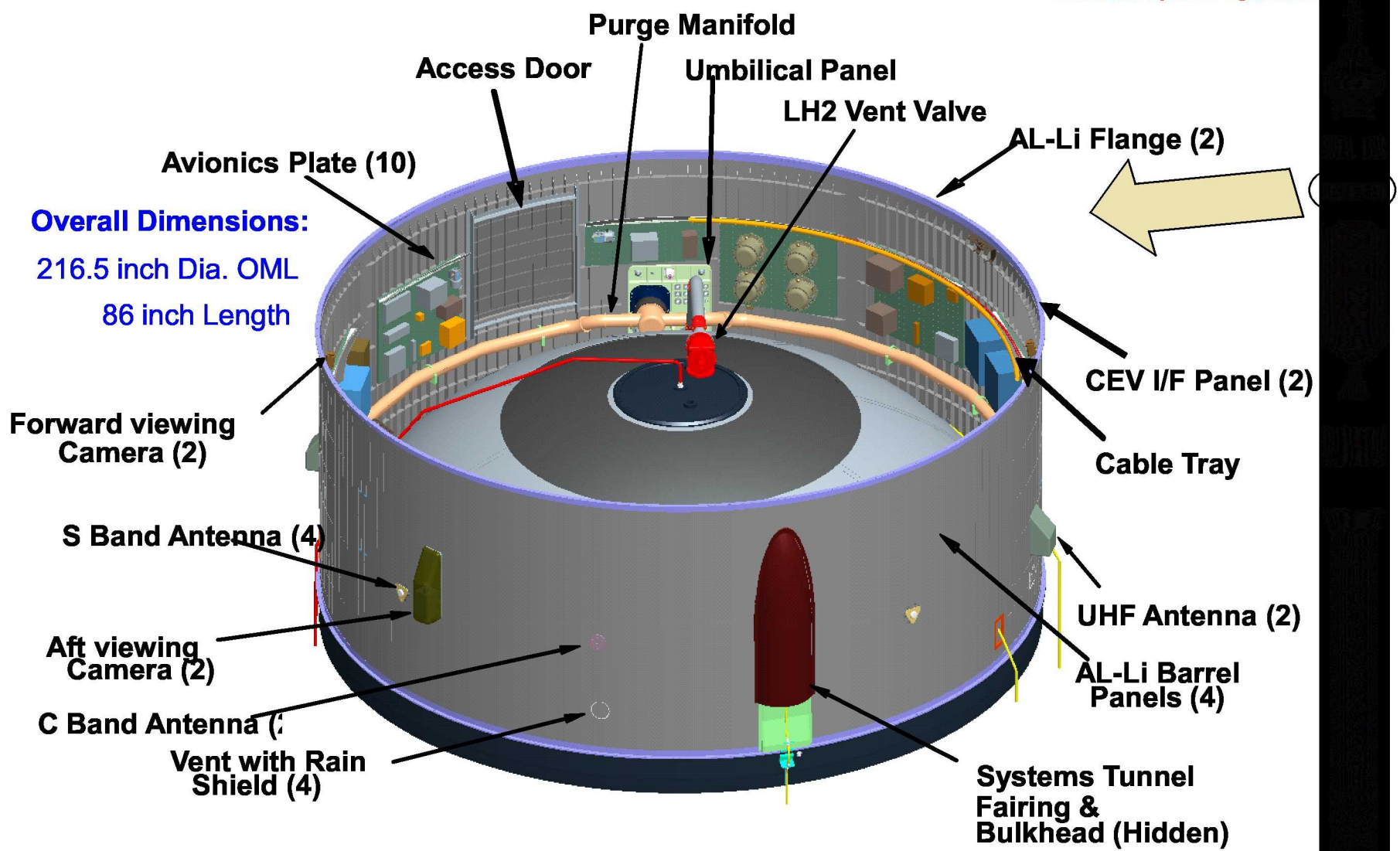
Upperstage Access



IU Access



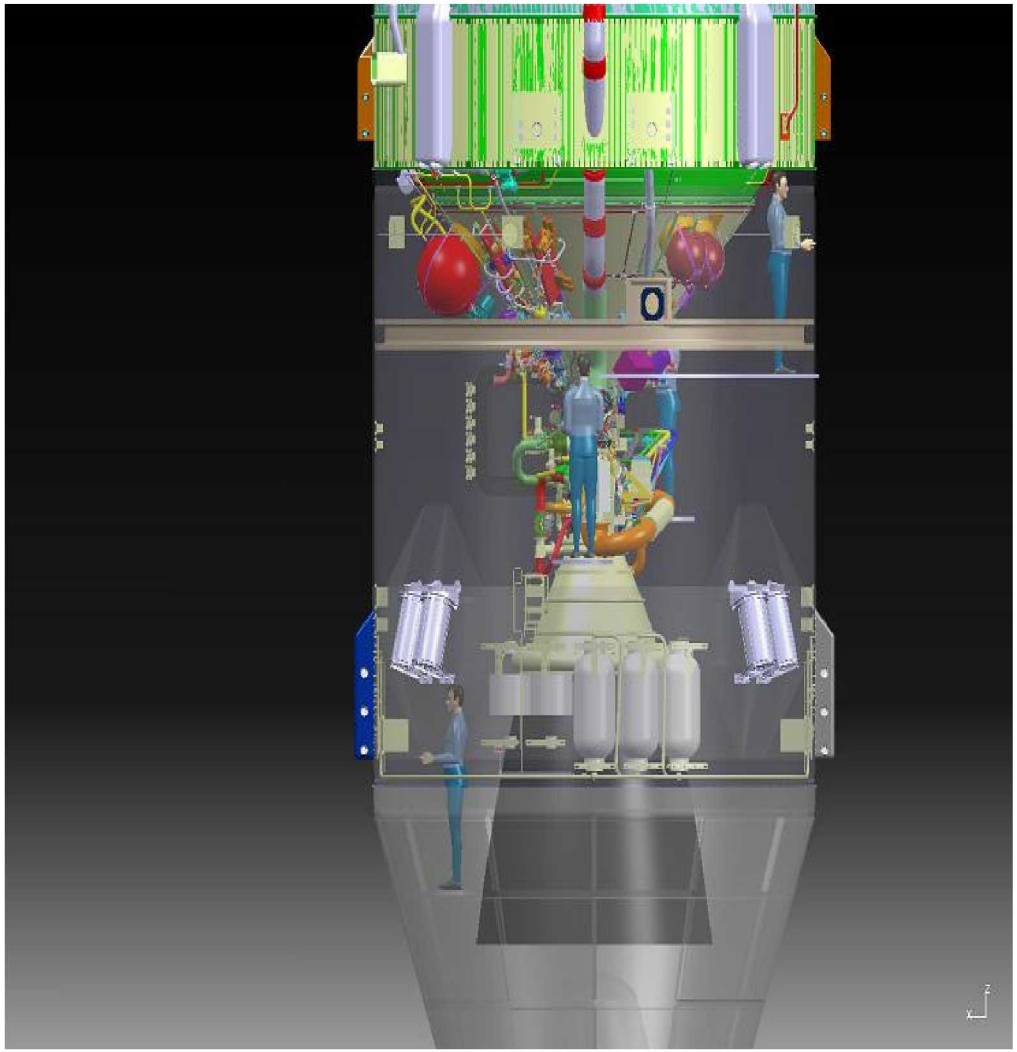
Instrument Unit (IU) Design Overview



**All component locations are notional and subject to change

Upper Stage- Interstage Access

- 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

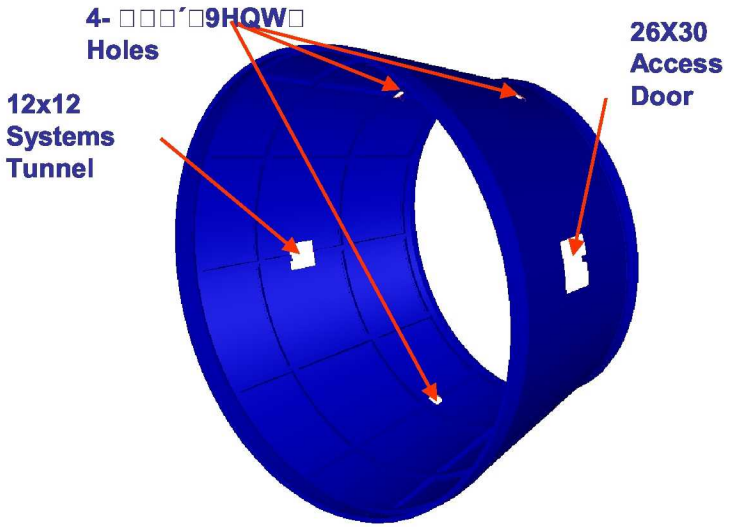
US Ares I Mockup for Operability Evaluations

