Healthy Tension:
The Mission & Technical Authorities

Ares I-X

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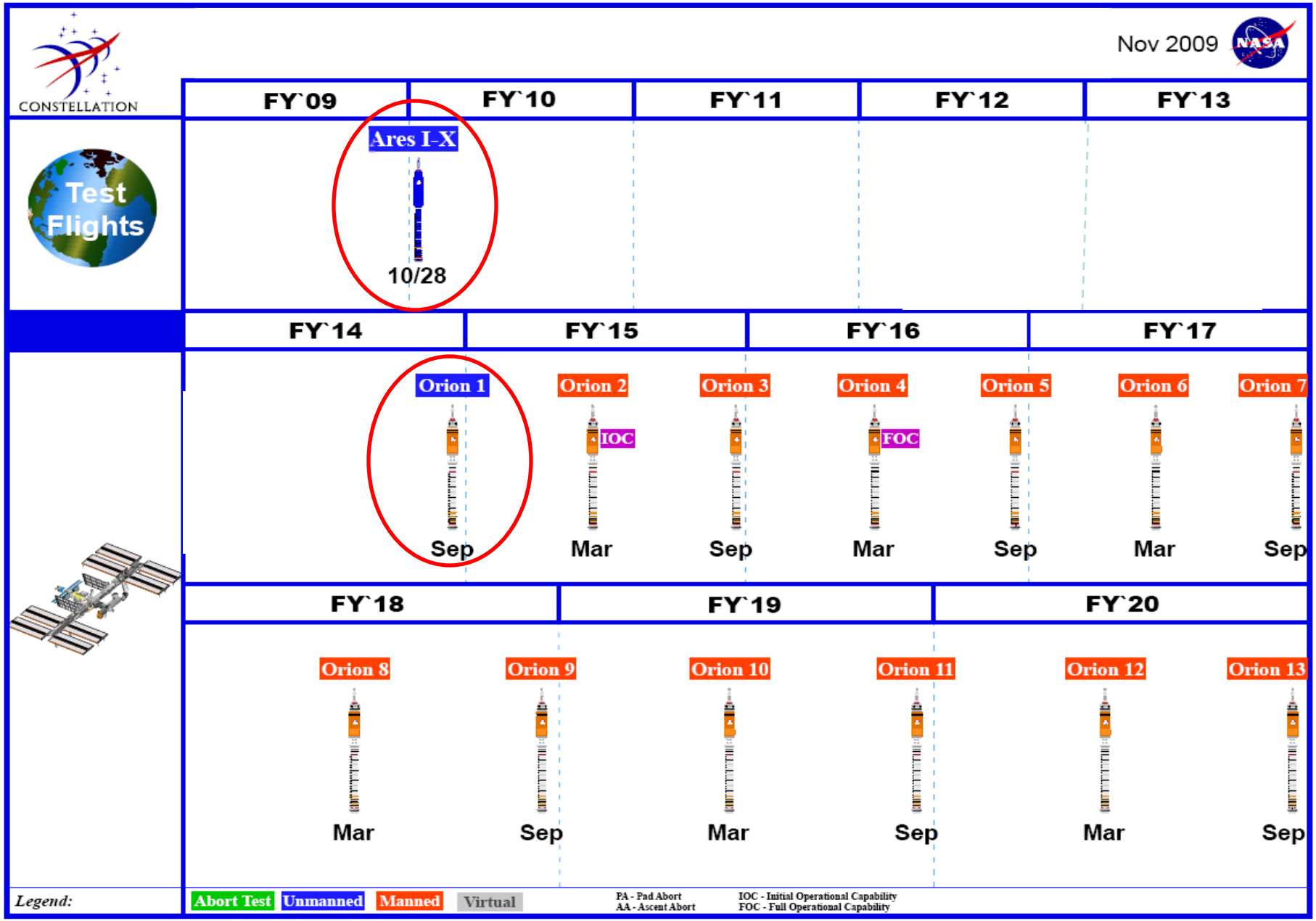
NASA 2010 PM Challenge
February 9-10, 2010

Used with Permission

Ares I-X Test Flight

- **Ares I-X was successfully launched from Kennedy Space Center's Launch Complex 39B on Oct 28, 2009**
  - First flight test for NASA's Constellation Program
  - Provided NASA an early opportunity to demonstrate the flight worthiness of a new launch vehicle class (Ares) while gathering data from over 700 onboard sensors
  - The strong desire for an "early" test flight relative to the Constellation Program's "mainline" launch vehicle (Ares I) life cycle necessitated an aggressive schedule for Ares I-X
  - "**Healthy tension**" between the Ares I-X Mission Management Office and the Ares I-X Technical Authorities was instrumental to the flight test's success

Ares I-X Test Flight's in relation to first flight of full-up Ares I



Based on Nov 4 2009 CxCB

Ares I-X Test Flight Background

- **Ares I-X was a Constellation Program-level managed test flight**
  - High-visibility
  - Relatively high-dollar (~$450 million dollar)
  - Aggressive schedule
    - get data early to help influence Ares I's development

- **Activity was spread across several NASA Centers**
  - GRC – Upper Stage Simulator
  - JSC – Constellation Program Management
  - KSC – Ground Systems and Ground Operations
  - LaRC – SE&I and Crew Module / Launch Abort System Simulator
  - MSFC – First Stage, Avionics, and Roll Control System

- **Successful implementation of a relatively large multi-Center activity with an aggressive schedule required strong teamwork and establishment of effective communication networks**
  - Among the Programmatic Authority and Technical Authorities
  - Internally within the Authorities communities
  - Externally to Customers and Stakeholders

Agency's Governance Model and establishment of Technical Authority

NPD 1000.0

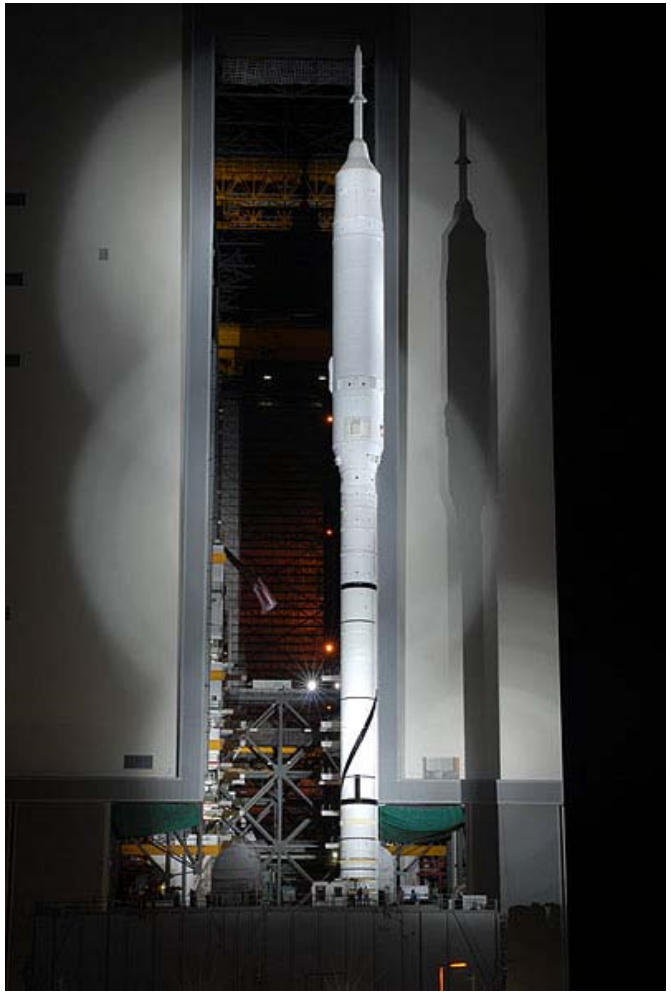
NASA Space Flight Program and Project Management Requirements

NPR 7120.5D
(Section 3.4)

