PM Challenge 2010

Ares I-X

Our Shot at One NASA

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Outline

- **Introduction to Ares I-X**
  - Mission overview
  - Vehicle overview
- **Org structure evolution**
- **Key enabling decisions**
- **Summary**

Ares I-X: The Basics (1 of 2)

Mission overview

- Uncrewed, suborbital development flight test
- Collected engineering data from launch to first stage recovery
- Support Ares I critical design review

Mission rationale

- The Ares Projects reflect the Apollo method of “test as you fly” as well as current modeling practices until we are certain the rocket is safe enough to launch astronauts into space

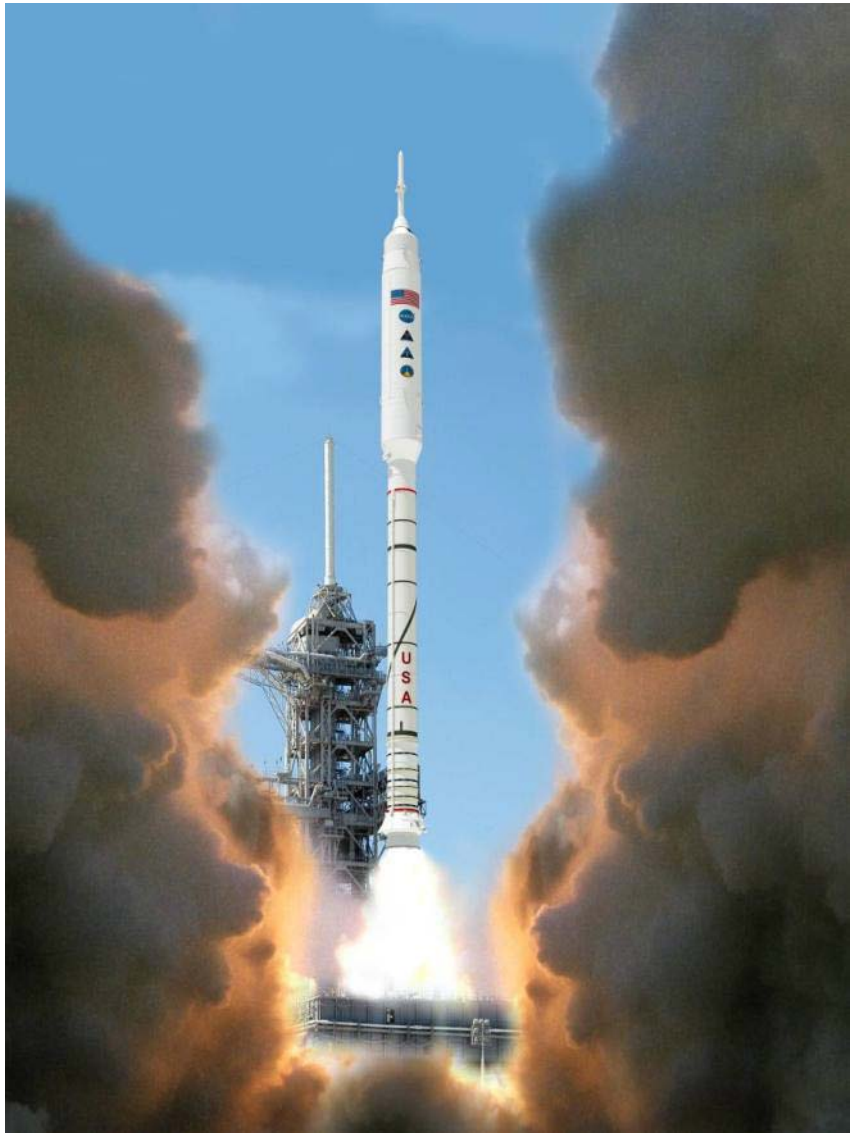
Launch operations

- Vehicle launched 11:30 a.m. Eastern Time, October 28, 2009, from Launch Complex 39B at Kennedy Space Center (KSC)

Ares I-X: The Basics (2 of 2)

- **Hardware overview**
  - Primary flight hardware consisted of a four-segment solid rocket booster from the Space Shuttle program
  - Rocket controlled by Atlas V rocket avionics
- **Mission responsibilities**
  - Bob Ess – Ares I-X Mission Management Manager
    - Stephan Davis and Jon Cowart – Deputy Managers
  - Jeff Hanley – Constellation Program Manager
  - Ed Mango – Launch Director
- **Status**
  - Mission successfully completed all primary mission objectives
  - Onboard and telemetered data now being recovered and assessed
  - First stage hardware being dismantled and examined

Ares I-X Flight Test Objectives



Achieved ALL objectives:

Demonstrated control of a dynamically similar, integrated Ares I/Orion, using
Ares I relevant ascent control algorithms