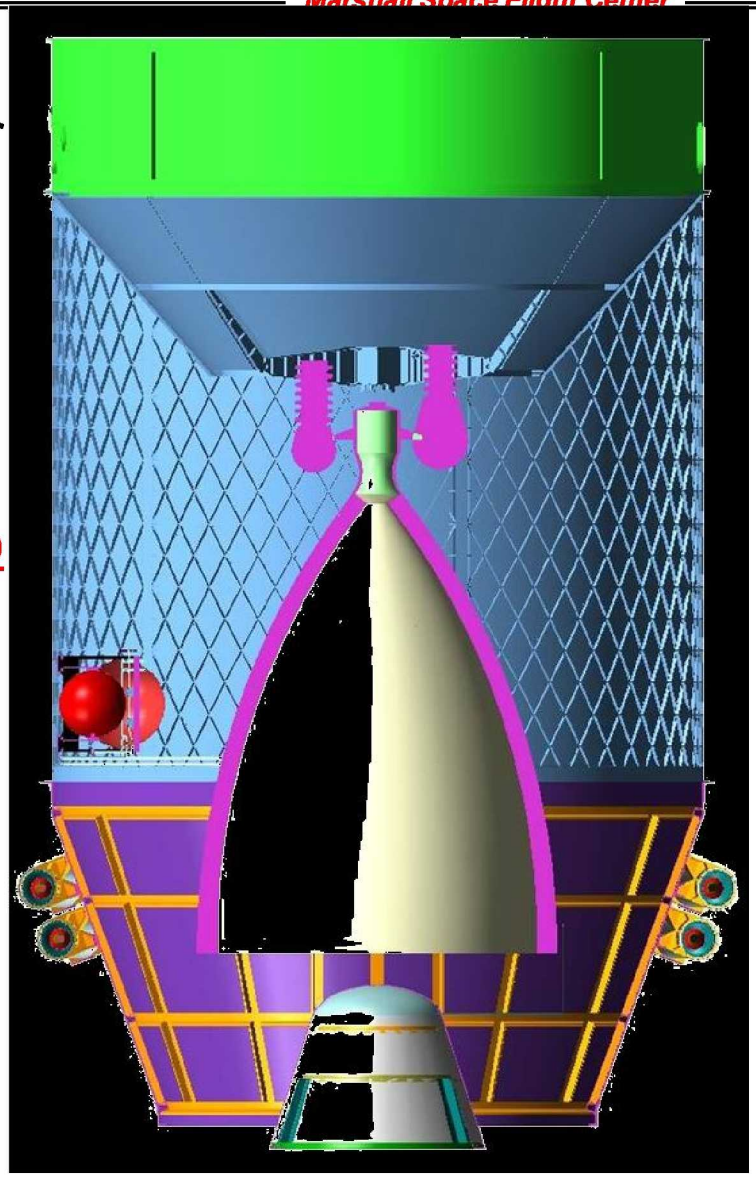
Figure 12-40 Instrument Unit Assembly

First Stage- Frustum Access

Frustum Access Door

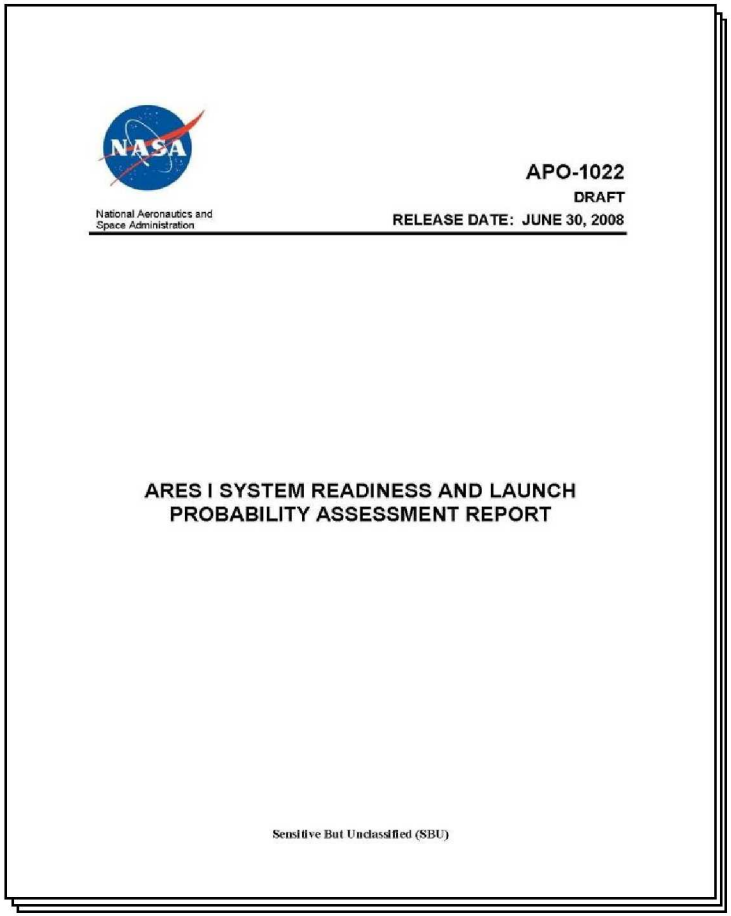
- Currently there is no requirement for a door
  - Access to the J2-X throat plug
  - J2-X purge
- If FS moves ahead with an access door, there will be a minimum 500 lb mass impact to the Frustum





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


National Aeronautics and Space Administration

APO-1022
DRAFT
RELEASE DATE: JUNE 30, 2008

ARES I SYSTEM READINESS AND LAUNCH PROBABILITY ASSESSMENT REPORT

Sensitive But Unclassified (SBU)

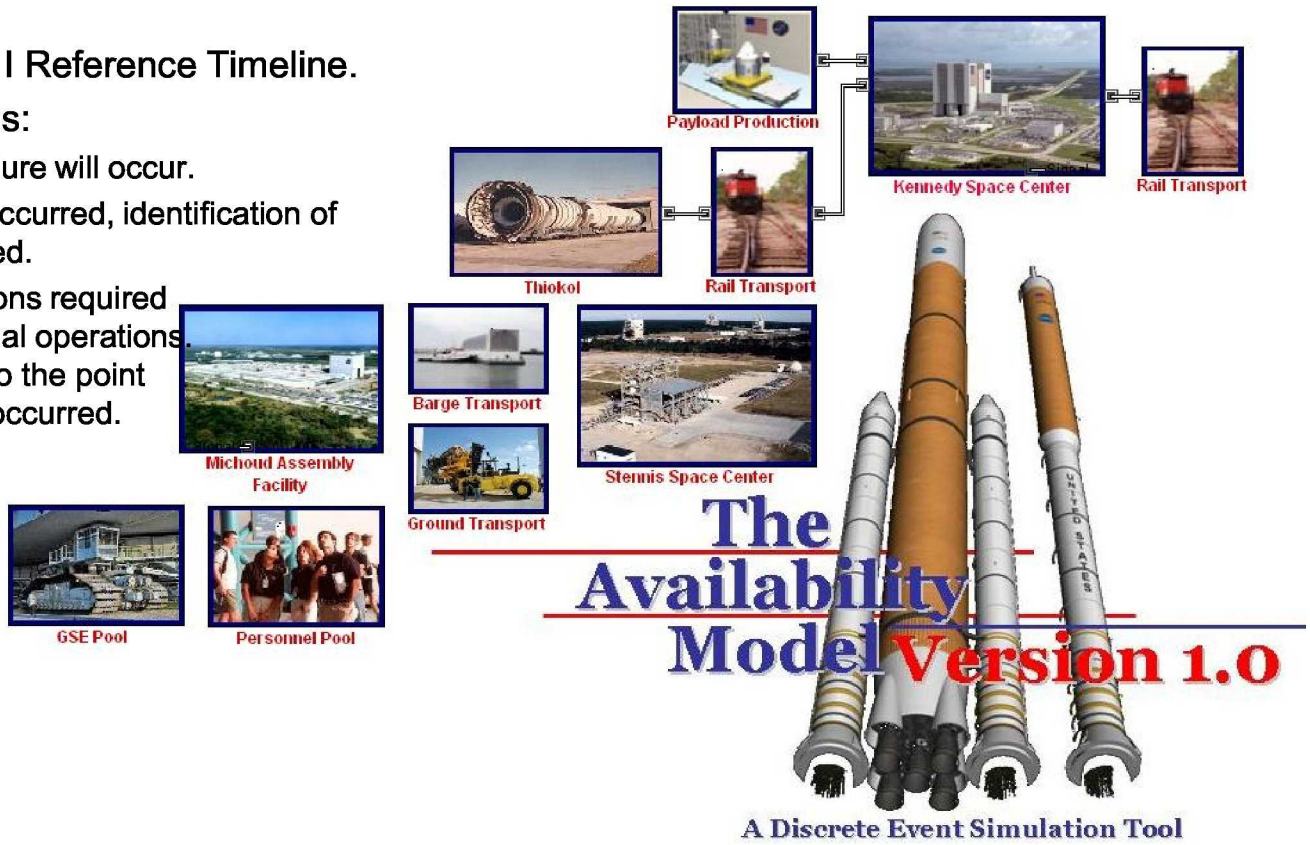
- The System Readiness TPM was levied on the Ares vehicle by the Ares Project to ensure the vehicle design has the ability to meet the defined launch date with a certain probability.
- The Ares I System Readiness measures that Ares I can be VWDFNHG□DQG□UHDG\□IRU□³GHFLVLRQ□WR□ORDG□ SURSHOODQWV´□LQ□□□□□□FDOHQGDU□GD\V□□□□□
  - System Readiness starts with stacking First Stage onto the Mobile /DXQFKHU□DQG□HQGV□DW□³GHFLVLRQ□WR□ORDG□FU\RJHQ
  - The System Readiness is measured against 34.8 calendar days ZKLFK□LV□WKH□$UHV¶□DOORFDWLRQ□RI□WKH□□□□FDOHQ 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*

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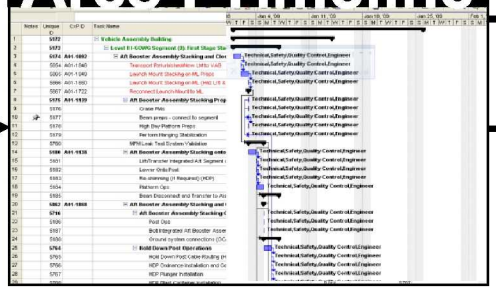
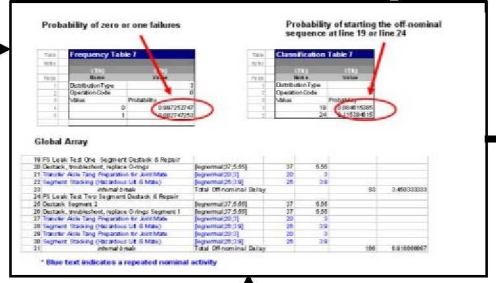
Ares I

Ares I Timeline



Off-Nominal Analysis

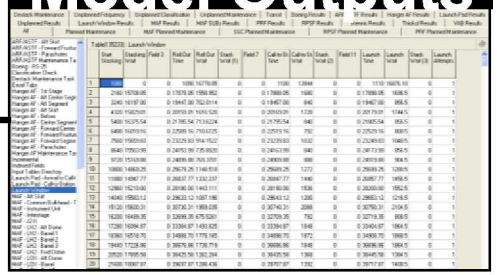


Reliability S&MA

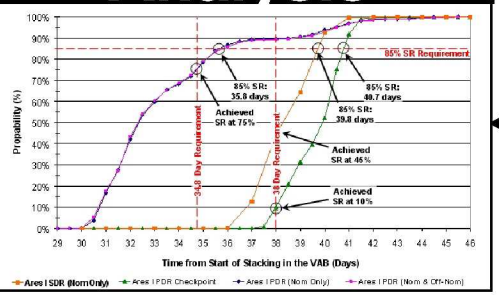
The Availability

Sensitivities

Model Outputs



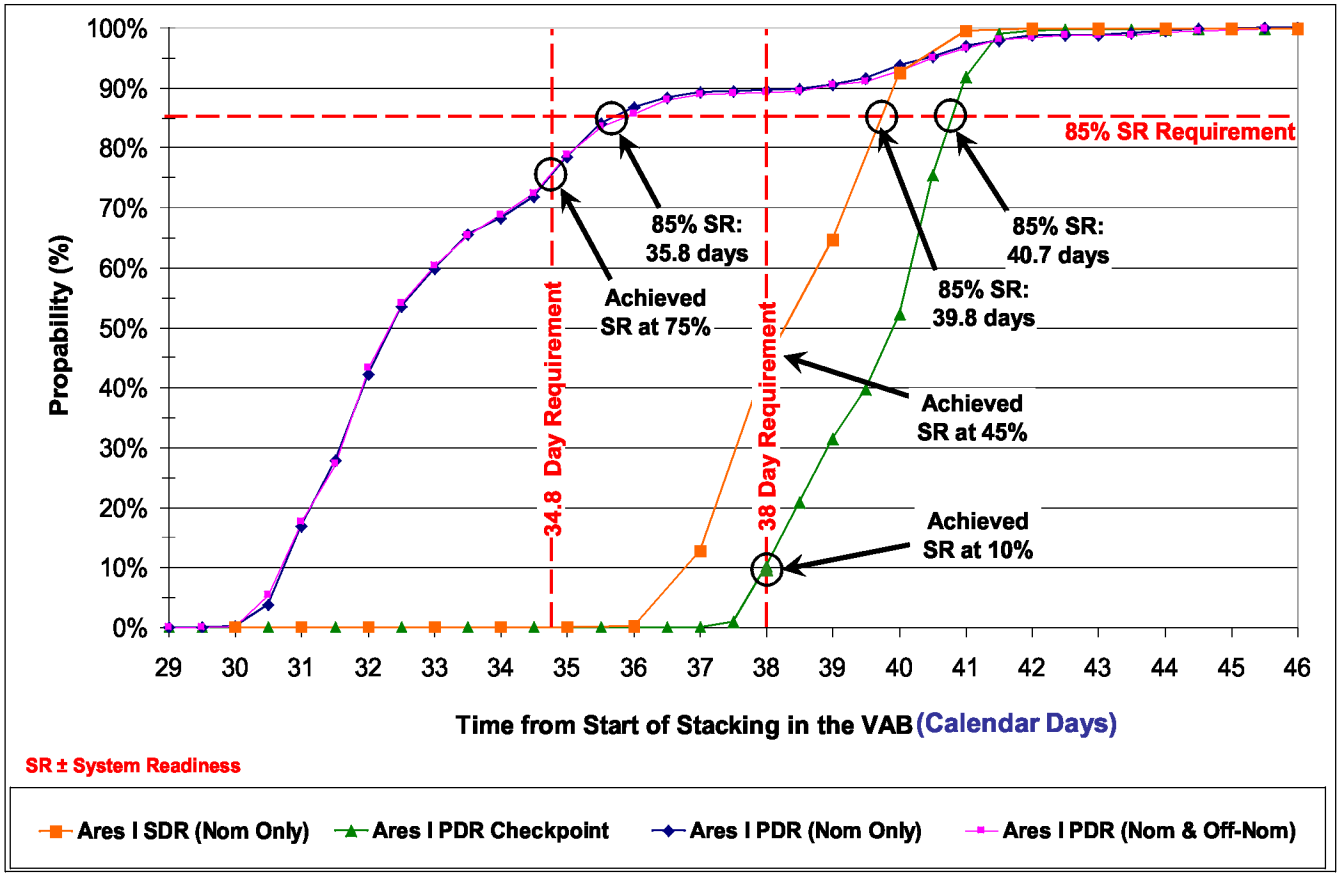
Analysis



Design Push Back

Requirements Met

Requirements



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.