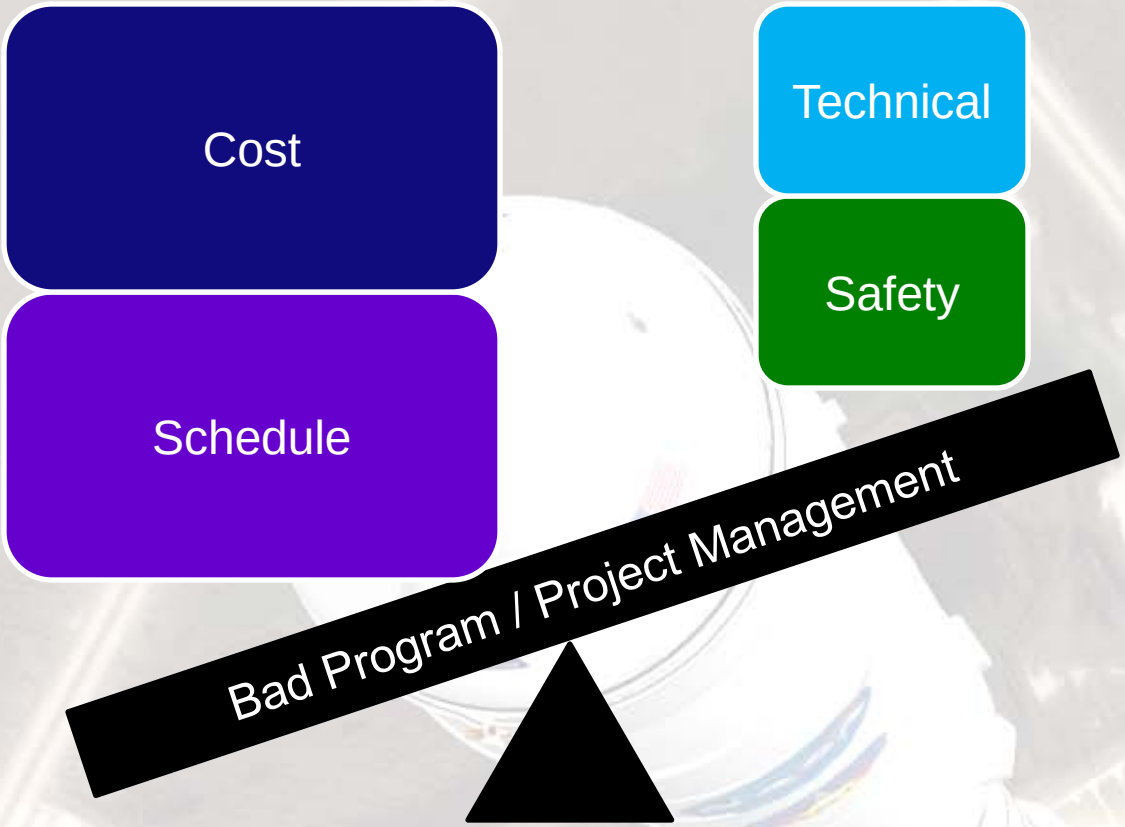
NASA Governance Model – Shared Authority

NPD 1000.0, "*NASA Strategic Management and Governance Handbook*"

- To provide a firm foundation for the **balance of power** between organizational elements via the separation of Programmatic and Institutional Authorities.
- To provides a management structure that employs **checks and balances** between key organizations to ensure that **decisions have the benefit of different points of view** and are not made in isolation.
- Enables the roles and responsibilities of both Programmatic and Technical Authorities to be wired into the basic organizational structure in a way that emphasizes their **shared goal of mission success**.
- Provides a means for handling **dissenting opinions**.

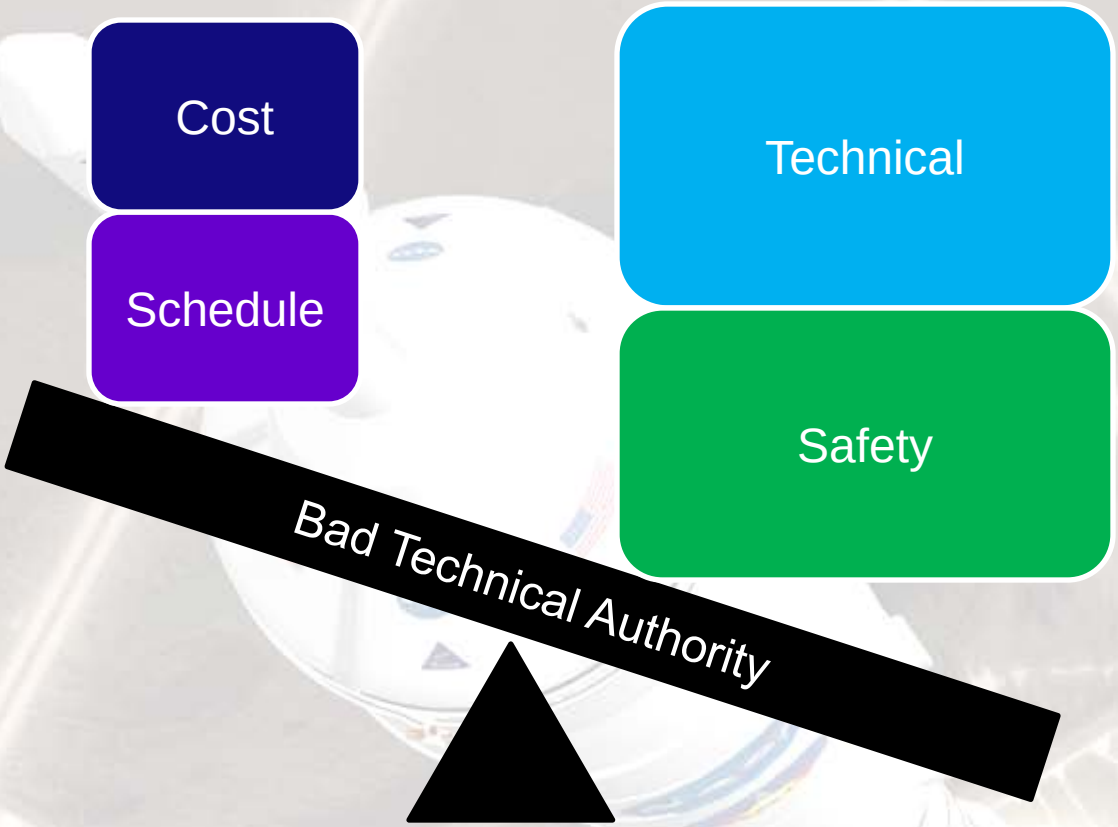


Goal of NASA Governance Model
"Finding the right balance"



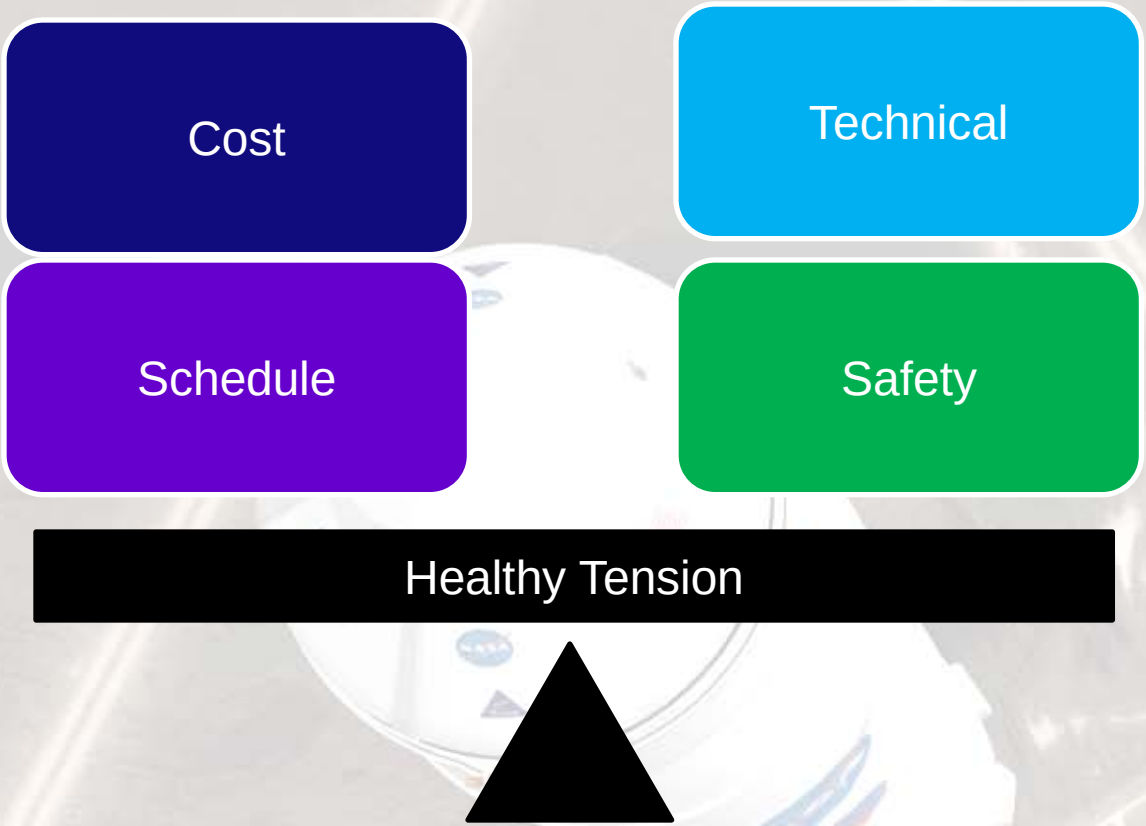
"*Schedules are essential tools that help large organizations effectively manage their resources. Aggressive schedules by themselves are often a sign of a healthy institution. However, other institutional goals, such as safety, sometimes compete with schedules, so the effects of schedule pressure in an organization must be closely monitored*." – **CAIB Report, Volume 1, Section 6.2**

Goal of NASA Governance Model
"Finding the right balance"



Over-emphasizing technical goals and trying to eliminate risk without consideration for cost and schedule constraints will likely lead to a program that never gets off the ground.