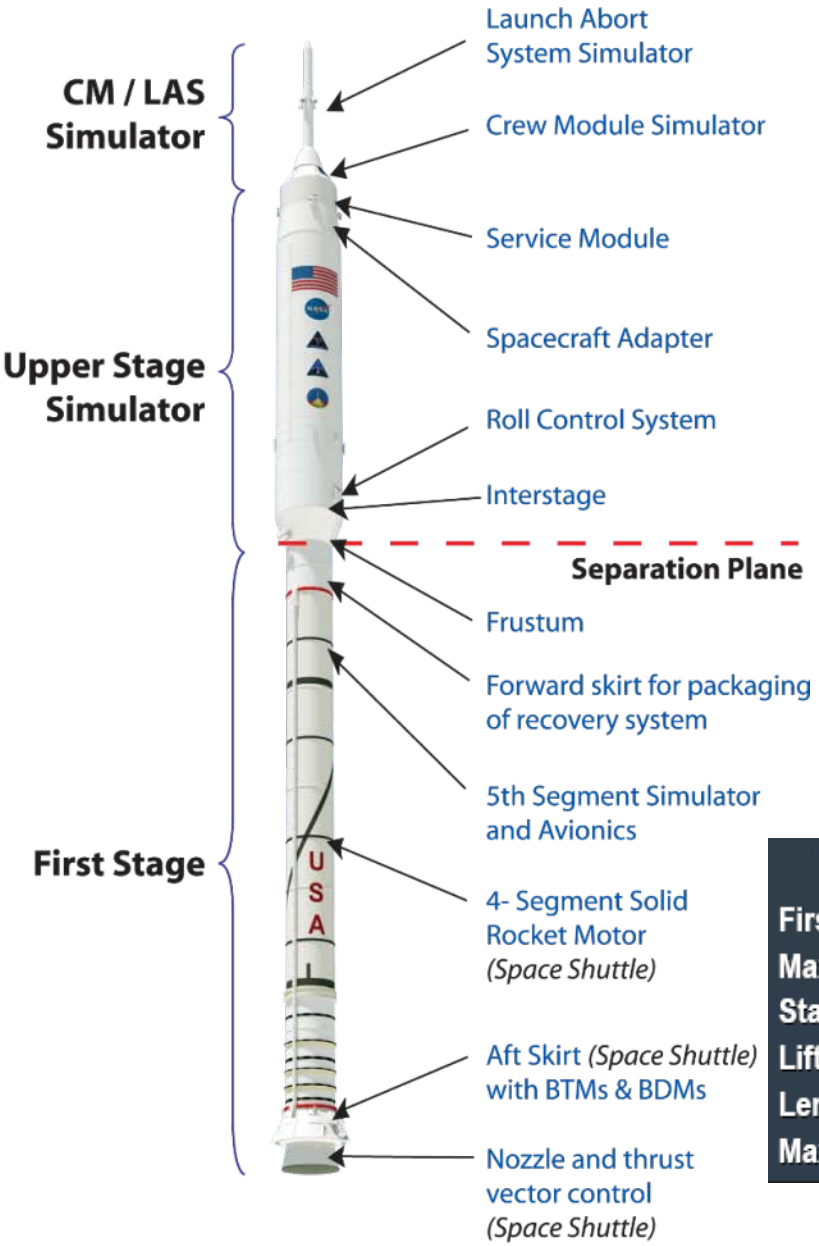
Performed an in-flight separation/staging event between a Ares I-similar First Stage and a representative Upper Stage

Demonstrated assembly and recovery of a new Ares I-like First Stage element at KSC

Demonstrated First Stage separation sequencing, and quantified First Stage atmospheric entry dynamics, and parachute performance

Characterized magnitude of integrated vehicle roll torque throughout First Stage flight