TPM	Design Compliance
Ares I shall have a system readiness not less than 85% at a Confidence Level of 95%.	**Watch**

- 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.

Ares I *Launch Probability: Overview*

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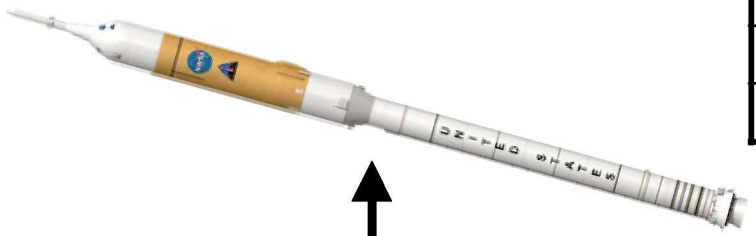
Blue	Requirement Value
Green	Requirement Met
Red	Requirement Not Met

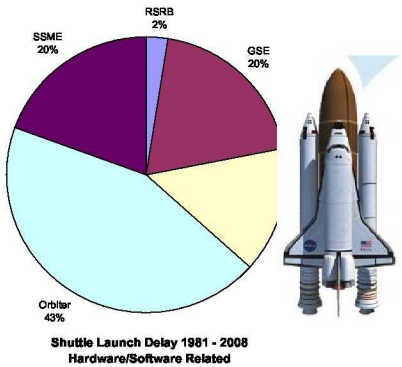
Launch Probability Assessment is based on initial preliminary analyses provided by each of the Elements



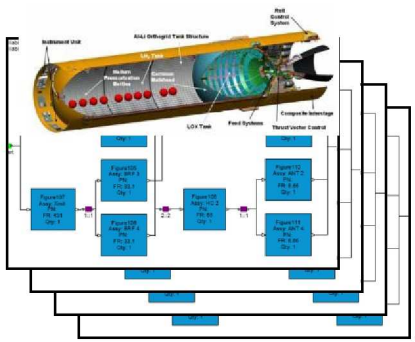
Requirement
>=0.98 (TBR)
(1 in 50)

Prediction
0.969
(1 in 32.3)

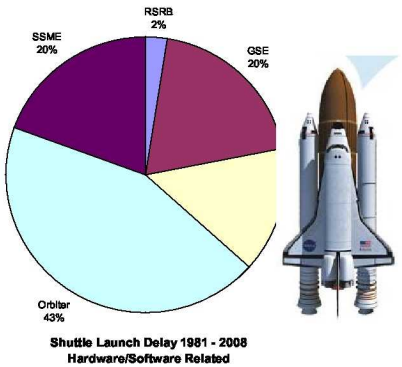
First Stage		Upper Stage		Upper Stage Engine	
0.993	0.9985	0.993	0.9716	0.993	0.9986



Similarity to RSRB Launch delay history



Prelaunch reliability logic model

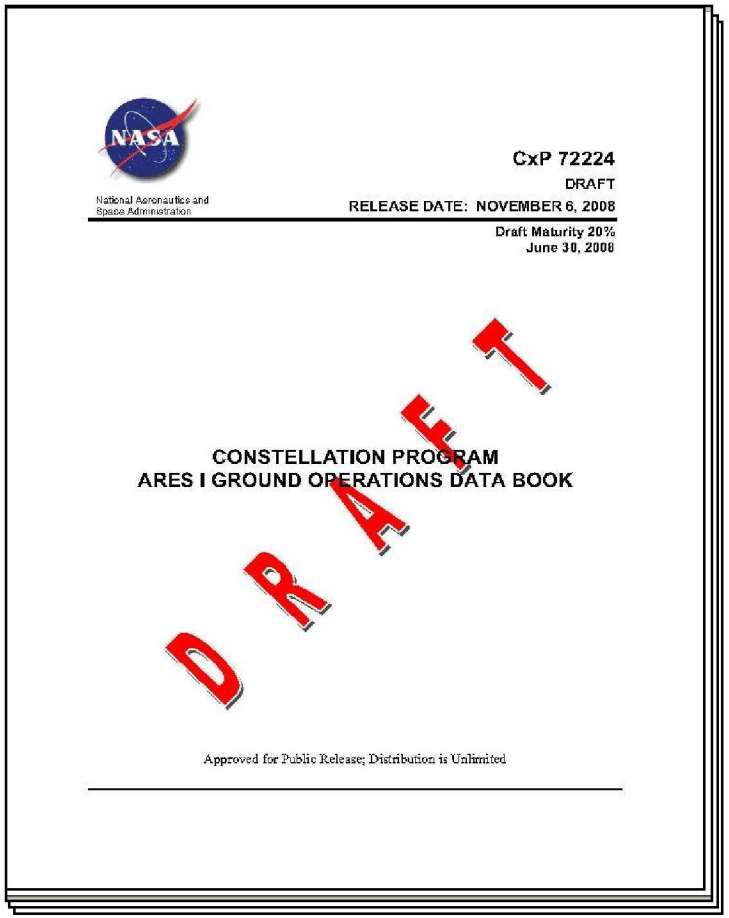


Similarity to SSME Launch delay history

Requirement	Design Compliance
R.EA1066 **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.**	**Watch**

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

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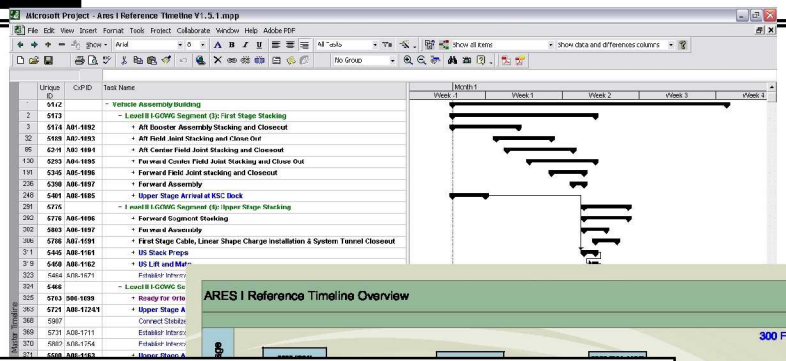
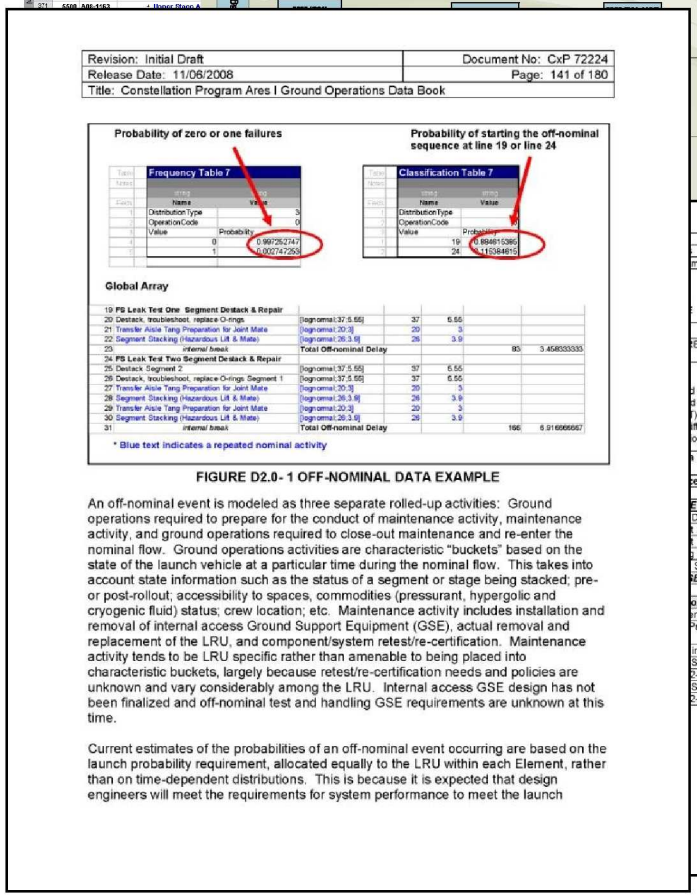
1. Captures Ares I Reference Timeline
2. Timeline Overview maps Ares I Reference timeline and CxP Integrated Timeline
3. Ground Operations / Task oriented perspective to Ares I documentation
4. Holding place for ground operations requirements until they move to ICDs, Specs, Drawings, etc.
5. Captures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





Revision: Initial Draft | Document No: CxP 72224
Release Date: 11/06/2008 | Page: 141 of 180
Title: Constellation Program Ares I Ground Operations Data Book

Probability of zero or one failures

Probability of starting the off-nominal sequence at line 19 or line 24

Frequency Table 7

Classification Table 7

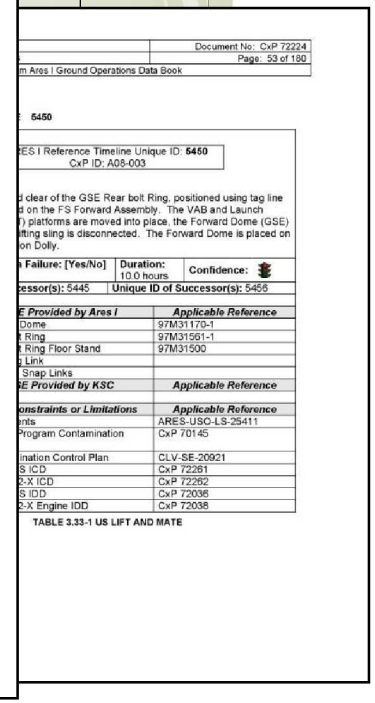
Global Array

* Blue text indicates a repeated nominal activity

FIGURE D2.0- 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-rollout; accessibility to spaces, commodities (pressurant, 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/re-certification. Maintenance activity tends to be LRU specific rather than amenable to being placed into characteristic buckets, largely because retest/re-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



Document No: CxP 72224
Page: 53 of 180
m Ares I Ground Operations Data Book

5450

ES I Reference Timeline Unique ID: 5450
CxP ID: A08-003

d clear of the GSE Rear bolt Ring, positioned using tag line
d on the FS Forward Assembly. The VAB and Launch
) platforms are moved into place, the Forward Dome (GSE)
ifting sling is disconnected. The Forward Dome is placed on
on Dolly.