Goal of NASA Governance Model
"Finding the right balance"

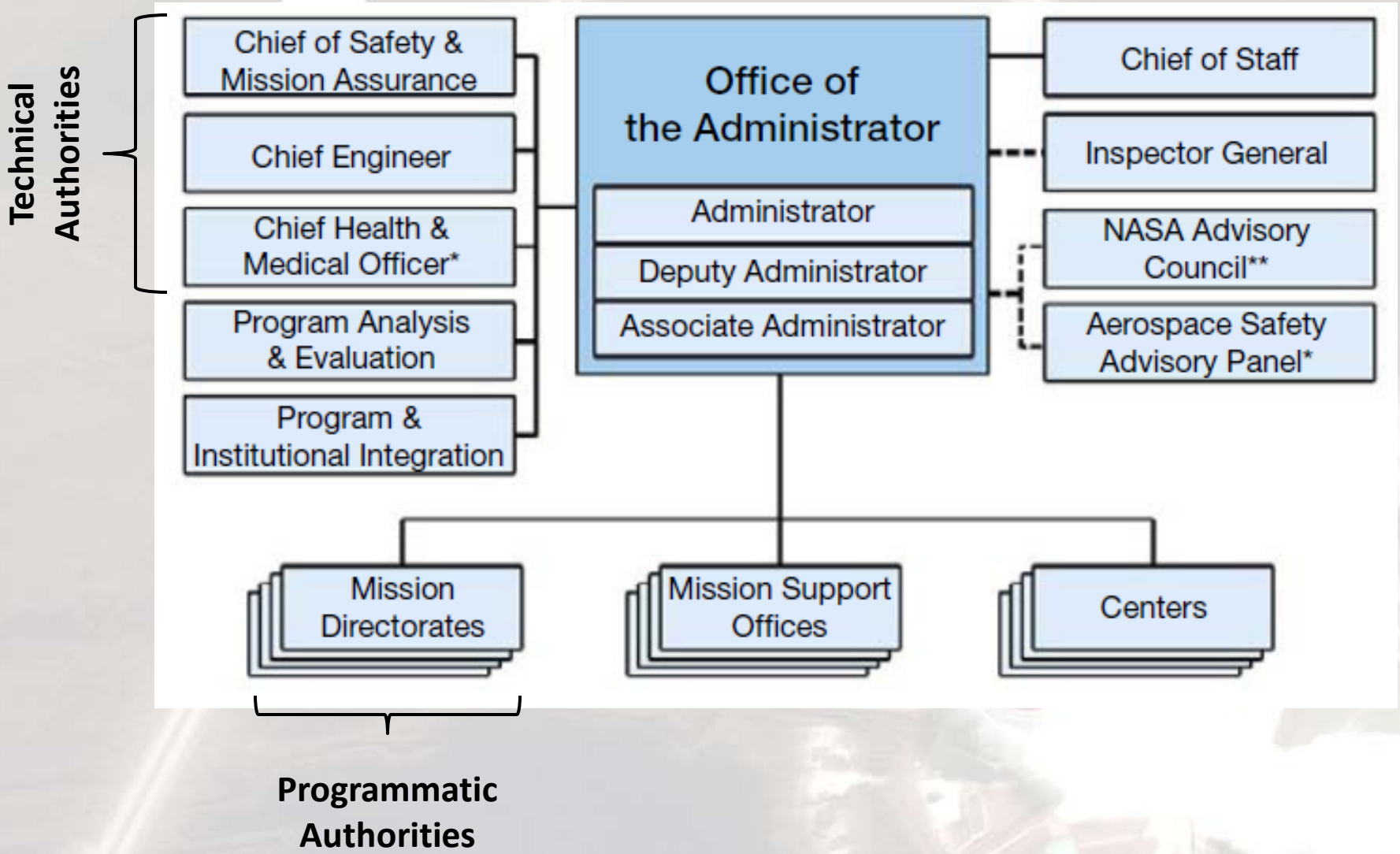


All Authorities are trying to achieve the same goal, a successful program. "Healthy Tension" between Program Management and the Technical Authorities is critical to mission success. Finding an appropriate balance (the "sweet spot") between cost and schedule constraints and an acceptable risk level is the key.

NASA Governance Model

Agency Organizational Structure

Illustration from NPD 1000.0A



Constellation Program

Program Manager
J. Hanley

Deputy Manager
L. (Dale) Thomas (MSFC)
JSC/ZA

Administrative Office
S. Castillo
JSC/ZA2

Lunar and Planetary Exploration Office
W. Mendell (M)
C. McKay (M-ARC)
JSC/ZA4/KA

Chief SMA Officer
J. Bye (M)
JSC/N 13

Chief Medical Officer
J. Davis (M)
JSC/SA

Chief Architect
B. Muirhead* (JPL)
Dep for Architecture: K. Joosten
Mgr for Tech Integration: A. Conde (M)
JSC/ZA3

Chief Engineer
S. Labbe (M)
JSC/E 3

Space Transportation
E. Mango (M)
J. Burnett (M)
KSC/M6

Ares I-X Mission Manager: B. Ess
S. Davis (MSFC)/J. Cowart (KSC)

Chief of Staff Technical: D. Neubek

Assistant Manager Integration: B. Ward

Special Assistant Integration: M. Ivins (M)

Chief of Staff Administration: S. Castillo*

Associate Program Manager for Lunar Formulation: K. Laurini
Special Assistant for Lunar Formulation: J. Rhatigan

Associate Program Manager KSC: Vacant

Associate Program Manager MSFC: S. Doering

Special Assistant for Operability: W. Arceneaux

Assistant for Strategic Communications: L. Madison (M)

Secretaries: K. Gabel, S. Vasquez

Program Planning & Control Office
C. Stegemoeller
K. Pollard
JSC/ZB

Operations & Test Integration Office
R. Castle
V. Wyche
L. Ham-Dep for Transition
JSC/ZD

Systems Engineering & Integration Office
L. Hansen
B. Laws
JSC/ZF

Safety, Reliability & Quality Assurance Office
C. Noriega
J. Williams
JSC/ZG

Information Systems Office
D. Monell (MSFC)
M. Digiuseppe
JSC/ZI

Orion Project
M. Geyer
M. Kirasich
JSC/ZV

Ares Projects
S. Cook
T. Vanhooser
MSFC/JP01

Ground Operations Project
P. Phillips
J. Kunz
KSC/LX

Mission Operations Project
J. Spivey
G. Bull
JSC/DA

EVA Systems Project
L. Kearney
R. Blanco
JSC/XA

Altair Project
K. Laurini*
C. Dorris
S. Doering* (A) (MSFC)