Vehicle Overview

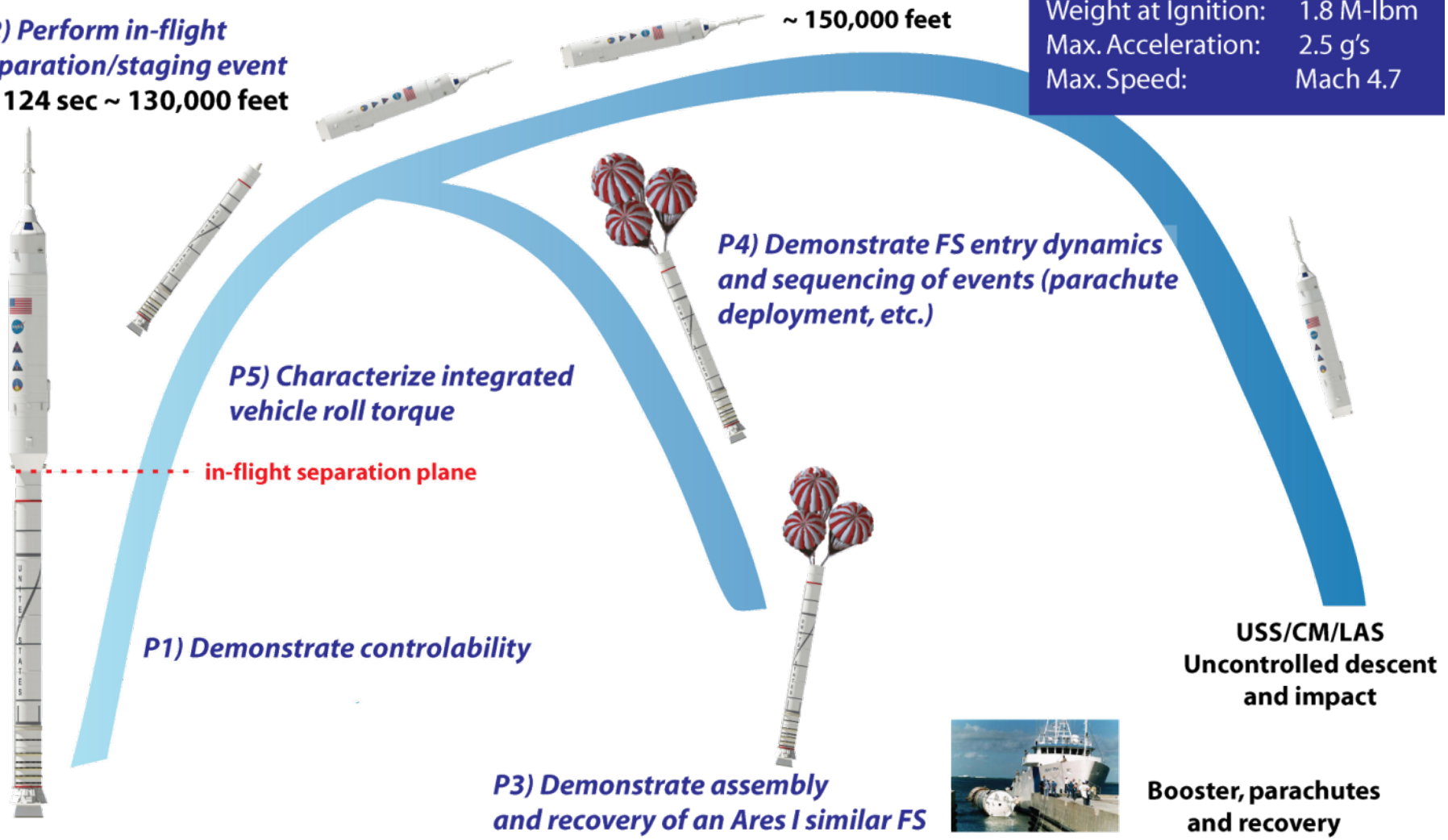


- **Combined proven space flight and simulation hardware**
  - **Active Systems included:**
    - Four-segment solid rocket booster
    - Atlas V-based avionics
    - Roll control system
    - Parachutes deceleration system
    - Booster deceleration and tumble motors
    - Developmental flight instrumentation
  - **Simulator hardware**
    - Upper stage
    - Orion crew module
    - Launch abort system
    - Fifth segment of booster

	Ares I–X	Ares I
First Stage Max. Thrust (vacuum):	14.1M N (3.13M lbf)	15.8M N (3.5M lbf)
Max. Speed:	Mach 4.7	Mach 5.84
Staging Altitude:	39,624 m (130,000 ft)	57,453 m (188,493 ft)
Liftoff Weight:	834k kg (1.8M lbm)	927k kg (2.0M lbm)
Length:	99.1 m (327 ft)	99 m (325 ft)
Max. Acceleration:	2.46 g	3.79 g

Ares I-X Development Flight Test

Vehicle Height:	327 feet
Weight at Ignition:	1.8 M-lbm
Max. Acceleration:	2.5 g's
Max. Speed:	Mach 4.7



Orion Crew Module/ Launch Abort System (CM/LAS) Simulator

Lifting fixture

C-5 Transport to KSC

- Outer mold line (OML) simulated Ares I design
- Developmental flight instrumentation (DFI) sensors measured aerodynamic and acoustic loads
- Developed at the NASA Langley Research Center, Hampton, VA

CM/LAS being hoisted to High Bay 3 in VAB

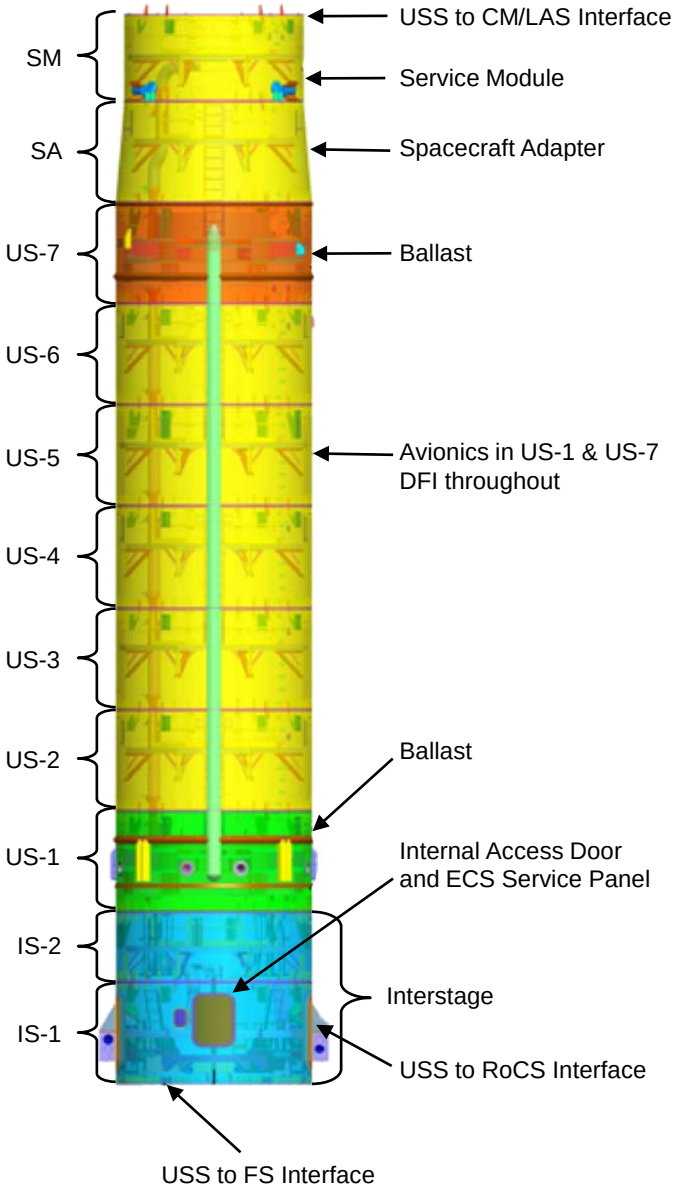
Upper Stage Simulator (USS)