Failure: [Yes/No] | Duration: 10.0 hours | Confidence:
cessor(s): 5445 | Unique ID of Successor(s): 5455

E Provided by Ares I	Applicable Reference
Dome	97M31170-1
Ring	97M31561-1
Ring Floor Stand	97M31500
Link	
Snap Links	
E Provided by KSC	**Applicable Reference**
onstraints or Limitations	**Applicable Reference**
nts	ARES-USC-LS-25411
Program Contamination	CxP 70145
ination Control Plan	CLV-SE-20921
S ICD	CxP 72261
2-X ICD	CxP 72262
S IDD	CxP 72036
2-X Engine IDD	CxP 72038

TABLE 3.33-1 US LIFT AND MATE

GODB
Ground Operations Data Book

Ares I Reference Timeline

T0-26.5 h Countdown (T0-4.9d) — T0 Ascent

Previous Launch	9.7 Days (T0-36.3 d)	41.1 Days	
Element Standalone Ops	VAB Integrated Ops	Pad Ops	

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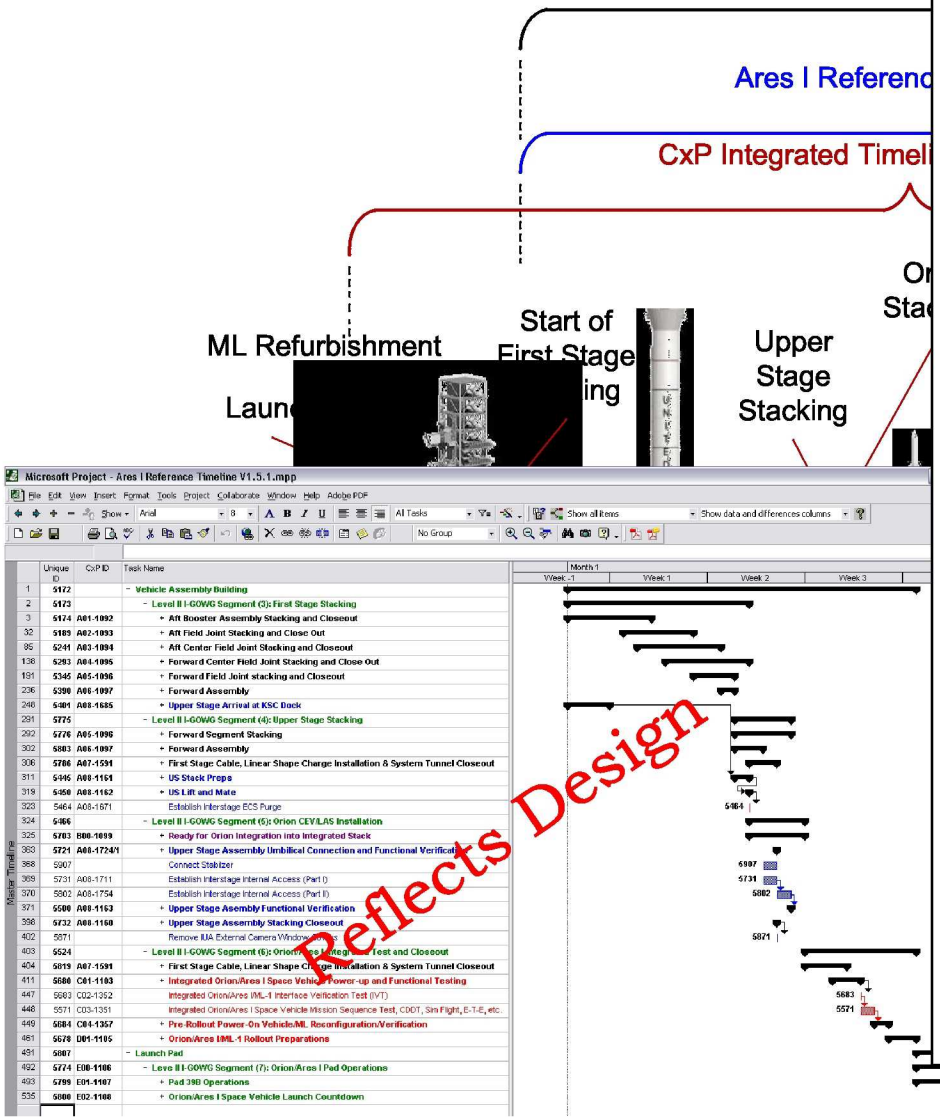
Ares I Integrated Mission Timeline (CxP 72071)



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

Ares I Launch Interval Assessment

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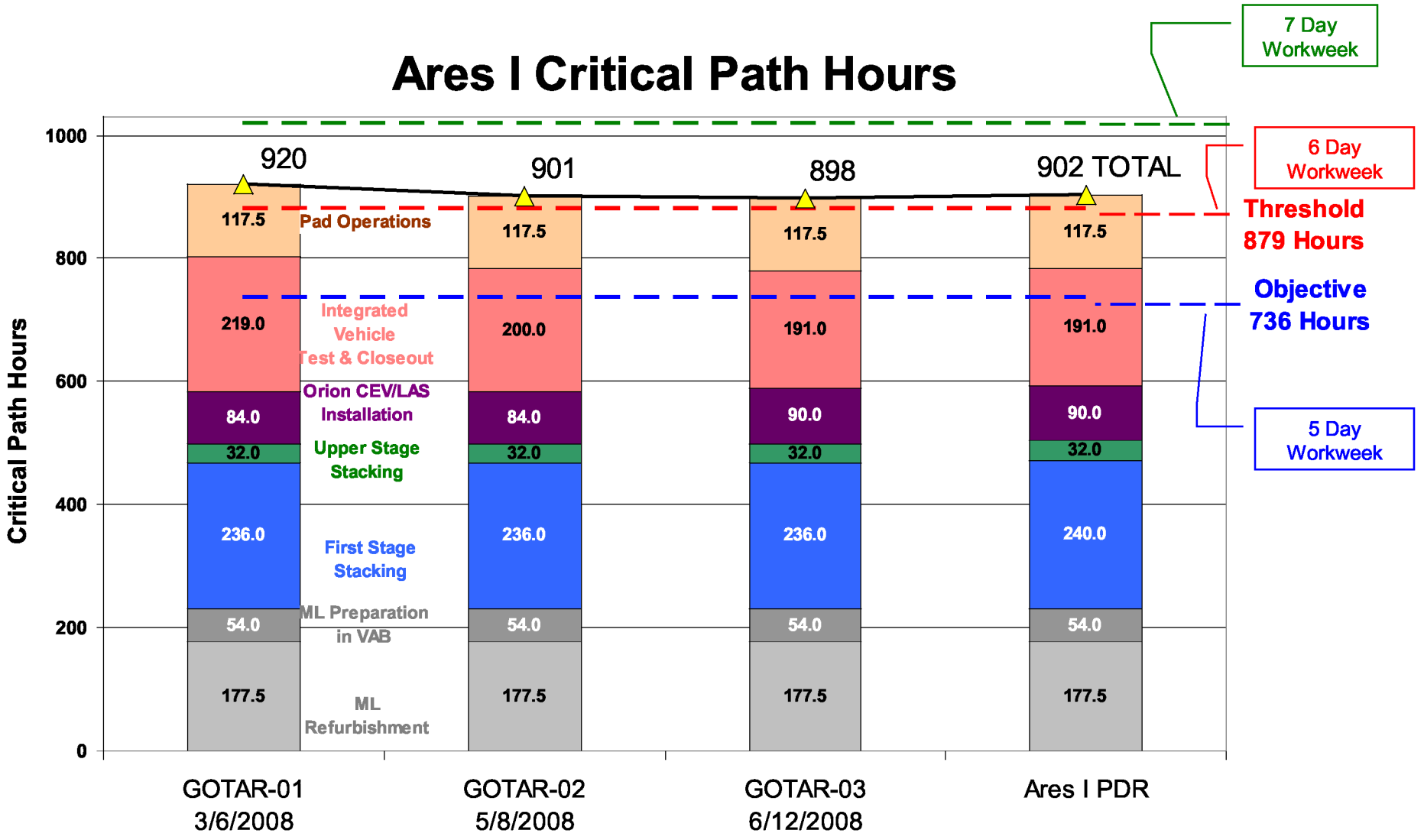

Ares I Preliminary Design Review (PDR)

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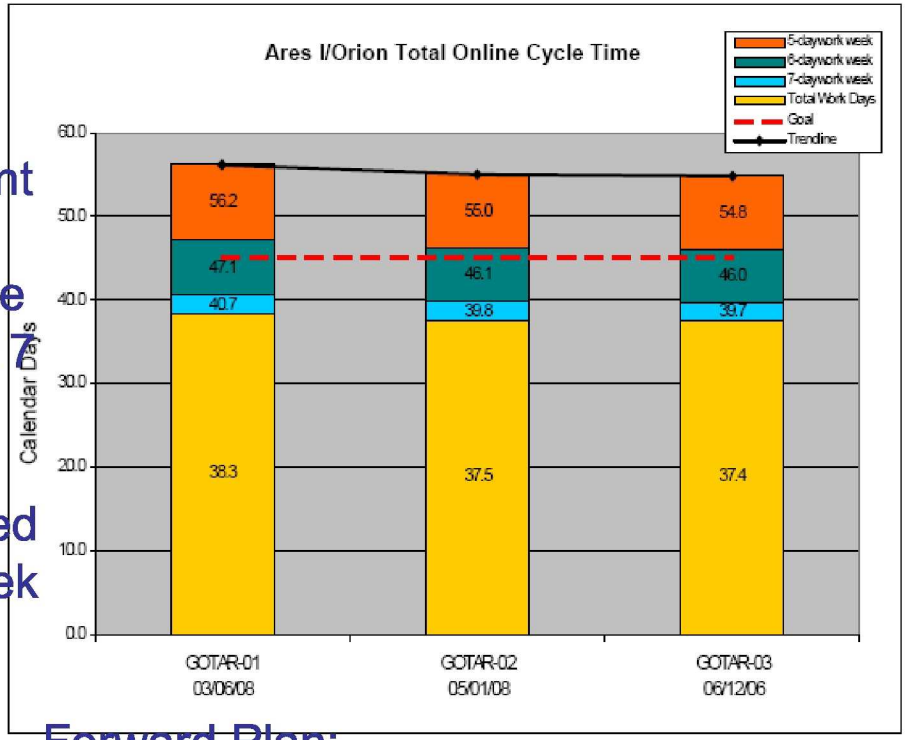
Requirement	Design Compliance
R.EA.6089 Launch Interval back to back within 45 Days **Ares I shall provide the capability for back to back launches within 45 days measured from the launch of the first integrated stack to the launch of the second integrated stack.**	WATCH ♦ Current assessment indicates this requirement can be achieved with 24 x 7 operations ♦ Can not be achieved with 6 day workweek  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

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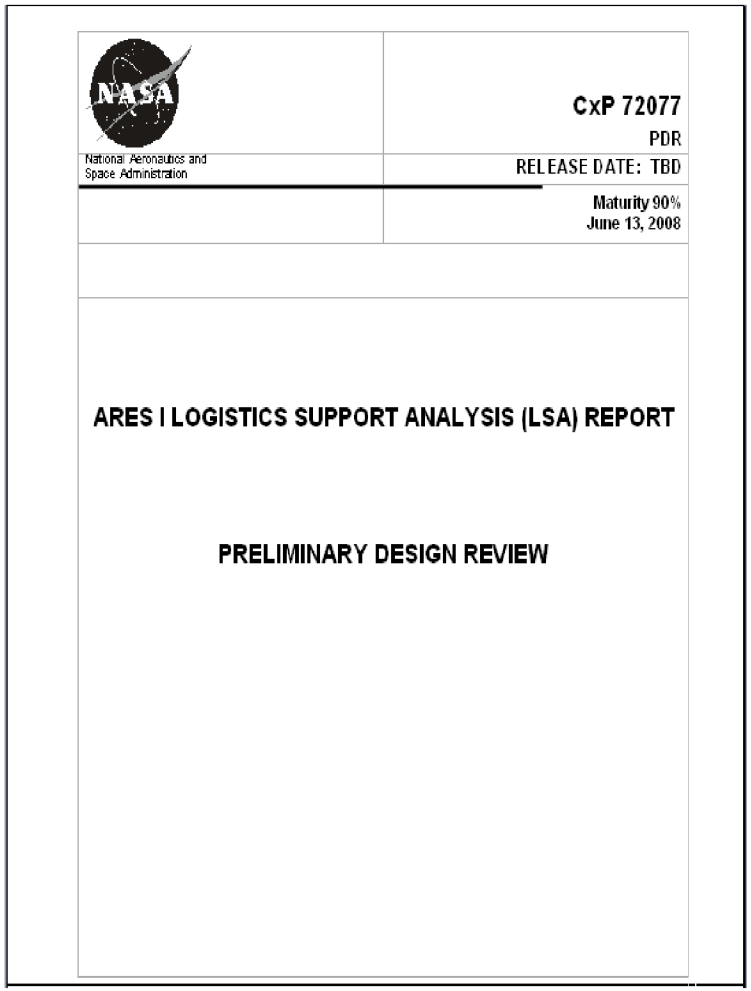
CARD, Rev C REQUIREMENT (Critical Path Hours)	Current CRITICAL PATH	POTENTIAL TIMELINE IMPACTS	THREAT / OPPORTUNITY
Start of Ares I First Stage Stacking to Ready for Upper Stage Mate (225 hours)	FS = 240 (+15 hours)	FS Off-Line Stacking Options	Opportunity
		Simplify Joint Closeout	Opportunity
		Simplify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