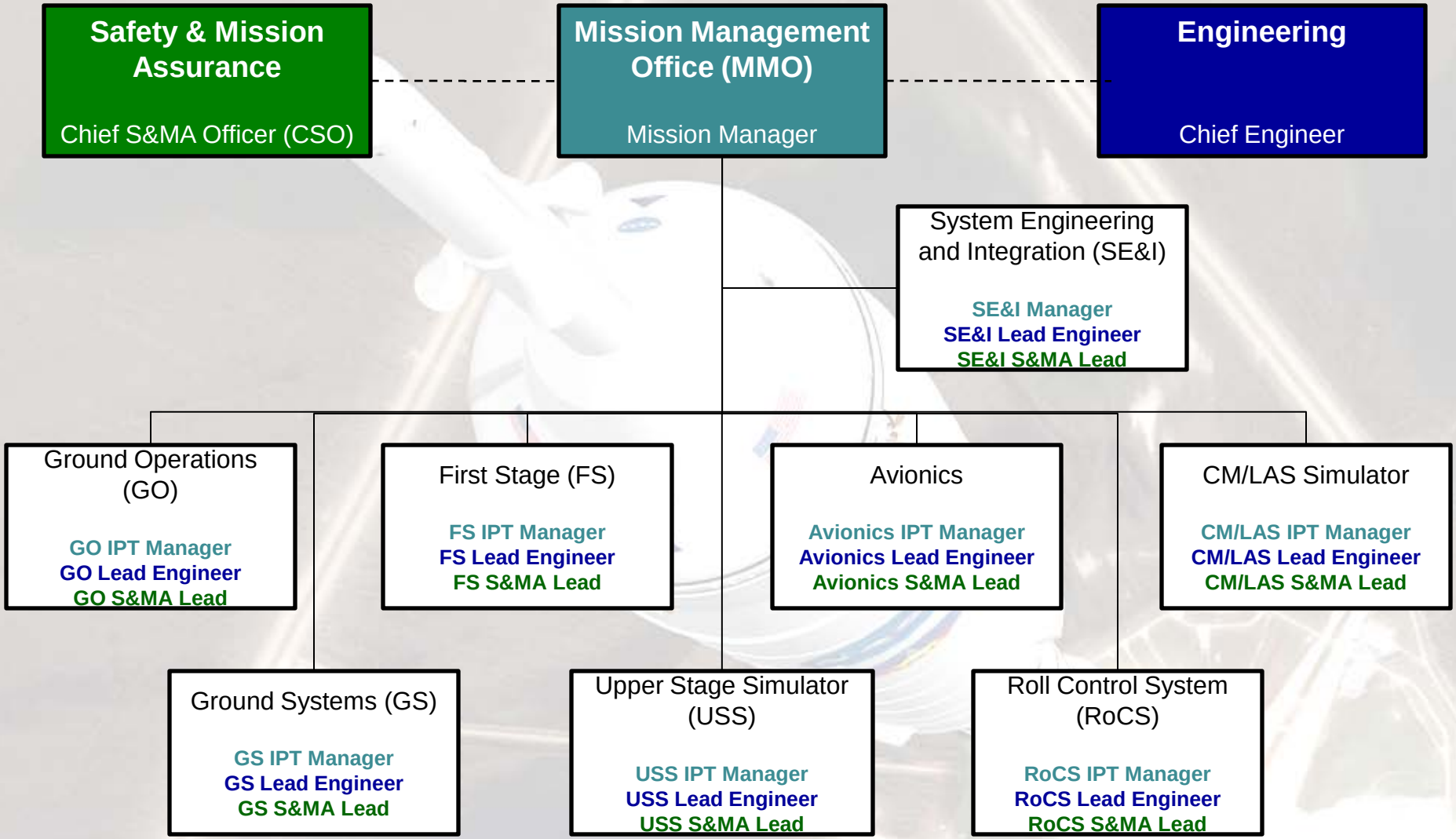
Lunar Surface Systems Project
C. Culbert (M)
M. Leonard
S. Vangen (KSC)
JSC/ZS

A- Acting
M – Matrix
—·—·— Pre-Project
* Dual Role

Jeffrey M. Hanley
Manager

6/19/09
Date

Ares I-X Organizational Structure



Programmatic and both Technical Authorities has leaders in each "box"

Implementation of Technical Authority on Ares I-X

- **Chief Engineer (CE) and Chief S&MA Officer (CSO) served as the primary representative of the Engineering and S&MA communities, respectively, to the programmatic authority**
- **Goal of the CE and CSO is to be a highly informed representative**
  - Influence overall technical direction via daily activities, participation in Board meetings, etc
  - Bring relevant information and different perspectives to the decision tables
  - Assure decisions are "risk informed" and result in acceptable levels of risk
  - Serve as the approval authority for deviations or waivers to OCE and/or OSMA owned Standards / requirements
  - Assure dissenting opinions have their "day in court"
  - Assure customers and stakeholders have awareness of risks
- **Connectivity of the CE and CSO to the broader Engineering and S&MA workforces, respectively, is critical to properly representing these communities**
- **Multi-Center cooperation and the associated communication flows were keys to Ares I-X success.**
  - Ares I-X team operated with a "One NASA" mindset.
  - Historical barriers that can be associated with "Centers" and "Levels" were broken down.
  - Information flow within and across communities was very good.

Implementation of Technical Authority on Ares I-X
- Information Flow and Meeting environment -

- **Mission Management Office (MMO) and Technical Authorities (TA's) established forums to promote information flow**
  - **MMO Weekly Tag-up's**
    - MMO, IPT Managers, and TA's
    - Routine communication of accomplishments, upcoming events, issues/concerns
  - **CE and CSO led Weekly Tag-ups**
    - CE led weekly Engineering leadership tag-ups
    - CSO led weekly S&MA leadership tag-ups
    - Meetings often focused on identification of issues/concerns and formulation of TA positions / recommendations (see next slide for mechanisms)
  - **Ares I-X Board meetings**
    - Often included "frank, spirited" discussions. Participants were "actively engaged"
    - Different perspectives were shared and generally respected….even if we chose to disagree
  - **TA's issues / concerns and recommendations were routinely communicated to Mission Management as well as customers and stakeholders**
    - Monthly Multi-Center (or integrated) Center Management Council (ICMC)
    - Constellation Program's top Control Board (CxCB)
    - Milestone Reviews (e.g., CDR's, Pre-ship Reviews, Acceptance Reviews, Mate Reviews, Flight Test Readiness Reviews, etc…)
    - **TA's perspective and recommendations was a standing item on Meeting Agendas**

EXAMPLE of S&MA communication mechanisms

SE&I S&MA Summary

News	Near Term Schedule (60 Day Outlook)
◆ Continuing to update IHRs, VTL and action items ◆ Supported Launch Team TIM and KSC Tng (13 -14 Jan) ◆ HAWG Team provided an outbrief to the GO/GS First Stage Process Surge Facility ◆ Supported the AV (ground) a ◆ Supported LC ◆ Helfrich atten ◆ Supporting th (Johnson, Jan	◆ HAWG will support Phase II hazard analysis forward work for the GO/GS Pad B Processing to T-0, GO/GS HB 1/3 Integration and Pad Transport, and FS Recovery Hazards

Issue Title
Thrust Oscillation
Recovery Hazard Analysis
Safety Risk Score standardization
Roll-out Stabilization
Buffet Loads

Avionics IPT S&MA Summary

News	Near Term Schedule (60 Day Outlook)	
◆ RRGU Delta-Qual Honeywell Successful ◆ CSERP Phase III Complete for Ground Hazards • Actions and agreements to be worked by 1/30 ◆ FSAM Pre-ship Brief to XCB ◆ FSAM Pre-ship Review	◆ Sequencing TIM at LM Denver ◆ FSAM on Dock at Astrotech (ASO) ◆ Avionics Flight Hazards Phase III ◆ Av System Acceptance Review/DCR	2/3 – 2/4 2/16 3/23 – 3/27 4/20

Top SR&QA Concerns / Risks / Issues (Continued)

Issue Title	Brief Description	Go-Forward Plan	Concur?
NSI Connectors	Shuttle connectors failed during ATK NSI Qual testing	Down selection testing occurred Nov. 12. Avionics pursuing a joint Qual test with FS. Engineering is working on the procedure. Discussed at SERF 1/28/09	Y
DFI			
5HP Non Conformance And Vendor Quality	Both the primary and backup probes are in question for non conforming issues that have not been addressed or documented	S&MA is currently researching the process by which Aeroprobe became a supplier for the 5HP. Currently LM only allows Aeroprobe to provide the 5HP. Aeroprobe is not on LM approved Vendor List.	N
DFI Single Point Failures	Mandatory DFI has single point failures	Mandatory sensors have been identified and spares will be procured based on this identification, so they can be replaced on the ground in the event of pre-launch failure. The 5 hole probe and the TAT contain redundant sensors within. This redundancy was provided due to the importance of these measurements and the difficulty in changing them out in the event they failed.	Y

Green: Planned resolution is mature and acceptable | Yellow: Resolution plan is immature | Red: Resolution does not exist or is unacceptable

S&MA Team inputs feed into overall S&MA Health Status reported monthly to customers and stake holders.