- **USS mass and OML simulator**
- **Developed at NASA Glenn Research Center, Cleveland, OH**

Flange Machining

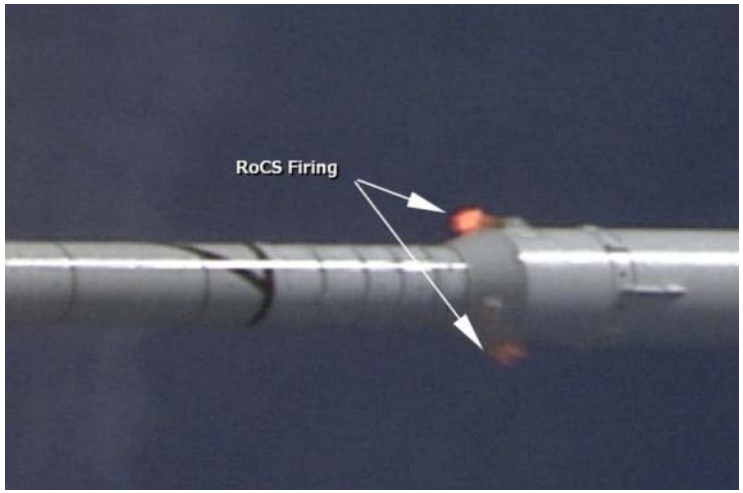
Road transport testing

Super Stack heading for stacking and integration



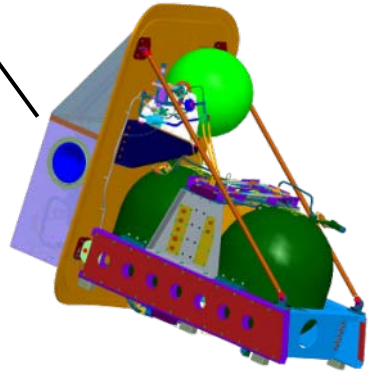
Roll Control System (RoCS)

Interstage installation



RoCS firing in flight

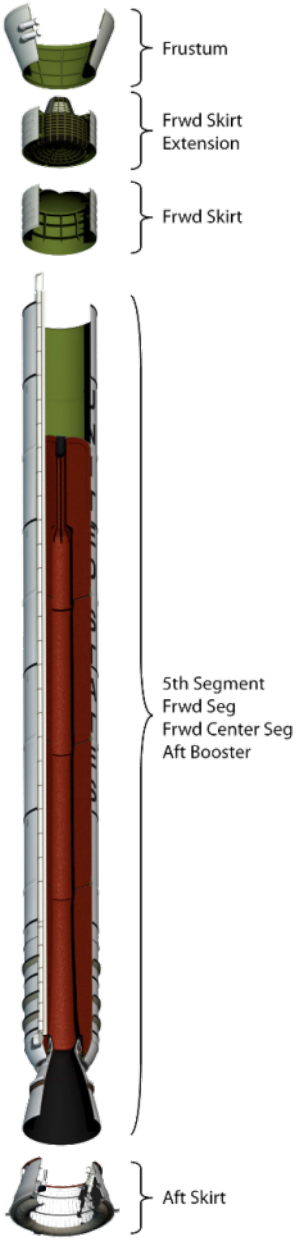
- Provided post-launch 90-degree roll and mitigated adverse roll torques, which were minimal
- Hardware harvested from Peacekeeper
- Managed at NASA Marshall Space Flight Center, Huntsville, AL



First Stage

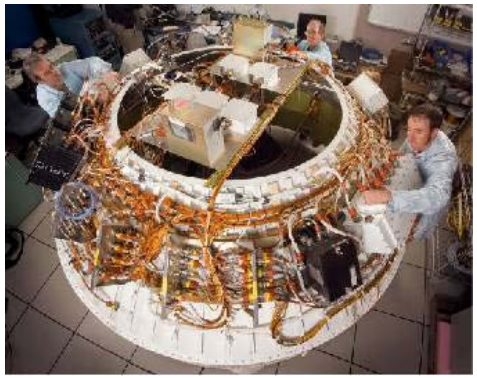
Ascent Operations

Forward Structures



- **Key Heritage Hardware**
  - 4 Segment Reusable Solid Rocket Motor (RSRM)
  - Thrust Vector Control (TVC)
  - Booster Separation Motors (BSMs)
- **Modified Heritage Hardware**
  - Shuttle Derived Avionics
  - Aft Skirt
- **Key New Developments for Ares I-X**
  - Fifth Segment Simulator (5SS)
  - Forward Skirt (FS)
  - Forward Skirt Extension (FSE)
  - Frustum
- **Ares I Designs**
  - Parachutes
  - Flight Termination System Extension to Aft Segment
- **Managed at NASA Marshall Space Flight Center**