Ares I Logistics Support Analysis (LSA) Report

- 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



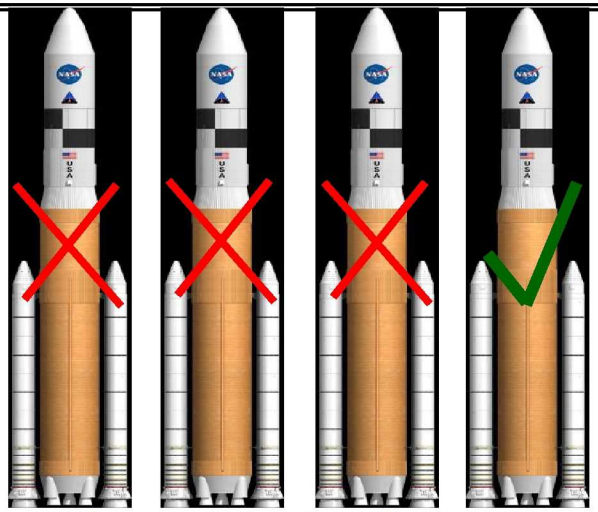
National Aeronautics and Space Administration

CxP 72077
PDR
RELEASE DATE: TBD
Maturity 90%
June 13, 2008

ARES I LOGISTICS SUPPORT ANALYSIS (LSA) REPORT

PRELIMINARY DESIGN REVIEW

Consecutive Launch Attempts Described



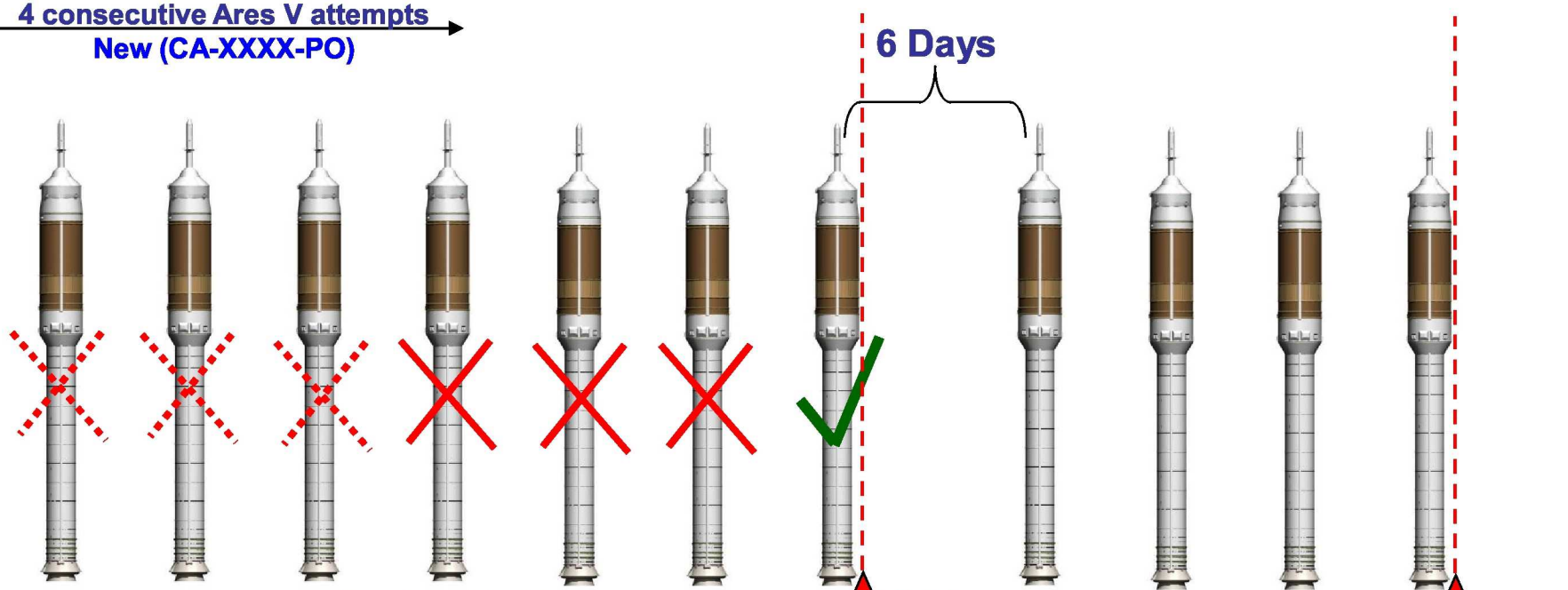
4 consecutive Ares V attempts

New (CA-XXXX-PO)

Legend

- = 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



7 consecutive Ares I tankings

(CA-0125-PO)

Burn-down Plan
R.EA6203 - Maintainability

Requirement	Design Compliance
R.EA6203 - 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.**	**Watch** ♦ **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.** ♦ **<u>Forward Work:</u>** ♦ **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.**

Interstage Internal Access

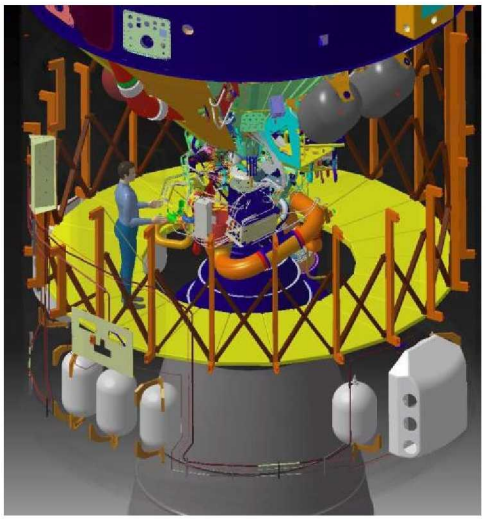
Interstage Mock-up

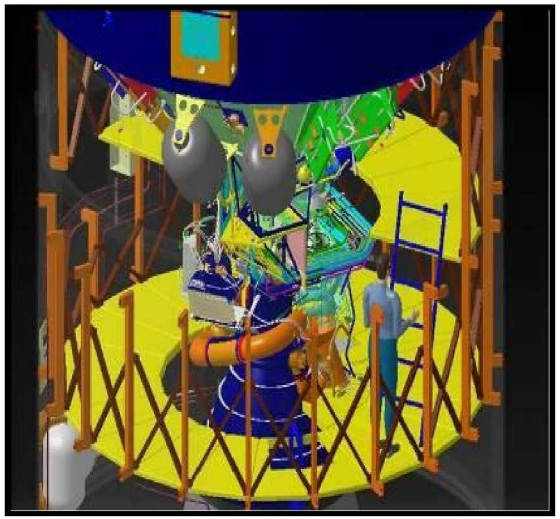
- Characterize design driven human actions and postures
- Simulate procedures

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

Interstage HFE Modeling (Conceptual)

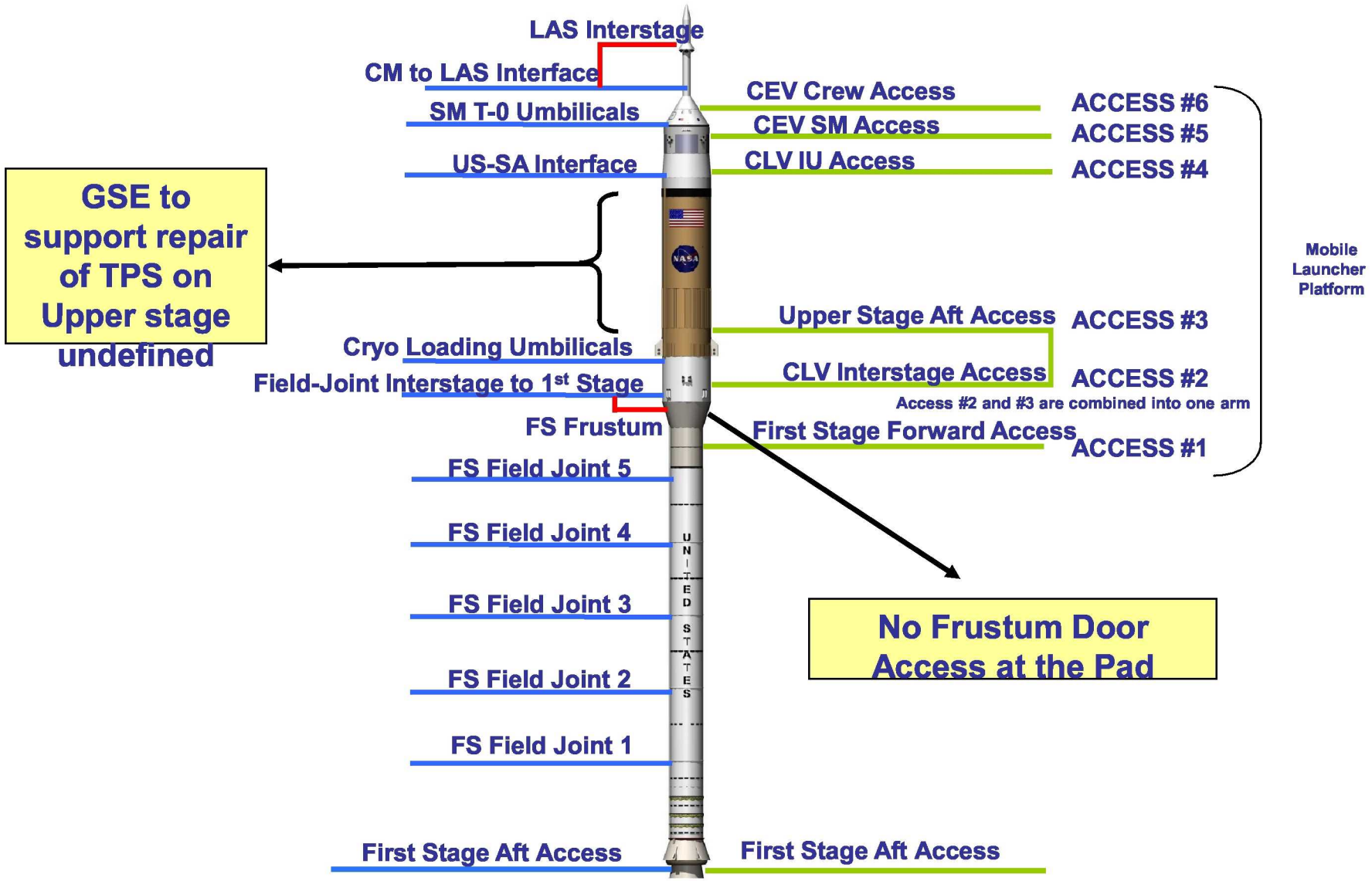
- Determine LRU access
- Simulate the large-scale integrated environment
- Define dynamic human operational envelop
- Measure physical performance attributes





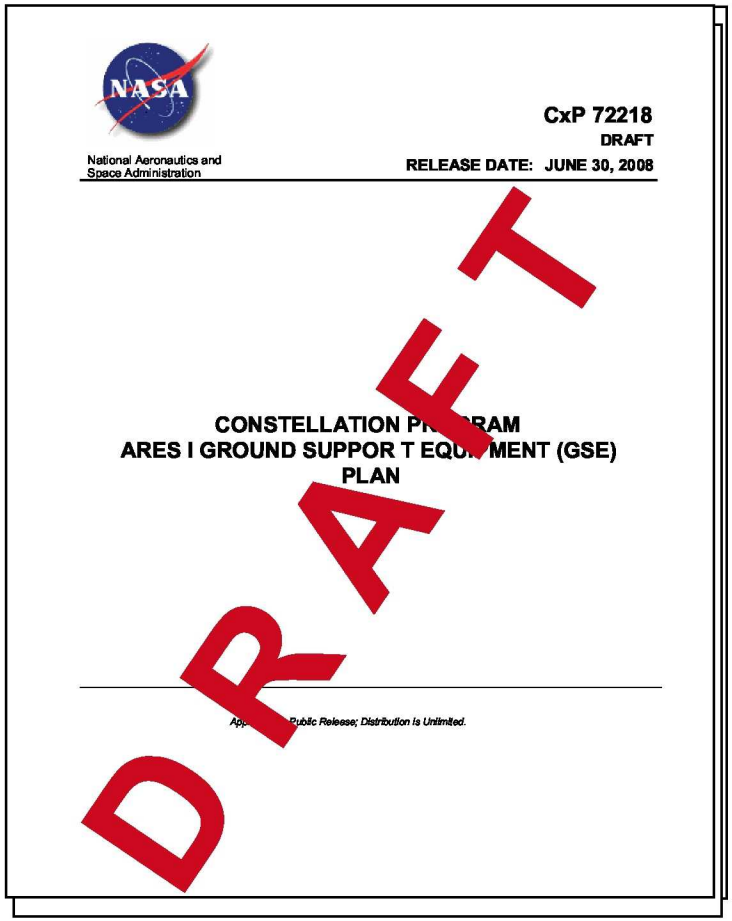
Virtual Human Modeling
Delmia V5 Digital Human Modeling with Human Task Simulation and Human Builder Solutions