Ares I-X S&MA Health Snapshot

Product / Activity	Health	Comments
SR&QA Plan	X	AIX SR&QA Plan (AI1-PLN-SRQA) baselined at XCB
Hazard Analyses Reports & CSERP status	X	Hazard Analyses and Reports on target for planned CSERPs – see attached HA & CSERP charts
Hazard Controls - verification status	X	Safety Verifications are being closed, but potential for late closures exits
Limited Life Items within allowed life	X	- All IPT S&MA's reporting that age sensitive items (e.g., pyro's) within life - Only known concern is a paperwork issue - potential disagreement on need for a waiver for out-of-cert life SSP RSRM. (Note: All parties agree flight rationale exist)
ALERTS	X	All IPT S&MA reporting ALERTs closed with no impacts identified to date
Design Verification	X	-Significant number of open design verifications, especially environmental qualification, exist late in the life cycle (i.e., h/w has already been manufactured, shipped, and being assembled) - High likelihood that additional waivers/risk acceptance will be required - Known FS TVC and FTS environmental non-compliances exists w/out agreed to flight rationale - Key issues summarized in back-up charts
Hardware Acceptance	X	-Acceptance Reviews continue to slip to right - Delta-reviews/tag-ups have been required for all AR's held to date (USS, CM/LAS, FS HAR-1) due to open issues and open paper -Atlas Bus Coupler failure indicts acceptability of Ares I-X Bus Couplers – root cause not well defined yet , acceptable path forward / flight rationale does not exist
LCC's incorporate any applicable HR derived requirements	X	Workforce limitations/priorities have somewhat limited ability to assure all identified HR LCC controls are satisfactorily incorporated into LCC's. - will shift emphasis to LCC's in near future
Schedule	X	+Mission has continuously chosen to "proceed at programmatic risk" with design, manufacturing and shipments, often occurring with known design/qualification open/unresolved issues (e.g., environments have continuously evolved (often with increases) throughout the mission's life cycle + Activities/reviews are occurring in parallel, compounded by I-X having a very lean workforce • Opportunity for misses/oversights is very real

Ares I-X S&MA CoFTR Status

CoFTR S&MA Req't	CoFTR Endorsement Statement	Concur	Comments	Exceptions / Constraints
Limited Life Items	Concur that any limited life items are within time, cycle, and age life (or appropriate waivers have been approved)	Yes	All IPT S&MA Leads reporting that age sensitive items (e.g., pyro's) are within certified life with the exception of: •RoCS pyros – AIX waiver approved •RSRM-91A motor segments and RSRM-90A AEC will exceed certified life (5 years) at flight •ATK Waiver approved •All parties agree that flight rationale exists. Witness panel testing underway to enhance waiver rationale. **Comment:** Avionics batteries schedule risk: •MVB Batteries - 11/23/09 •Pyro Batteries- 12/03/09 (LM has indicated a lack of a quick turn-around time ability for Pyro batteries)	None
Hardware & Software Acceptance	Concur that hardware and software conforms to released engineering and that any departures have been documented in the applicable nonconformance reporting system (e.g., Cx PRACA)	Yes	**Hardware:** AIX S&MA (including DCMA), insight into h/w processing via inspections, surveillance, and h/w acceptance activities yields high-confidence that the as-built is consistent with the as-designed h/w and any departures have been documented on non-conformances. **Software:** Ares I-X Software Assurance and Aerospace IV&V has confirmed that software is ready for flight	None
	2. Concur that all non-conformances have been satisfactorily dispositioned in accordance with Ares I-X SR&QA Requirement	No	Nonconformance's remain open, but significant progress has been made closing nonconformance's •GO and Flight IPT's are tracking open nonconformances closely •Anticipate ability to confirm that nonconformances have been dispositioned and any required work has been performed • **No "show-stoppers" have been identified during review of open nonconformances**	1. GO and FS and Avionics IPT's to confirm disposition and any required work complete on open nonconformances. These items are being tracked in GO Constraint system. 2. Avionics IPT confirm disposition and work complete on open LM Q-Notes
	3. Concur that Government Mandatory Inspection Points (GMIPs) have been completed	Yes	All IPT's reporting satisfactory implementation of GMIP's	None
	4. Concur that any manufacturing audit/surveillance findings have been satisfactorily closed	Yes	All IPT's reporting closure of audit/surveillance findings	None
	5. Deviations/Waivers - have reviewed and concur with any deviations or waivers	Yes	All AIX waivers have been approved	None

All inputs eventually feed into the S&MA CoFTR Endorsement

EXAMPLE of CE communication mechanisms

Waiver Number	Waiver Title	Schedule	Requirement	Brief Description	Technical Rationale
AIX-260	DFI ESD Handling Controls AIX-260	[illegible]	CPW1-3826, Rev C, 3.5.1.10.3 FS-051	The installation of DFI Avionics without ESD protection could result in instrument failure.	Waiver: ES guidance is that current controls satisfy requirements and no requirements are violated. Waiver in work
Potential-36	CEC OPT envir exceedence d thrust oscillatio				
RWW2001	RSRM Center Segment CFE RWW2001				
RWW2004	Nozzle LSC Ga Levels Exceed RWW2004				
RWW2005	RSRM Age Lif RWW2005				
RWW2029	Connector crin DFI				

Ares I-X RoCS IPT Lead Engineer Summary

Key Decisions / Milestones / Activities	60 Day Outlook
♦ Fit checks completed at KSC ♦ Through Bulkhead Initiator bomb tests performed at ATK – no anomalies yet uncovered ♦ Acceptance review data dropped 2/19	♦Acceptance Review – 3/10 ♦Loading of consumables – 3/12? ♦Begin final integration to Interstage – 3/26? ♦Vibe testing – 2/27-3/21 ♦Cold flow / Initiation / Check Valve Interaction Test – 3/?

Product Status				
Waivers (total: 0)	3			
Deviations (total: 6)	6			
Verification Status	42			
☐ In work (not ready for IPT approval)	42			
☐ Ready for IPT approval	33			
☐ Ready for XCB approval	0			
☐ Closed (at IPT Level, including institutional engineering)	0			
☐ Closed (at XCB Level)	0			
Material Review Board Status	12			
☐ # Nonconformances	6			
☐ # Use as is	5			
☐ Scrap or Return to Print	1			

Top Lead Engineer Concerns / Issues

- ♦ Cannot complete verification prior to scheduled dates for acceptance orloading of consumables
  - Vibration tests to occur after acceptance review
  - Pyro assays to occur after acceptance review
  - Initiation / cold flow / initiation test to occur after review
  - Also need time for test data review
- ♦ Peacekeeper pyro valve ordnance is roughly 10 years passed its original design life of 10 years
  - Through Bulkhead Initiator (TBI) acceptance data not found
  - Life Extension data for booster cartridges does not exist
  - Bomb tested 10 TBIs from each of the two "lots" used for flight
  - Planning to chemically assay a booster cartridge from lots used for flight (3 types/lots of booster cartridges)
  - Will functionally test two of each type of pyro valves utilized by RoCS (3 types) using the same lots of TBIs and booster cartridges used for flight
- ♦ Fairing redesign appears necessary; analysis ongoing
  - Some combination of stiffening and/or more fasteners and/or stronger fasteners.
  - Notionally planning to do both
  - Four new vertical ribs are likely to be riveted in the large flat section of the panel
  - Fairings shipped without flight torqueing fasteners or sealant to allow removal / rework

Green: Products will be delivered on schedule and will be at the appropriate level of maturity. | Yellow: Product delivery or maturity is behind schedule but is recoverable within the IPT. | Red: Product delivery or maturity is not achievable within the IPT's schedule or without help from outside the IPT.

Lead Engineer Team inputs feed into overall CE Health Status reported monthly to customers and stake holders.