Avionics

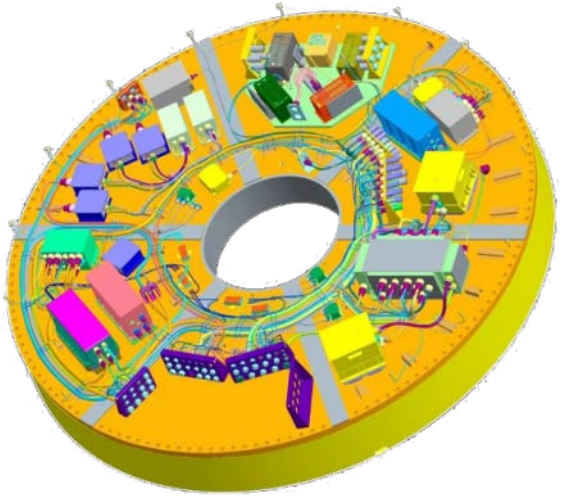


Avionics Systems Integration Lab

First Stage Avionics Module (FSAM)

Developmental Flight Instrumentation

- **Primary avionics subsystems:**
  - FSAM
  - Guidance & Control System
  - Ground Command, Control, and Communication
- **Managed at NASA Marshall Space Flight Ctr.**



First Stage Avionics Module Engineering Model

Ground Operations

Vehicle Stabilization System installation at Pad 39B

- USS segments and CM/LAS assembled into stacks in Vehicle Assembly Building (VAB) Hi-Bay 4
- The First Stage segments and stacks integrated in VAB Hi-Bay 3
- Recovery operations used refurbished launch control center existing Shuttle recovery ship

Vehicle in VAB

Ares I-X Recovery Operations

Ares I-X on Mobile Launch Platform

Rollout

PLAY VIDEO

Ares I-X Key Milestones and Reviews

Initial Concept Development	Oct-05
Initial Concept Briefing	Dec-05
Second Concept Briefing	Mar-06
ATP for FTP Ares I-X	Aug-06
Systems Requirement Review	Nov-06
Avionics PDR	Mar-07
RoCS PDR	Apr-07
CM/LAS PDR	Apr-07
Ares I-X System PDR	May-07
USS CDR	May-07
I-X IMS Baselined	Jun-07
Avionics ATVC CDR	Jun-07
"X-Synch" Review	Jul-07
USS Charge 1 CDR	Aug-07
Avionics FSAM PDR	Sep-07
USS Charge 2 CDR	Oct-07
Avionics System CDR	Nov-07
RoCS CDR	Dec-07
GS PDR	Dec-07
FS CDR	Jan-08
USS Charge 3 CDR	Feb-08
CM/LAS CDR	Feb-08
System CDR Part 1	Mar-08
Avionics Flight Software CDR	Mar-08
Administrator's Briefing	Apr-08
Avionics FSAM CDR	May-08
CDR Part 2	Jul-08
USS Shipment Review	Oct-08
RoCS AR #1	Mar-09
CM/LAS AR	Apr-09
RoCS AR #2	May-09
USS AR	May-09
FS HAR 2	Jun-09
GS MLP/VAB/CCC ORR	Jun-09
FS HAR 3	Jun-09
Mate Review	Jun-09
Avionics System AR	Jul-09
FS Recovery Ops Readiness	Jul-09
IRR #3 – Pad Ops / Countdown	Jul-09
Avionics Flight Software AR	Aug-09
FS EAR Check Point	Sept-09
First Stage EAR	Oct-09
ESMARR	Oct-09
MMO Pre-FTRR Dry Run	Oct-09
CxP Pre-FTRR & Roll Out Review	Oct. 17
SMSR & Center Director's Review	Oct. 19
FTRR	Oct. 23
Certification Launch Simulation	Oct. 24
L-1 Day Review	Oct. 26
Ares I-X Launch from Pad 39B	Oct. 28

Challenges

- **Very aggressive schedule**
  - Conceptual Development — November 2005 – May 2006
  - Interim ATP — May 2006
  - Authority to Proceed — August 2006
  - Launch Date Target — April 2009

- **Distributed team**
  - GRC — Upper Stage Simulator
  - LaRC — Orion Simulator, Systems Engineering and Integration (SE&I)
  - JSC — Program Management
  - MSFC — Avionics, First Stage, Roll Control, vehicle management
  - KSC — Launch facilities, operations

- **Program and project management and approval structure still under development while work already being done**
- **Ares I-X work was being done in conjunction with long-term Constellation Program (CxP) work: Ares I-X lacked a clear project identity**