Platform Access Locations



Ares I GSE Plan

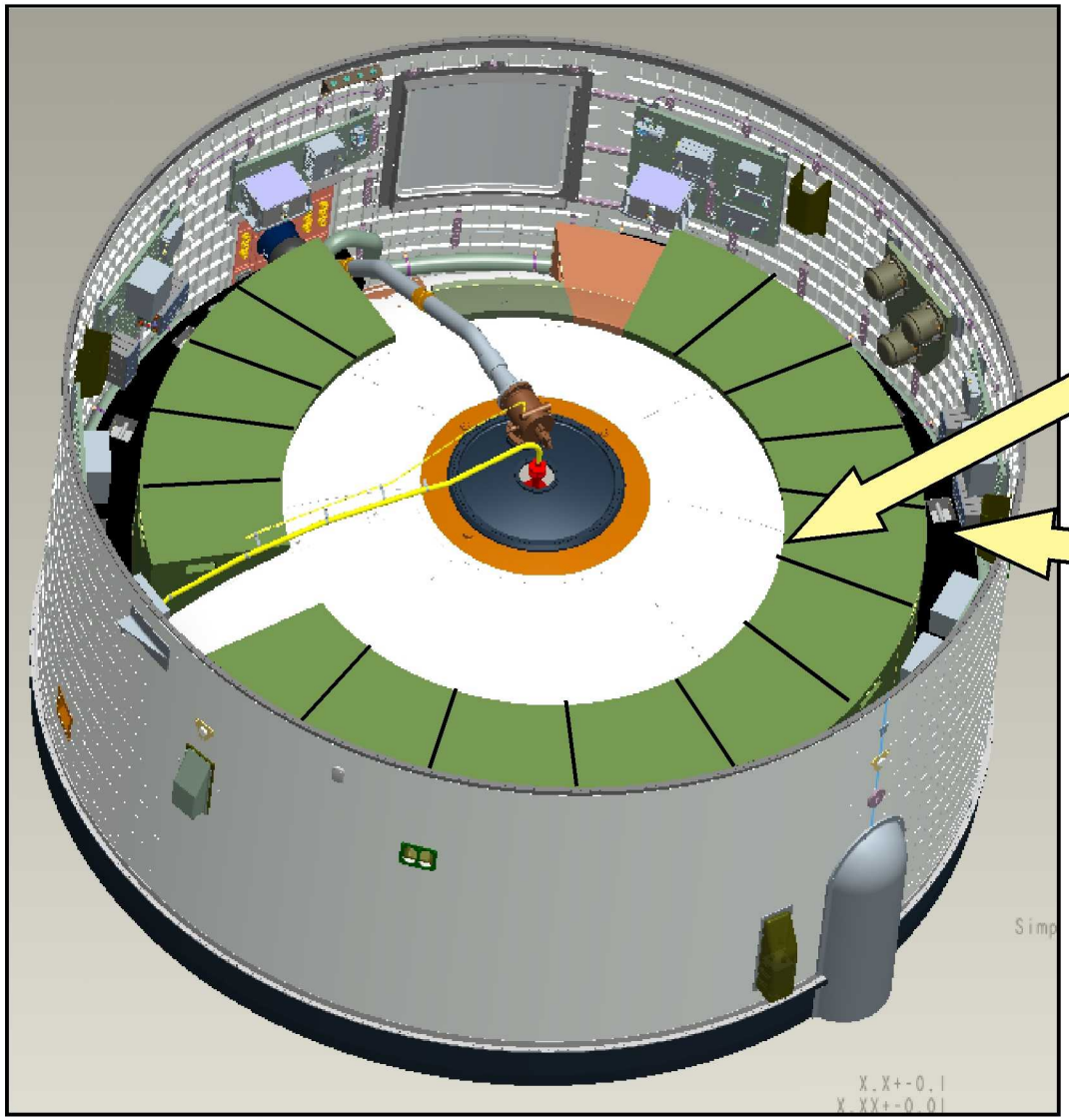
- **Document #:** CxP 72218
- **Document Title:** Ares I Ground Support Equipment (GSE) Plan
- **Purpose:**
  - Defines the GSE Policies & Responsibilities
  - Defines the GSE Working Groups
  - Establish the process for GSE Certification
  - Establish the process for the development of the Acceptance 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.

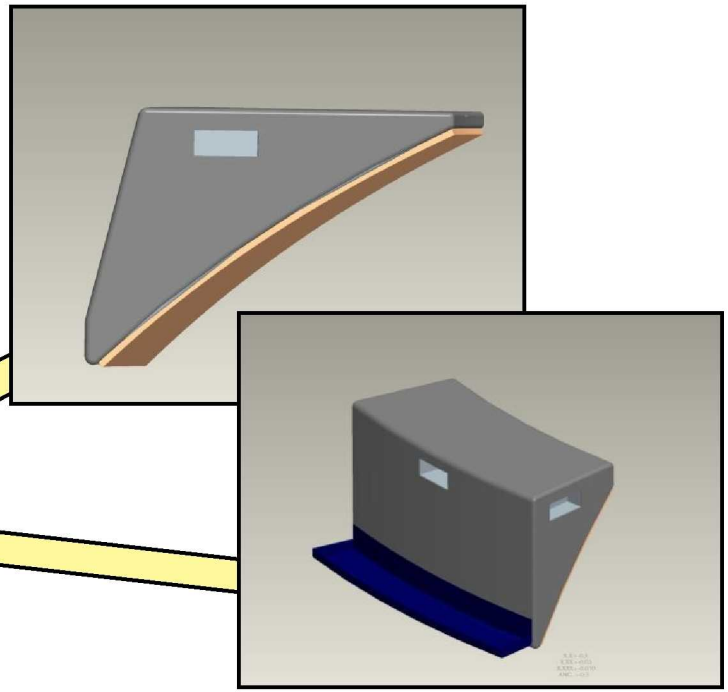


Ares I GSE Matrix

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)

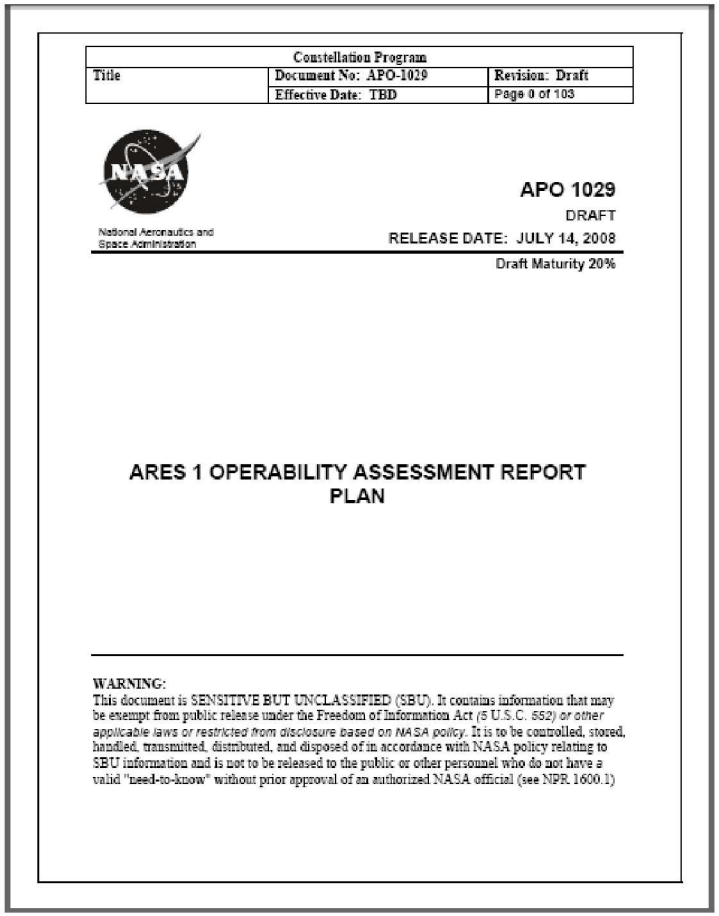
Interstage Access GSE

The Ares/KSC GSE Working Group

- **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 & POC Info

- 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



Constellation Program

Title	Document No: APO-1029	Revision: Draft
	Effective Date: TBD	Page 0 of 103

National Aeronautics and Space Administration

APO 1029
DRAFT
RELEASE DATE: JULY 14, 2008
Draft Maturity 20%

ARES 1 OPERABILITY ASSESSMENT REPORT PLAN

WARNING:
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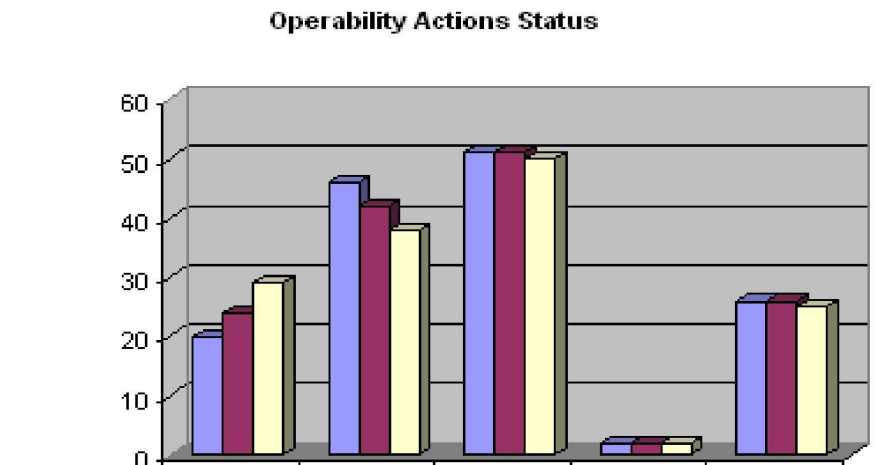
OAT Activities Status



	Closed	Actions	Tracking	Forward Work	Study
December	20	46	51	2	26
January	24	42	51	2	26
February	29	38	50	2	25

Voting Members Reviewed & Vetted 145 Operability Inputs:

Voting Members:

Ares I Project - Operability Manager
Ares Project - WBS Manager for 5.2.5
Eng ± O & S Team Lead
FS Chief Engineer
J-2X Chief Engineer
US Chief Engineer
KSC Operability Lead
VI Chief Engineer
Avionics Chief Engineer
Chief S&MA Officer
Level II Support

- **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□WKLV□LWHP□□□7KH□VWXG\□LV□MXVWLILHG□E\□D□&\FOH´□EHQHILWV□□□6WXG\□ZLOO□UHTXLUH□DGGLWLRQDO□UHVRXUFHV□

Orbiter At Pad PRACA Data

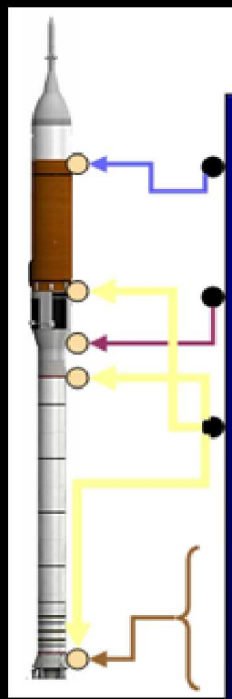
Based on Shuttle PRACA data from 1996-2005