Ares I-X Engineering Scorecard/July '09

Technical	Schedule	Sub-System	Comments
🔴	🔴	Overall Assessment	Launch October 31 (including 14 day Mission Manager reserve; team working to October 17 launch), inadequate time to complete required reviews, incomplete ADP, hardware is at KSC and being processed prior to acceptance and verification, many waivers still to be processed and approved
🔴	🔴	SE&I	System verifications slip to the right pending closure of IPT verifications; Tiger Team assessments of loads for SDB v6.0 leading to changes in liftoff and ascent loads, unknown results from IPTs especially FS – TVC and FTS; Modal Test I preliminary results indicate coupling of FSAM with Motor; DFI Configuration 2 test stopped before completion (including mandatory sensors - 5 hole probe and air vanes – plan is to return to complete (if time allows); Possible loss of video cameras due to problems with 1) single point ground and 2) noise from the cameras and video power units. ; Possible loss of cooling fans for USS mounted flight control hardware due to EMI issue.
🔴	🔴	Avionics	Salt fog requirements; 1553 bus coupler issue; connector pin recession issue (final report due 7/31/09); still assessing environments/loads; 25 nonconformances in work, 5 waivers being processed
🟢	🟢	Roll Control System	All verifications are complete; MRB review of of vib and cold flow test nonconformances – need to ask Patton about status
🔴	🔴	First Stage	Hardware being processed (booster stacked on MLP) – working with tiger team on loads and negative margins; FTS exceedances ;(pursuing delta qual testing for battery and CRD); Numerous potential waivers and exceedances on hardware not approved; TVC exceedances; 1553 bus coupler; recessed pin on connectors; no verifications approved (15 submitted for XCB approval); First Stage EAR slipping
🟡	🔴	Upper Stage Simulator	Waivers have been approved; Options for addressing negative margins are still being assessed (negative margins on secondary structures – ECS duct, platforms, protuberances) – update per 7/24 ERB
🟢	🟢	Crew Module/Launch Abort System	CM/LAS mounted mandatory sensor fastener assessment pending receipt of avionics IPT analyses – Check with Andrew Panetta or Troy Mann on this
🟡	🟢	Ground Systems	Adding dynamic testing of VSS; Concern is drift analysis effects on FSS if liftoff placards changed.
🟡	🟡	Ground Operations	DFI configuration 3 channelization test underway; WAD approval holding up work

Ares I-X CE CoFTR Status

Item	CoFTR Responsibility	Endorsement Statement	Yes/No	Exceptions	Comments
a.	System and Element Requirement Verification	Did the CE review and concur with all System Requirement Document (SRD) including Ground Systems Requirements Document (GSRD) verification closure rationale?	NO	1. The CE's position is that there is an insufficient number of System VRDS' complete for this stage of the mission. 2. System level verifications - Only 49/132 approve thru XCB, 29/132 submitted for XCB review & 54/132 unsubmitted for review. 3. The mission has prioritized the System VRDS burndown list but the CE was not involved in the process. 4. See CoFTR Exception for System VRDS **Closure of verifications prior to flight with adequate technical review**	1. *The CE has reviewed and is in agreement with all of the IPT VRDs that have been submitted for closure.*
b.	Unexplained Anomalies (UAs) and relevant In-Flight Anomalies (IFAs) of heritage hardware used for Ares I-X have been reviewed, dispositioned, and approved at the XCB (First Stage, Roll Control System, Avionics, and Ground Systems IPTs only)	Did the CE obtain concurrence from engineering or review and concur with the Prime Contractors' UA/IFA assessments and conclude that there are no UA/IFAs significant enough to delay flight or ensure appropriate action was taken to address UA/IFAs?	YES		1. RoCS comment - PK did not use UA or IFA nomenclature. An observed tendency of the engine valve to stall was corrected for Ares I-X by a fuel assist modification. 2. Spare APUC repair plan was developed without complete root cause analysis. Plan was successfully implemented.
c.	Software Verification	Did the CE obtain concurrence from engineering or review and concur with all software requirement verification closure rationale?	YES	None	1. CE participated in the review of software verification closure at IPT and system level.
d.	IPT Acceptance Data Packages (ADP)	Did the CE obtain concurrence from engineering or review of the IPT ADP or Ground Ops/Systems equivalent?	YES	None	1. *The CE and secured independent reviewers participated in the review of IPT and SE&I ADPs.* 2. *The RoCS, CM/LAS, USS & FS IPT LEs have certified that their respective IPT ADPs are complete*
		Have all open CE issues with the ADP or Ground Ops/Systems equivalent been properly closed?	YES	None	1. *Open Work items from First Stage and Avionics Acceptance Reviews are in work but are being close-looped tracked.* **CLOSED**

All inputs eventually feed into the CE CoFTR Endorsement

Identifying, Communicating, and Managing Ares I-X Risks

- **A key TA objective was to make sure that risks were being systematically identified, characterized and mitigated…and that decisions were "risk informed"**
- **Risk assessment activities included:**
  - Fault Tree-driven Hazard Analyses
  - Use of "Cx IRMA" Continuous Risk Management tool
  - Risk assessments of all waivers
- **Risk discussions were often "spirited" and they forced participants to discuss the potential consequences and technically justify likelihood characterizations**
  - Biggest RM challenge - use of CxIRMA system
  - (Too) often disagreement on how to capture and characterize CxIRMA risks – *discussed in next chart*
- **TA community desires for additional data to characterize risk levels forced certain activities that not all parties thought necessary. Examples included:**
  - First Stage motor age life – (*e.g., witness panel testing*)
  - RoCS Pyro Valves – (*e.g., pyro age life testing*)

Hazard Analyses risk roll-up

Ares I-X Hazard Cause Distribution

LIKELIHOOD \ SEVERITY	NEGLIGIBLE	MINOR	MARGINAL	CRITICAL	CATASTROPHIC
VERY HIGH					
HIGH					
MODERATE					1
LOW	1	44		21	980
VERY LOW	4	6	16	49	"1000's"

Cx IRMA Example

Risk Title: First Stage Nose-First Re-Entry
Escalation Level: TPrgIR
Cost Level: 0
Cost Threat Escalation: None
Phase(s): IOC

Owning WBS Element: ARES_I_X
Risk Owner: Christopher Calfee

Risk Statement:
Given the current FS (First Stage) mass properties and given environments; there is a possibility that the FS may re-enter nose-first resulting in loss of the FS and Data recorder.

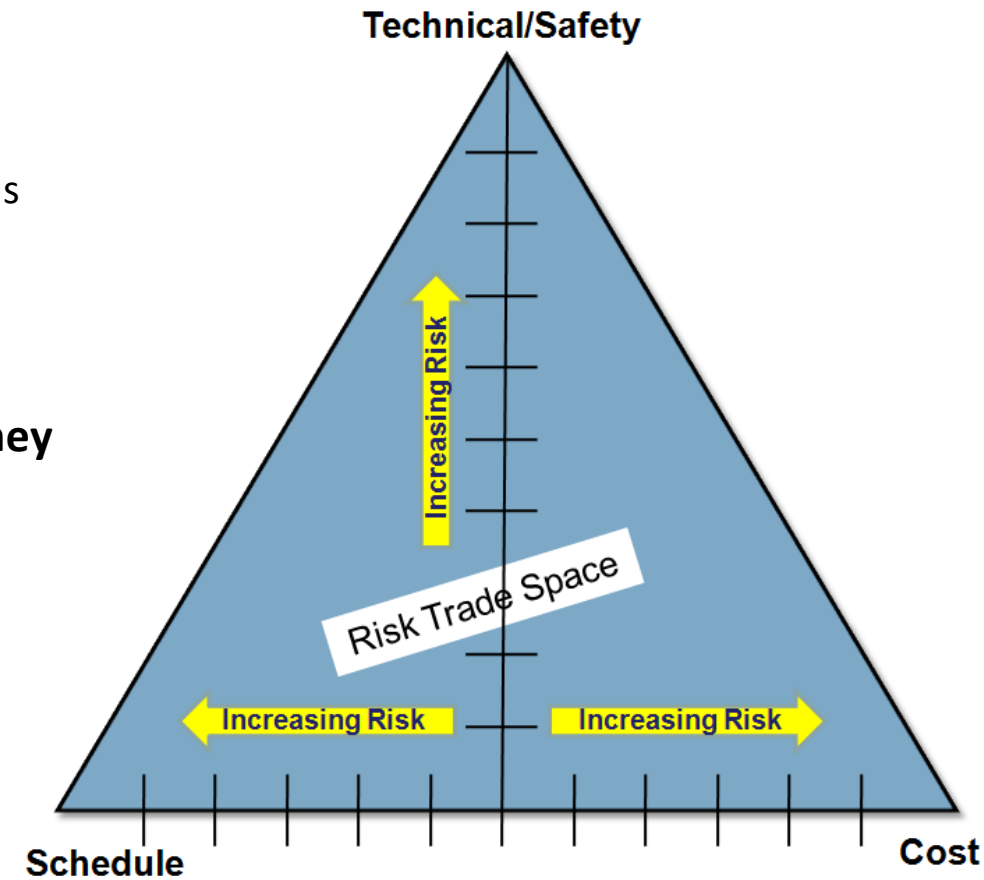
Context:
Current analysis shows that the First Stage may experience nose-first lock-up during re-entry. If nose-first re-entry occurs, it is predicted that the nose cap and/or thrusters will fail due to excessive loading. Heritage nose cap & thruster hardware was selected for the Ares I-X recovery system to facilitate the schedule and it was assumed Shuttle re-entry loads / environments would envelope Ares I-X conditions. The re-entry attitude is highly dependent upon stage CG, ascent trajectories, free stream aero, and wake interference aero. The loss would be failure to meet a primary objective (booster recovery).