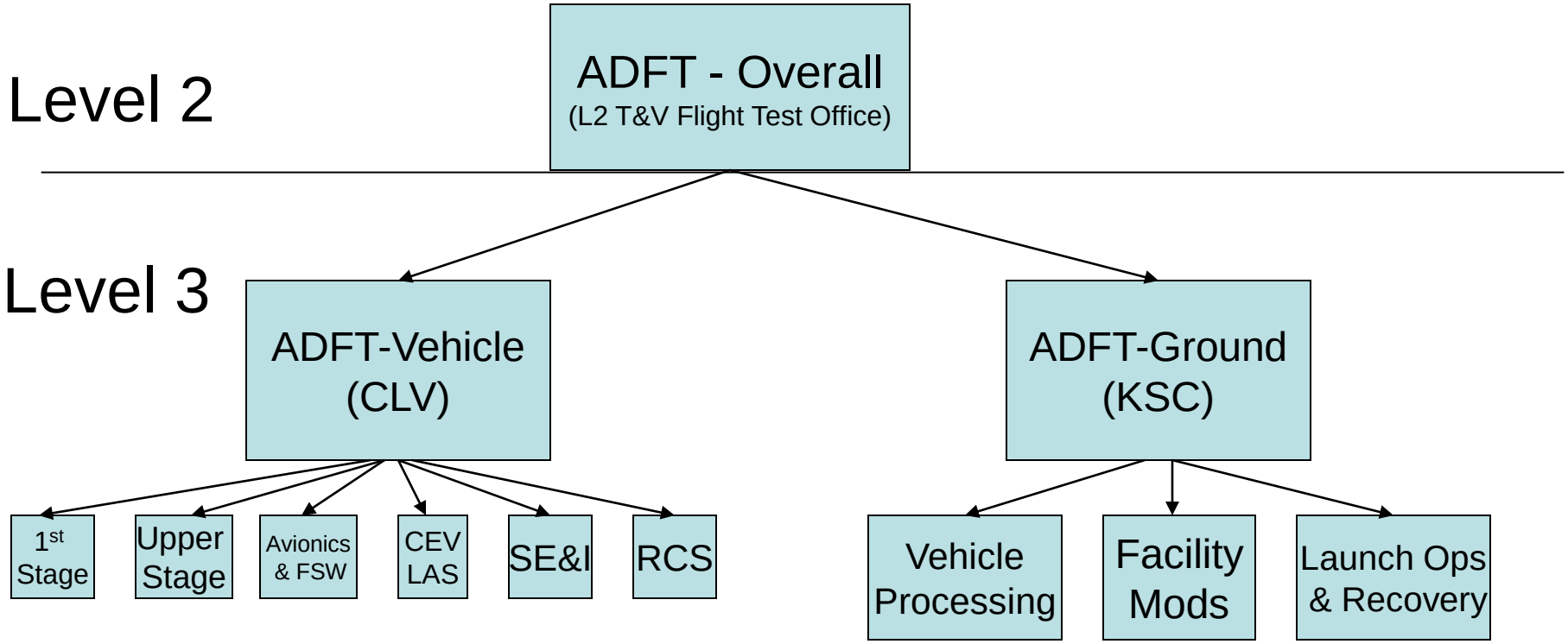
Organizational Structure

- **Key to successful completion of Ares I-X was the organizational structure**

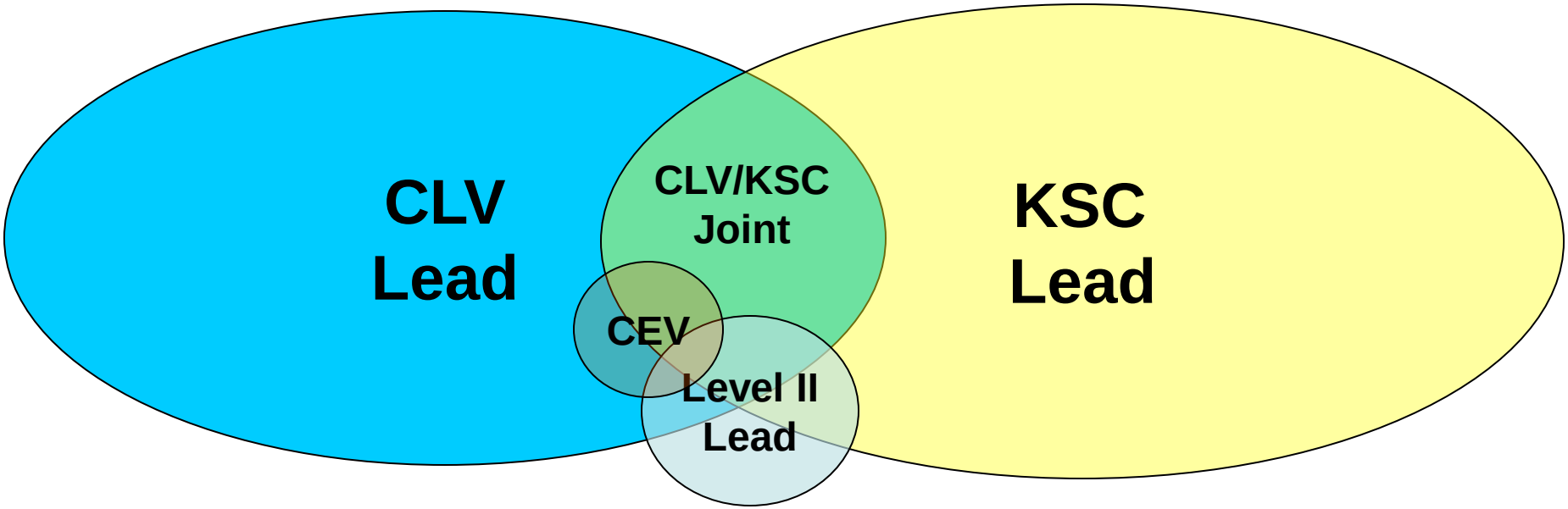
- **Initial organizational structure mirrored Constellation Program (CxP) structure**
  - Launch vehicle components and SE&I were assigned to CLV (Ares)
  - Ground activities assigned to Ground Operations (GO) at KSC
  - CxP provided overall integration