Defect	Count	Percent
Operational Degradation	169	38
Unexplained Anomaly	48	11
Workmanship	45	10
Materials Deficiency	41	9
Vendor Responsibility	32	7
Failures	28	6
Design Deficiency	23	5
Others	60	13
Total	446	

Historically, a likelihood of pre-launch contingency event includes more than just hardware failures

OAT Identified Studies

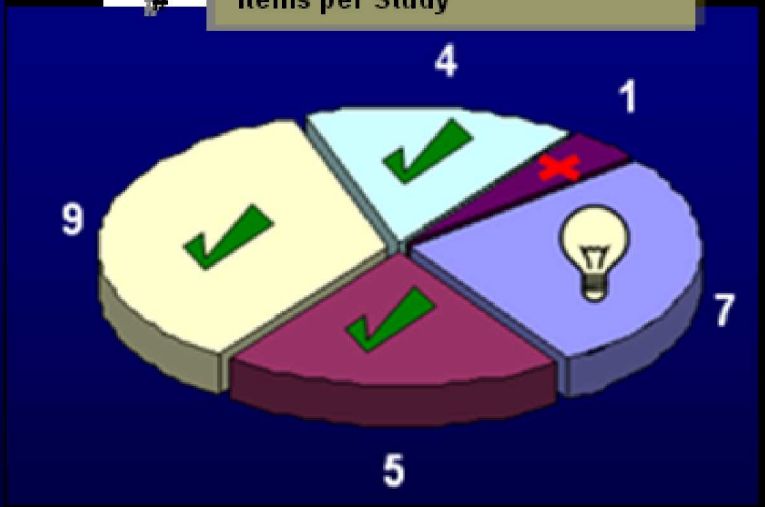
Studies Proposed



- 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

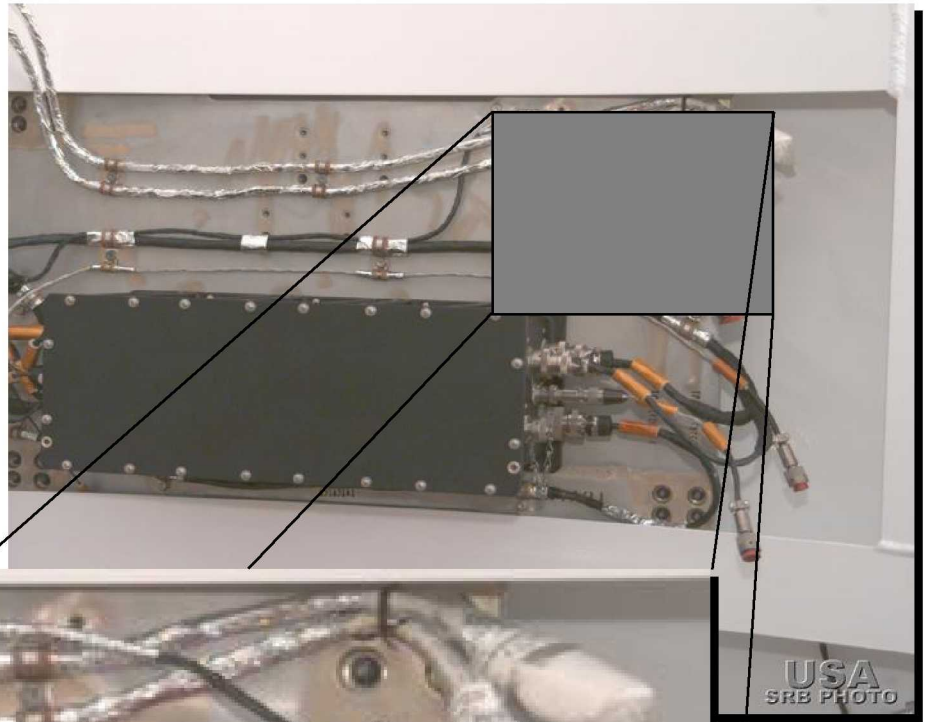
- Study Denied
- Study Conditionally Approved Awaiting ROM Cost & Schedule
- Study Underway
- # Items per Study

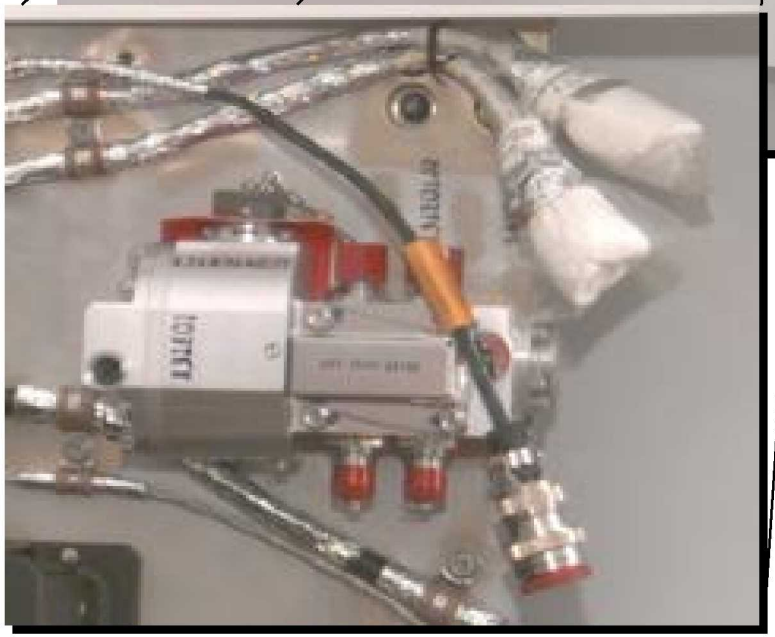


Study 1: Early Fwd Skirt Closeout

- 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
  - roll-out
  - eout metho
  - ocessing

Early Fwd Skirt Closeout





Benchmarking Activities

- 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
- 7KHUH□ZHUH□VRPH□³FRPPRQ□WKUHDG´□ILQGLQJV□DPRQJ□W and operators as well as some unique characteristics for each launch vehicle
- 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

Benchmarking Activities

- 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
  - H-IIA / JAXA redesigned solids rockets from 4 segment booster to a single composite segment. Loaded solid propellant at launch site. Atlas uses single segment solid. Ariane casts solid at launch site.
  - 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

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	Ares I	Ariane 5	Atlas 5	Delta IV	H IIA	STS
Access at Pad	Yes	No	No	Yes	No	Yes
Time for Pad Ops	7 days	1 day	9 hours	10 days	12 hours	1 Month
Time to roll back (rollback, repair, and roll-out if problem detected prior to tanking)	4 + days	1 day	<1 day	??	<1 day	Varies
Upgraded design for operability	New design	Yes	Yes	Yes	Yes	No
Access doors	1 per volume	Multiple (8)	Multiple	Multiple	Multiple	Multiple
Wet dress rehearsal	3 +2 No	Yes	Yes	Yes	12 No	First flights, No

Comparison to Ares

	Ares I	Ariane 5	Atlas 5	Delta IV	H IIA	STS
Time to process	40 + days			30 days		2 Months (VAB stacking)
Multiple vehicle processing	No	Yes	No	Yes	Yes	Yes
Inventory of Spares	TBD	No	No	No	No	Yes
Number of people required in LCC (Front Room)	Est. 100	30	~30	~30	20	~230
Reduced testing at launch facility	Yes	Yes	No	Yes	Yes	No

Backup

Ares I Operability Improvements

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*

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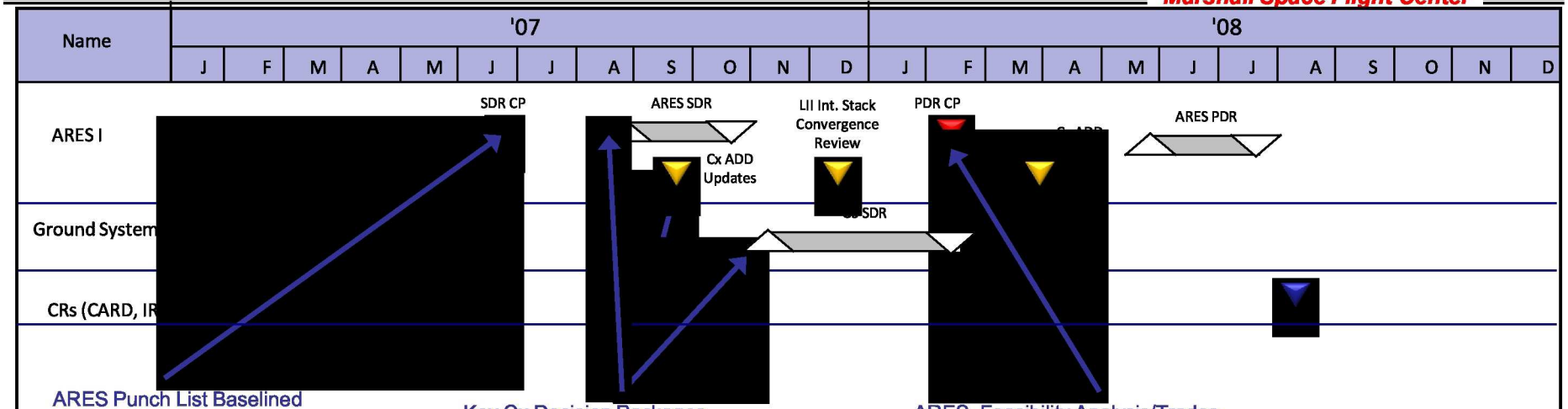


ARES Punch List Baselined
- Ship to Integrate
  - US Nozzle Extension
  - US TVC Testing
- Pad Processing
  - US Cold He
- Pad LRUs
  - PAD/VAB LRU Trade
  - US/Engine Maintenance
  - US Storage
- Reduced Reliance on Ground Networks
  - ARES Ascent Communications
- Reduced Assembly Operations
  - FS 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)

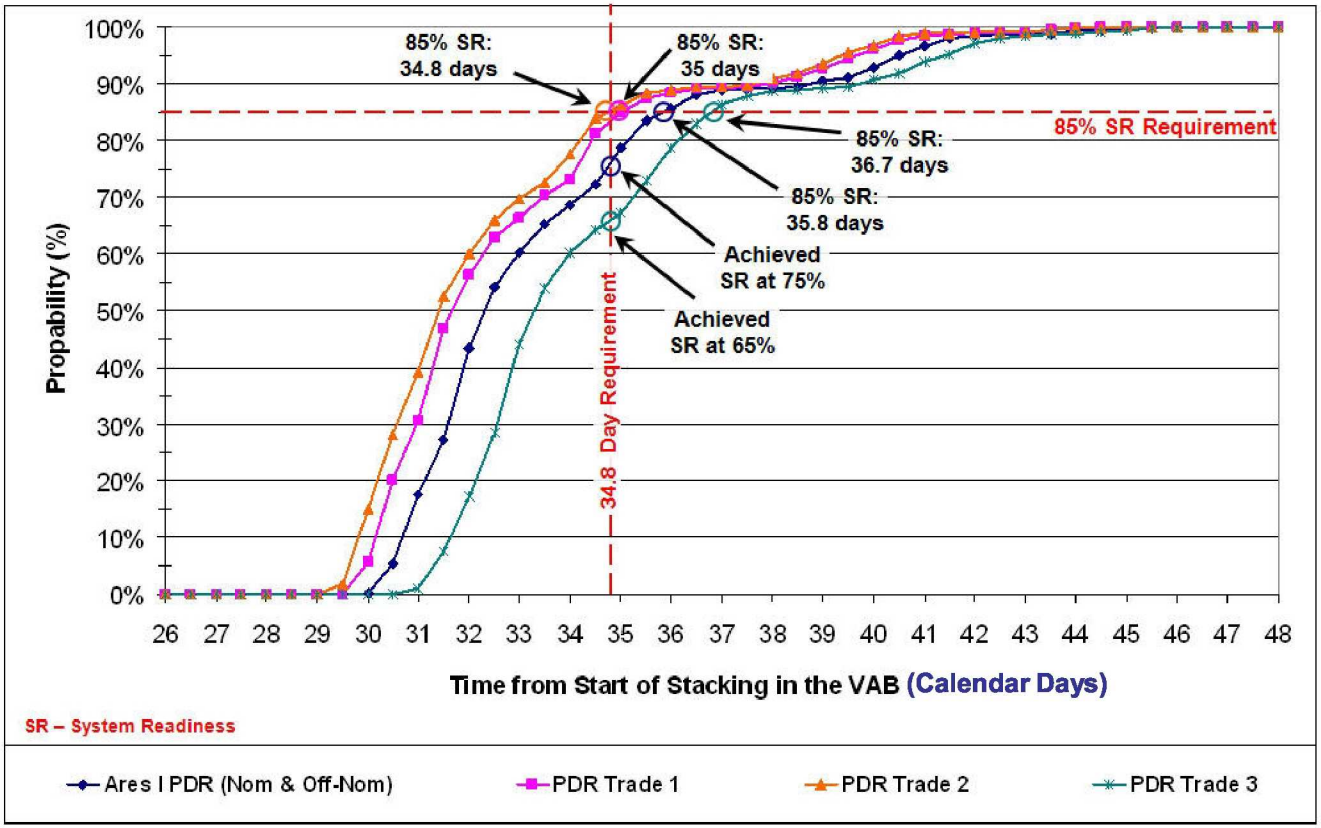
ARES Feasibility Analysis/Trades Completed
- US/J2 Offline Maintenance
- US Storage
- VAB/PAD Access