Likelihood: 4 **Safe:** 4 **Perf:** 4 **Sched:** 0 **Cost:** 0

Status:
9/29/2009 XCB recommends acceptance. Better Mass and Aero data provided better information for Monte Carlo estimates. The new estimates yield 3% nose first lockup as opposed to the 9% estimates from April 2009. The 3% estimate has been confirmed by independent analysis from Aerocorp and SE&I. Refer to XCB presentaion dated 9/29/2009.

"Notional" Risk Trade Space

- **Risks and their mitigations often have schedule, cost, and technical/safety components.**
  - Risk statements and risk characterizations should accommodate these potential outcomes.
- **Too often, Ares I-X CxIRMA risk statements stated or suggested that they only potential consequences were schedule or cost growth.**
  - Justified by statements such as "if in the end its not "safe", we won't fly it"
  - Actions to mitigate schedule risks, can increase cost risk and/or technical risk postures - *these potential implications need to be captured*



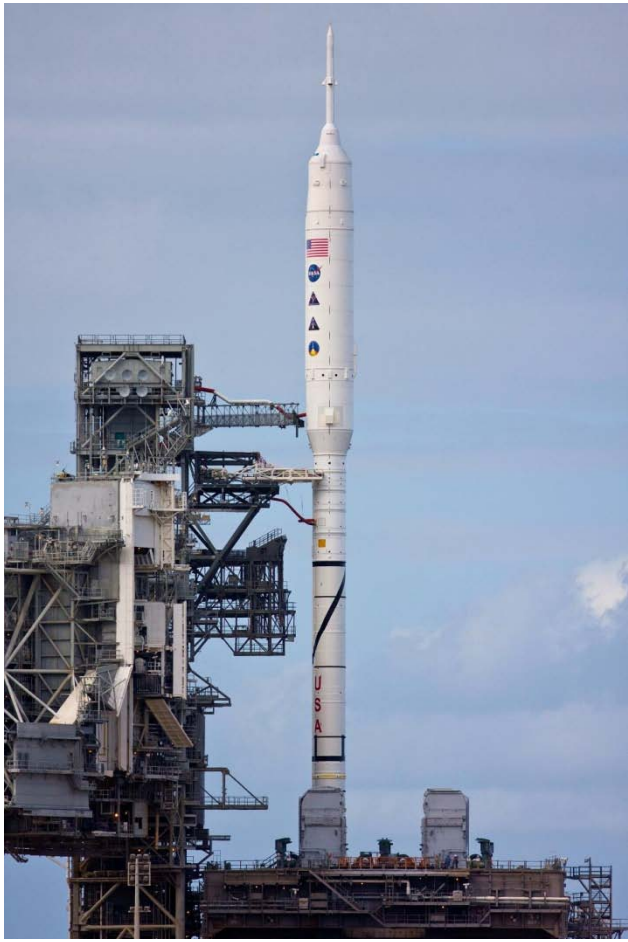
Writing risks statements and identifying and characterizing the various risk sub-components is not a simple task…but is essential to "good" risk management

Examples of some issues with different resolution paths

1. **Thrust Vector Control (TVC) "Hot-fire" Test at the Pad**
   - Issue resolved within Ares I-X Team

2. **Post-installation testing of avionics harnesses**
   - Issue elevated to Constellation Program's Control Board (CxCB)

3. **First Stage IPT's application of Aluminum Tape to avionic harnesses**
   - Dissenting opinion that was discussed at Ares I-X and CxP levels and eventually elevated up to the Agency's Flight Test Readiness Control Board (FTRRB)

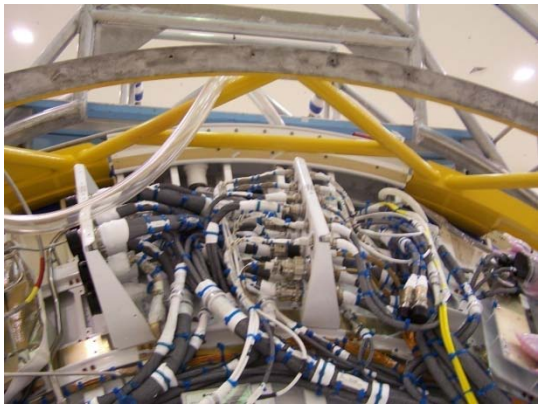


Example 1
Thrust Vector Control (TVC) Hot-fire Test at the Pad

- **Ares I-X used "heritage" systems to facilitate an expedited deployment**
  - A Space Shuttle Reusable Solid Rocket Motor and its associated Thrust Vector Control system used for First Stage
  - Atlas V avionics and modified Atlas V software used for vehicle control
  - The ability of the Atlas V-based avionics system to seamlessly control the SSP based TVC system was critical
  - Ares I-X would be the first launch of such a hybrid vehicle
- **The TVC system would be hot-fire tested prior to delivery to the VAB**
  - SSP test support equipment to control this test
- **The Avionics system would be subjected to end-to-end testing in the VAB**
  - TVC Hot-fire testing could not be performed inside the VAB for safety reasons
- **Only opportunity to perform an integrated test would be at the launch Pad**
  - Ares I-X MMO had goal to demonstrate ability to fly with minimal Pad stay time and thought that subsystem tests were sufficient
- **TA's strongly recommended a hot-fire test at the Pad to increase confidence that an Atlas-based avionics system was properly integrated Space Shuttle Thrust Vector System**
  - TA recommendation was eventually adopted by the Mission Manager

Example 2
Post-Installation testing of installed harness

- **Ares I-X accelerated development schedule hinged on the use of "existing or heritage" hardware and processes**
  - Avionics IPT contracted with Jacobs / Lockheed Martin (LM)
    - Embedded in the contract was plan to use existing Atlas based h/w and processes
  - First Stage contractor was Space Shuttle RSRB contractor team of ATK and USA
    - Embedded in the contract was plan to use existing SSP based h/w and processes
  - LM's Atlas workmanship Standards did not require DWV (Hi-Pot) testing of harnesses following installation
    - Atlas had eliminated post-installation years ago due to low perceived risk based on their process controls and experience
  - SSP RSRB was required to meet NASA Workmanship Standards which required DWV testing following installation
- **This disconnect between these two Standards was not realized until relatively late in the Ares I-X flow**



Example 2 (Cont'd)
Post-Installation testing of installed harness

- **Issue was first realized during First Stage IPT's installation of Avionics IPT supplied harness.**
  - The disconnect between governing workmanship standards, delays in harness deliveries and MMO's strong desire to prevent schedule growth led to a series of debates associated with this issue.
- **Following identification of the post-installation testing disconnect, the MMO created a Tiger Team to assess the situation and provide a go-forward plan.**
  - On Thursday, March 5, the Tiger Team recommended performing the full suite of DWV testing on a subset of FS Aft Skirt harnesses, those with the most-complex runs.
  - The Mission Manager accepted the Tiger Team's recommendation and issued a directive to implement it.
  - The TA's disagreed with this direction and elevated this issue to the Constellation Control Board (CxCB).
  - On Thursday, March 19, the CxCB reversed the XCB decision, directing the post-installation testing of the contested cables.