- **Challenges with org structure**
  - Insufficient resources for program and projects to work on Ares I-X and complete tasks for long-term products
  - Ground and CLV “self-integrated”
  - Normal internal project boards/panels were used for review and approval
  - SE&I in Ares (CLV) was unable to integrate CLV and GO
  - “Multiple Chiefs”
    - JSC, MSFC, LaRC

Original Org Structure



Roles & Intersections



CLV Lead Tasks

- Acquisition of Flight Test Article:
- Development & Integration
- First stage
- Dummy U/S, CEV/LAS
- Roll Control
- Interstage
- Project Management up to delivery of checked out elements stacking

Level II Tasks

- Cx Flight Test Objectives
- ADFT Integration Flight Test Plan
- Key Technical drivers, Acquisition value trades
- Review key risk trades
- Post-test review/report lead
- Integration with SR&QA, Range & others

KSC Lead Tasks

- Acquisition of:
  - Pad modifications
  - Stacking Operations
  - Pre-launch Operations
  - Launch Operations
  - Recovery Operations

Evolution

- **Work progressed from ATP in August 2006 to Spring 2007**
  - Challenges became more pronounced and impeded efficient progress
- **Overall system plagued by slowness in integration and decision-making**
  - Too many organizations in charge
  - SE&I established within launch vehicle segment, then assigned to LaRC while CLV project management retained at MSFC
  - No true system integrator between vehicle and ground
  - Technical Authority path/approach not defined
    - Multiple Chief Engineers, delegated (minimal) Safety and Mission Assurance (S&MA) involvement
- **Program recognized that current management structure would not be successful for a 'fast-track' project with very tight budget constraints**

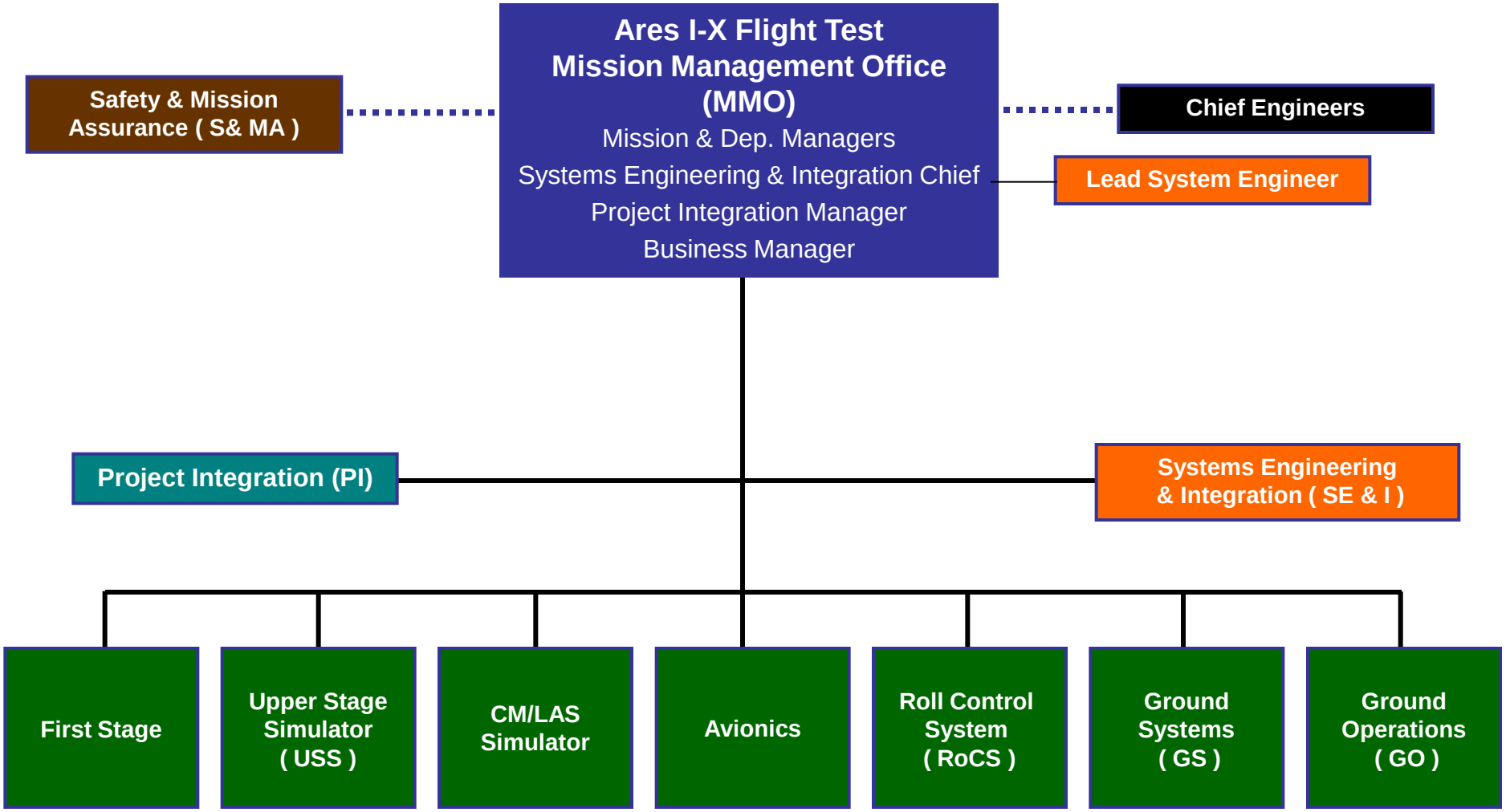
New Approach (1 of 2)