ARES P/L Resync to PDR
- VAB/PAD Access
- Closeouts prior to rollout
- Protective Covers Enclosures
- Automated Diagnosis

Red = Ares I / GO Baseline Disconnect

Ares I Preliminary Design Review (PDR)

System Readiness: Sensitivities



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

Previous Launch	9.7 Days (T0-36.3 d)	41.1 Days	T0-26.5 h Countdown (T0-4.9d)	T0 Ascent
Element Standalone Ops	VAB Integrated Ops	Pad Ops		

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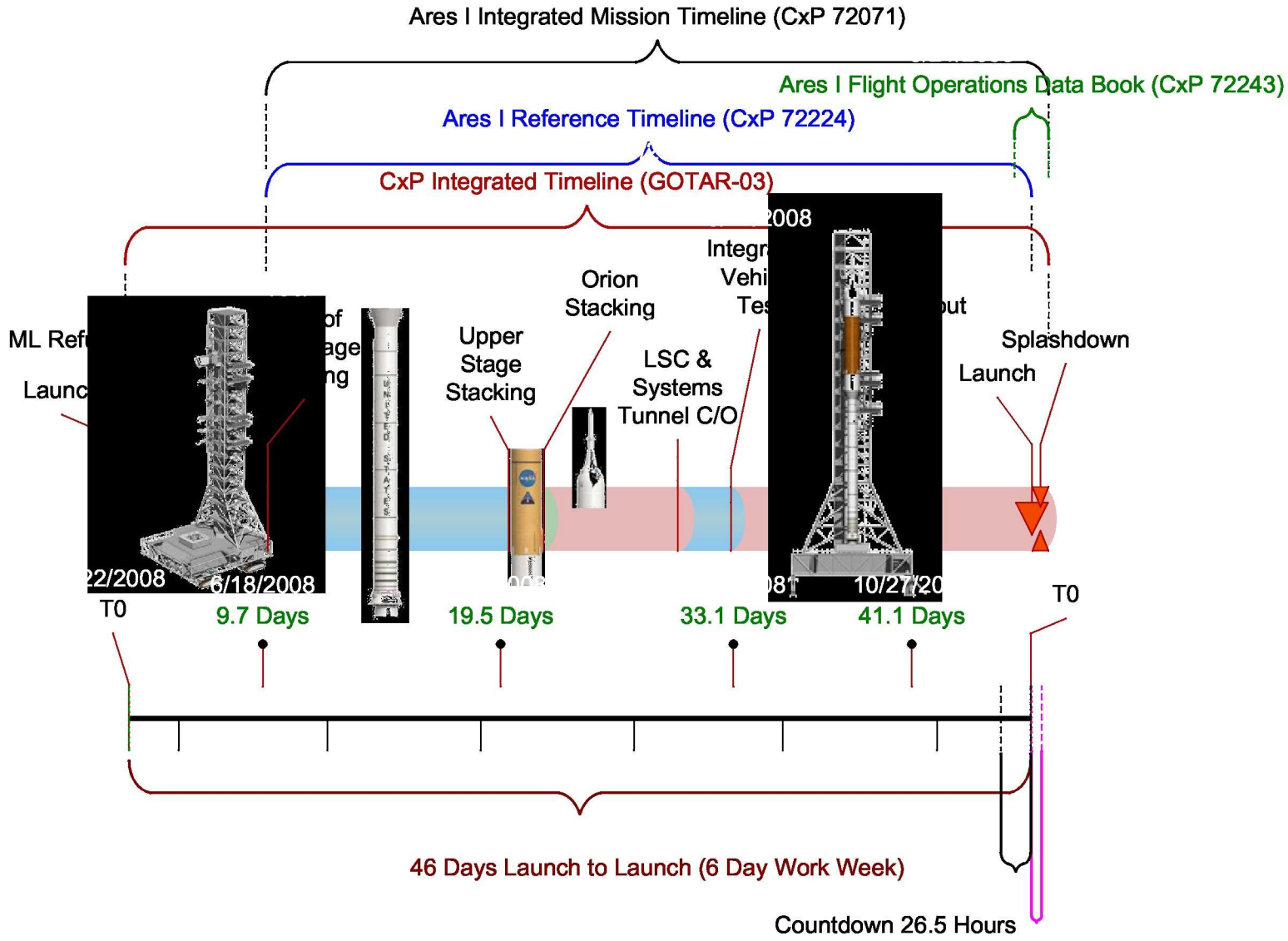


Center

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

Ares I Preliminary Design Review (PDR)

Requirement	Design Compliance
R.EA.6004 Ground Ops for the Critical Path Allocations shall be conducted within time limits **Ares I shall conduct ground operations for a single Ares I/Orion mission within the time limits identified in Ares I Critical Path Allocations for Ares I/Orion Ground Operations Table.**	**WATCH** *CARD Rev C, CR 000294, Ground Missions Operations SIG* 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

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

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 and 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).

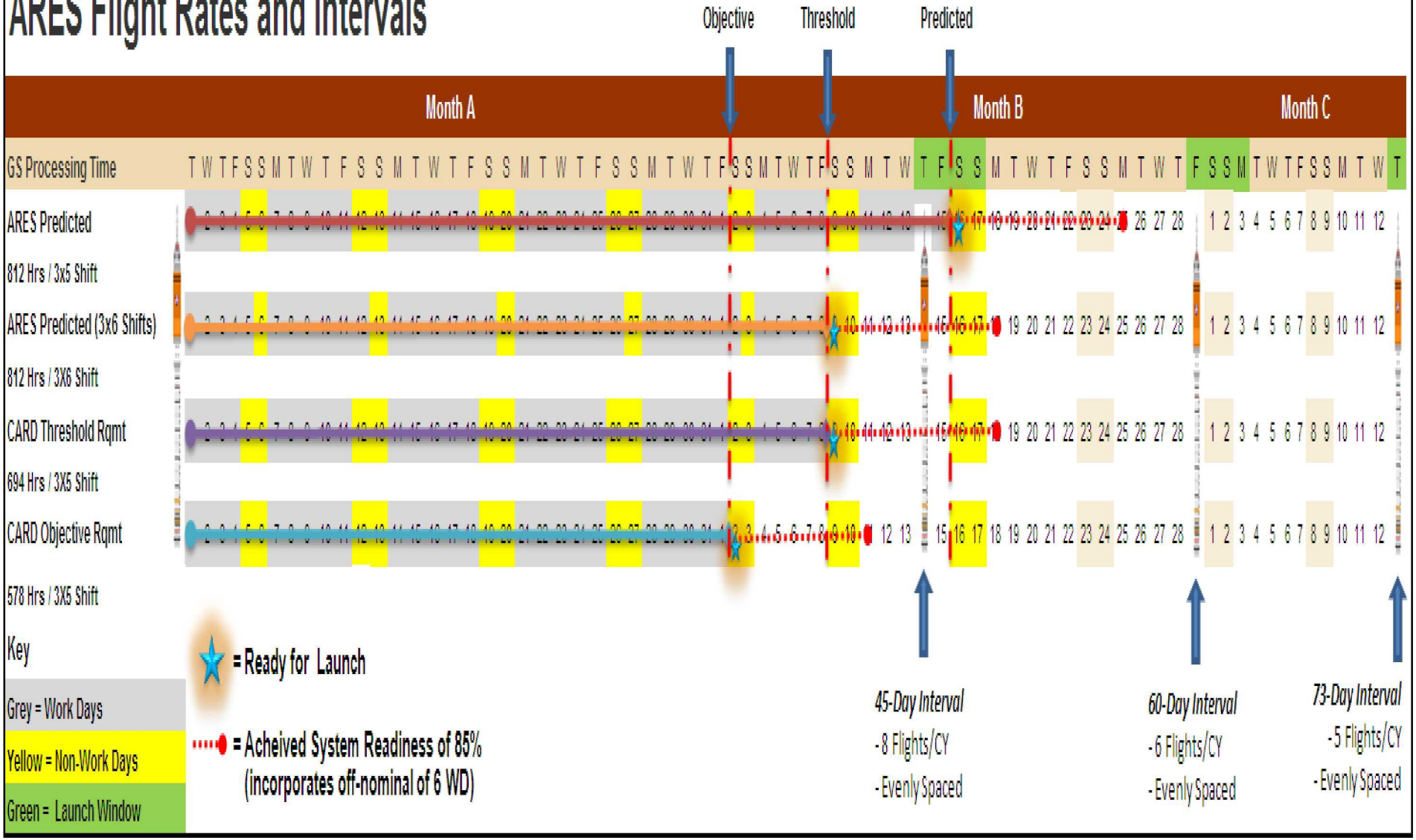
[R.US.214] Upper Stage Production Cost

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).

[R.J2X.124] J-2X Engine Production Cost

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).

ARES Flight Rates and Intervals



COOL Items

IRD Focus at SDR

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*

Now thru PDR

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

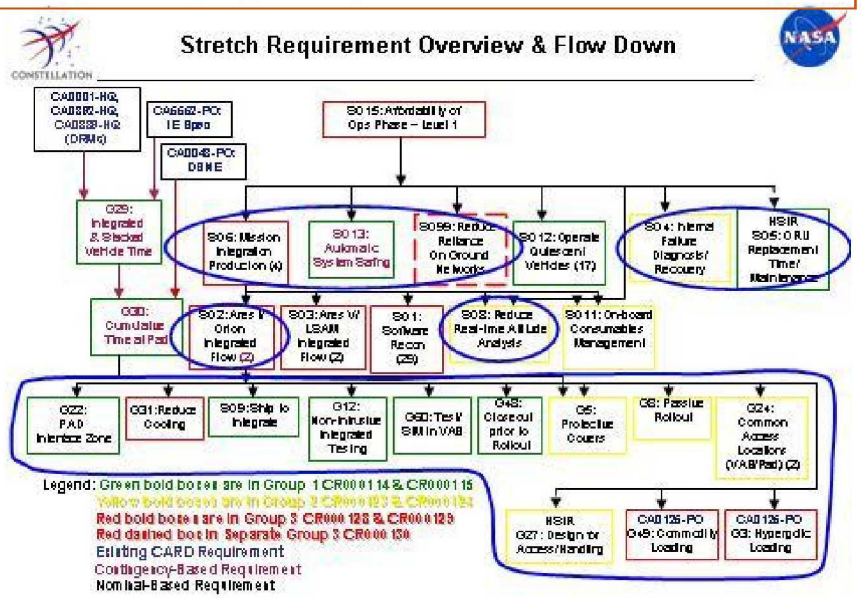
In process to name lead for remaining items

Now thru PDR

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