Example 2 (Cont'd)
Post-Installation testing of installed harness

- **The issue did not end with the March 19th CxCB decision.**
  - Further problems and delays in getting the test equipment operating properly and completing installations and testing.
- **The Mission Manager decided to re-visit the situation.**
  - In summary, the Mission Manager was convinced that the more complex vehicle installation runs had been completed and future post-installation testing would be low value.
- **On April 15, the CxCB heard presentations from the Mission Manager and the Ares I-X Chief Engineer on the benefits and risks associated with testing the remaining harnesses.**
  - After discussion, the Program Manager concurred with the Mission Manager's decision to cancel any remaining testing. He was satisfied that the highest risk areas had been tested, and acknowledged that there was some increase in risk and that he was willing to accept this additional risk.
- **The Technical Authorities were satisfied the residual risks had been accurately portrayed and formally accepted the Program Manager's decision.**

Example 3 – First Stage IPT application of Aluminum Tape on Avionics IPT's harnesses

- **First Stage (FS) IPT application of Aluminum Tape on Avionics IPT's harnesses**
  - During installation of Avionics IPT harness, the First Stage IPT's contractor wrapped the harnesses with Aluminum Tape for protection, a practice that was consistent with its heritage Space Shuttle RSRB process.
  - Lockheed-Martin (LM), Avionics IPT contractor, expressed electrostatic discharge (ESD's) concern with the resultant configuration.

- **Issue was studied and debated within Ares I-X**
  - MSFC Engineering and Aerospace assessments were performed and presented to the Ares I-X Control Board (XCB). Both assessments concluded that any risk associated with the tape was low.
  - The MMO and TA's agreed that while the use of Aluminum tape was unfortunate, the resultant risk was acceptable and outweighed the potential collateral damage risk associated with removing tape.
  - Lockheed Martin disagreed with the XCB decisions
    - LM's dissenting opinion was respectfully elevated up all the way the Agency Flight Test Readiness Review (FTRR).
  - FTRR Board agreed that resultant risk was acceptable for flight.

Some Key Lessons Learned from Ares I-X

- **Establish processes that promote information flow within and across communities**
- **Eliminate or minimize barriers that can inhibit information flow (e.g., "Center-centric" or "Levels" mentalities)**
  - We're all on the "NASA team" and all want the same thing (mission success)
- **Establish and implement processes to systematically identify, mitigate and characterize risk**
  - Decisions need to be "risk informed"
  - Understand that cost/schedule risks mitigations likely have technical/safety implications…make sure that all components of risk are identified and characterized
- **Create a working environment that fosters candid, open exchanges of information, ideas, and different perspectives**
  - No one knows it all, but collectively we know a lot
  - Respect and welcome different opinions and perspectives
  - Provide avenues for dissenting opinions to appeal to higher authorities
- **Provide a mechanism for both "Programmatic Authority" and "Technical Authority" assessments and recommendations to be formally, periodically presented within a given team as well as to external customers and stakeholders at milestones throughout the life cycle**

DEVELOPMENT FLIGHT TEST
ARES I-X

Organization as defined by the Flight Test Plan and Implemented by the Mission Team

Ares I-X Mission Management Office (MMO)

- **Bob Ess** – Mission Manager
- **Jon Cowart / KSC** – Deputy
- **Steve Davis / MSFC** – Deputy

Safety & Mission Assurance (S& MA)

- **Dan Mullane** – Chief S&MA Officer
- **Jeff Hamilton** – Deputy
- **Angie Wise** – Deputy

Chief Engineers

- **Joe Brunty** – Chief Engineer
- **Shaun Green** – Ground CE
- **Dawn Stanley** – Deputy Vehicle CE

Project Integration (PI)

- **Bruce Askins / MSFC** – Manager

Systems Engineering & Integration (SE&I)

- **Marshall Smith / LaRC** – Chief

Integrated Product Teams (IPTs)

- **Ground Operations (GO)** – Tassos Abadiotakis / KSC
- **First Stage** – Chris Calfee / MSFC
- **Avionics** – Kevin Flynn / MSFC
- **CM/LAS Simulator** – Jonathan Cruz / LaRC
- **Ground Systems (GS)** – Mike Stelzer / KSC
- **Upper Stage Simulator (USS)** – Vince Bilardo / GRC
- **Roll Control System (RoCS)** – Ron Unger / MSFC

Ares I-X S&MA Technical Authority

Ares I-X
Safety and Mission Assurance (S&MA)
Dan Mullane
Jeff Hamilton
Angie Wise

Systems Engineering & Integration (SE&I)
LaRC S&MA
Dave Helfrich

Integrated Product Teams (IPTs)

Ground Operations (GO)
KSC S&MA
Barry Braden
JJ Joyner

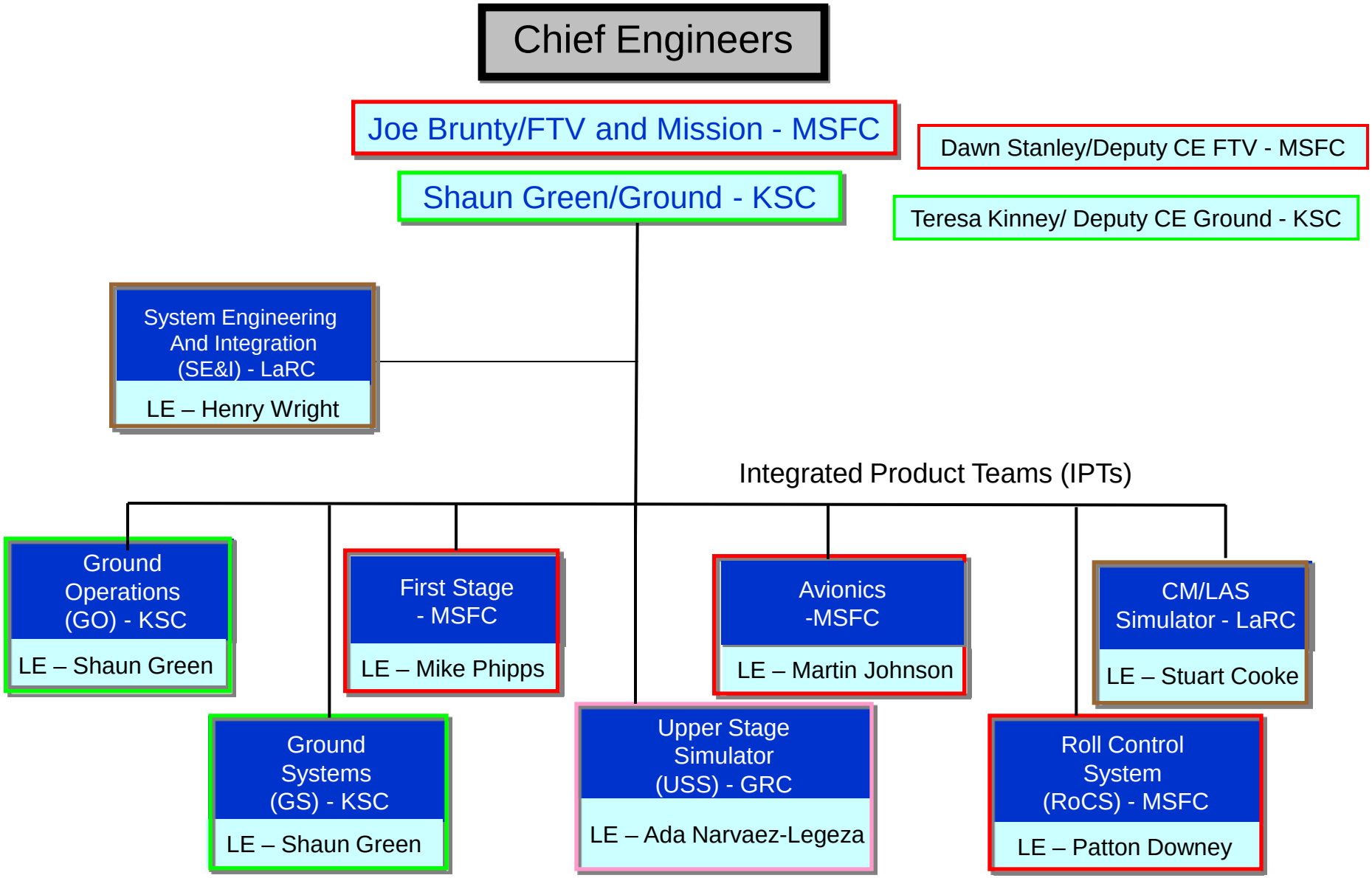
First Stage (FS)
MSFC S&MA
Randall Tucker
John Crisler

Avionics
MSFC S&MA
Andy Gamble
Jennifer Spurgeon

CM/LAS Simulator
LaRC S&MA
Duane Pettit
Frank Williams

Ground Systems (GS)
KSC S&MA
Barry Braden
Eduardo Jezierski

Upper Stage Simulator (USS)
GRC S&MA
Jeff Rusick

Roll Control System (RoCS)
MSFC S&MA
Jennifer Spurgeon

Ares I-X Engineering Technical Authority