- **"Lean Event" held May 2007 with representatives from key aspects of flight test**
- **Goal: establish clean-sheet approach to completing flight test efficiently and on time**
- **New organizational structure established**
  - Ares I-X recreated as stand-alone "Mission Management Office"
  - Appointed single Mission Manager with decisional authority, reporting directly to CxP Manager
  - Established one Ares I-X Control Board (XCB)
  - Expanded scope of SE&I to include all aspects of mission
  - Gave Mission Manager responsibility for budget reporting

New Approach (2 of 2)

- **Mission identity established**
  - Established “zero-based” CxP and NASA requirements
    - Established clear S&MA requirements
    - Identified applicable technical standards
    - Established system engineering process relevant to one-time flight test
  - “Branded” mission with new Ares I-X name, logo
  - Conducted additional “Lean Events” on all mission elements to gain schedule margin back and minimize excessive or heritage requirements

New Ares I-X Organization



Successes Enabled by New Organizational Structure

- **Strong Management structure allowed for Managers to Accept Risk**
  - Not all possible analyses or tests needed to be performed
  - “Good Enough”
  - Factors of safety were reviewed and changed

- **Technical Disagreements handled within Mission Management Office**
  - Hi-Pot Cable testing requirement example
    - NASA Standard
    - Not planned for I-X
    - Disagreement between Management and TA
    - Elevated to CxP Control Board
    - Resolved in a few weeks

Key Lessons Learned (1 of 6)

- **(1) Establish clear mission objectives – in our case this…**
  - Supported early definition flight and ground configurations
  - Defined the organizational structure
  - Supported a more rapid development timeline
  - Reduced continual assessment of mission objectives and requirements
    - **Lesson: Establishing clear objectives early is recommended as a good thing to do – In our case it made a big difference**
    - **Don't let them "evolve"**

Key Lessons Learned (2 of 6)

- **(2) Ares I-X a employed a small and "flat" team organization, which...**
  - Minimized decision times
  - Encouraged communication
  - Enhanced the "sense of team"
  - At times, caused work overloading
    - **Lesson: A small, flat team worked well for Ares I-X. It may not work in other situations. The one drawback is the threat of work overload on key people.**

Key Lessons Learned (3 of 6)

- **(3) The difficulty in developing loads and environments was underestimated…**
  - Load changes occurred right up to the end and this caused a strain on the team and additional time pressure
    - **Lesson 1: Work loads and environments diligently starting as soon as possible**
    - **Lesson 2: Expect loads and environments changes and plan accordingly**

Key Lessons Learned (4 of 6)

- **(4) Regarding DFI (Development Flight Instrumentation) activities…**
  - Asking the engineers & scientists what sensors they needed (wanted) resulted in over 5,000 sensors!
    - **Lesson: Working top down from objectives leads to a more appropriate sensor suite.**
  - More time was spent in discussing potential sensor removal (or better stated as “not installation”) than actual time installing the sensors
    - **Lesson (1): Realize that proposing to reduce an approved sensor suite will most likely result in a lengthy discussion (controversy)**
    - **Lesson (2): Identify a DFI Control Board to handle issues**

Key Lessons Learned (5 of 6)

- **(5) Very strong institution and program ways of doing business are very hard to alter**
  - Multiple Centers needs some common interfaces to work together
  - Terminology is very different between centers
    - Verification
    - Integrated Testing
    - Flight Readiness (CoFR)
    - CM, CAD, etc.
  - Institutions may ask for additional studies, reviews
    - Drives program costs
    - Establish review process early (not every center has to review work if it is in support of another center – just have one review)
  - Avoid NASA watching NASA watching contractor(provider)
    - Too many groups want to see and review themselves
    - Establish review (IV&V) process in detail
  - NASA does NOT do it better
    - Many contractor process are as good or better
    - Reluctance to use if different than NASA Standards, experience, etc.

Key Lessons Learned (6 of 6)

- **(6) Establish an Engineering Development Fixture (EDF) of CAD 3-D models – in our case this…**
  - Supported fit checks of interfaces and configuration changes/updates
  - Supported moving fast in the design process with communication at the design level between IPTs
  - Supported the engineering and independent review process used in detailed communication of the design
    - **Lesson: Establishing the requirement for an EDF early in the design process is a good thing to do**
      - **– In our case it found interferences early that saved schedule, cost, and rework**
    - **Include a CAD model delivery schedule and format specifications as contractual requirements**
      - **– In our case it was done out of team goals**
    - **Develop fixed standards for model submission formats at the start of the design**
      - **– In our case we did not, and much time was spent on conversion that slowed our use of EDF**

Summary

- Ares I-X is the first successful flight of NASA's Constellation Program
- Data being analyzed now but we have learned many valuable lessons already
- This test returns NASA to its history as an aerospace pioneer
- Lessons from Ares I-X will apply to any vehicle the Constellation Program called upon to build

Backup

http://WWW.NASA.GOV

http://www.nasa.gov/aresIX