Ares Launch Vehicles Overview - Space Access Society

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Abstract

America is returning to the Moon in preparation for the first human footprint on Mars, guided by the U.S. Vision for Space Exploration. This presentation will discuss NASA's mission, the reasons for returning to the Moon and going to Mars, and how NASA will accomplish that mission in ways that promote leadership in space and economic expansion on the new frontier. The primary goals of the Vision for Space Exploration are to finish the International Space Station, retire the Space Shuttle, and build the new spacecraft needed to return people to the Moon and go to Mars. The Vision commits NASA and the nation to an agenda of exploration that also includes robotic exploration and technology development, while building on lessons learned over 50 years of hard-won experience.

NASA is building on common hardware, shared knowledge, and unique experience derived from the Apollo Saturn, Space Shuttle, and contemporary commercial launch vehicle programs. The journeys to the Moon and Mars will require a variety of vehicles, including the Ares I Crew Launch Vehicle, which transports the Orion Crew Exploration Vehicle, and the Ares V Cargo Launch Vehicle, which transports the Lunar Surface Access Module. The architecture for the lunar missions will use one launch to ferry the crew into orbit, where it will rendezvous with the Lunar Module in the Earth Departure Stage, which will then propel the combination into lunar orbit. The imperative to explore space with the combination of astronauts and robots will be the impetus for inventions such as solar power and water and waste recycling.

This next chapter in NASA's history promises to write the next chapter in American history, as well. It will require this nation to provide the talent to develop tools, machines, materials, processes, technologies, and capabilities that can benefit nearly all aspects of life on Earth. Roles and responsibilities are shared between a nationwide Government and industry team. The Exploration Launch Projects Office at the Marshall Space Flight Center manages the design, development, testing, and evaluation of both vehicles and serves as lead systems integrator. A little over a year after it was chartered, the Exploration Launch Projects team is testing engine components, refining vehicle designs, performing wind tunnel tests, and building hardware for the first flight test of Ares I-X, scheduled for spring 2009.

The Exploration Launch Projects team conducted the Ares I System Requirements Review (SRR) at the end of 2006. In Ares' first year, extensive trade studies and evaluations were conducted to refine the design initially recommended by the Exploration Systems Architecture Study, conceptual designs were analyzed for fitness, and the contractual framework was assembled to enable a development effort unparalleled in American space flight since the Space Shuttle. Now, the project turns its focus to the Preliminary Design Review (PDR), scheduled for 2008. Taking into consideration the findings of the SRR, the design of the Ares I is being tightened and refined to meet the safety, operability, reliability, and affordability goals outlined by the Constellation Program. The Ares V is in the early design stage, focusing its activities on requirements validation and ways to develop this heavy-lift system so that synergistic hardware commonality between it and the Ares I can reduce the operational footprint and foster sustained exploration across the decades ahead.

National Aeronautics and Space Administration

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Steve Cook, *Director*
Exploration Launch Projects Office
NASA Marshall Space Flight Center

March 22, 2007

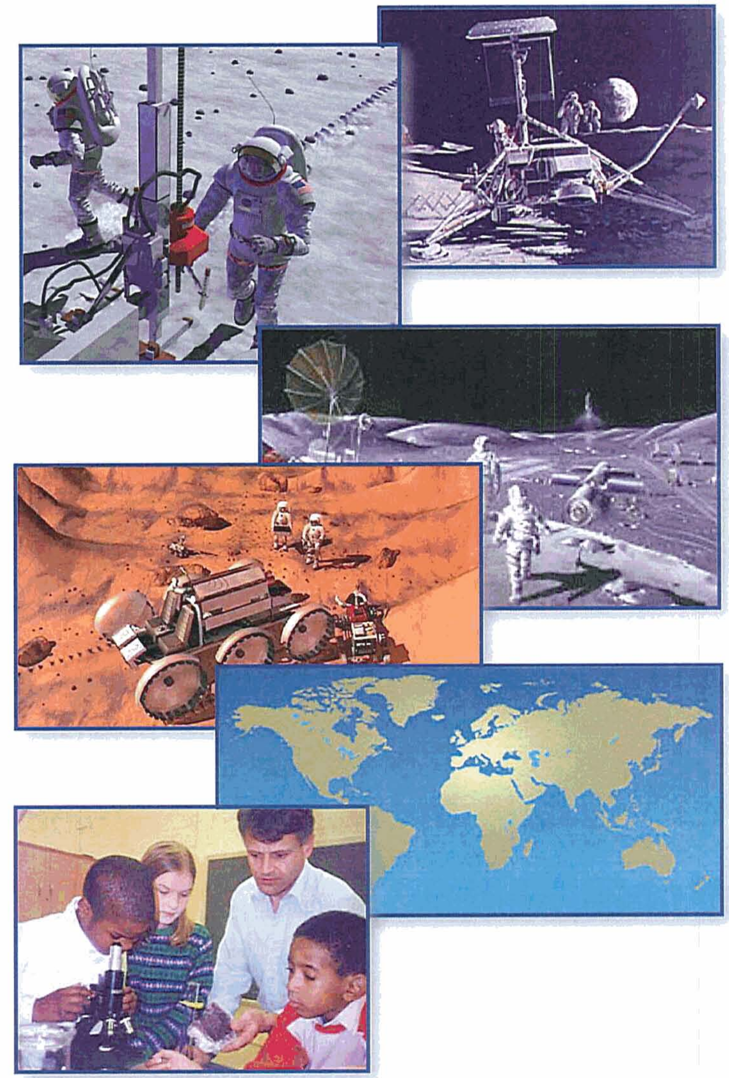
www.nasa.gov

Agenda

- U.S. Launch Vehicle Relevance and Design Evolution
- Ares Launch Vehicle Development
- Progress to Date
- Ares I Technical Description
- Ares V Technical Description
- Summary

Great Nations Explore

- **Leadership**
  - U.S. sets the example and leads the journey, while ensuring global competitiveness and national security.
- **Knowledge**
  - Supports technological advancements and a comprehensive understanding of Earth's systems.
- **Relevance**
  - Yields tangible economic benefits and other positive impacts on daily life, including technology transfer and satellite-based services.
- **Inspiration**
  - Encourages students to study math, engineering, and science, and to pursue their dreams.
- **Discovery**
  - Fulfills humanity's destiny to explore by opening the door to new frontiers.



The process of exploring new worlds improves life on Earth.

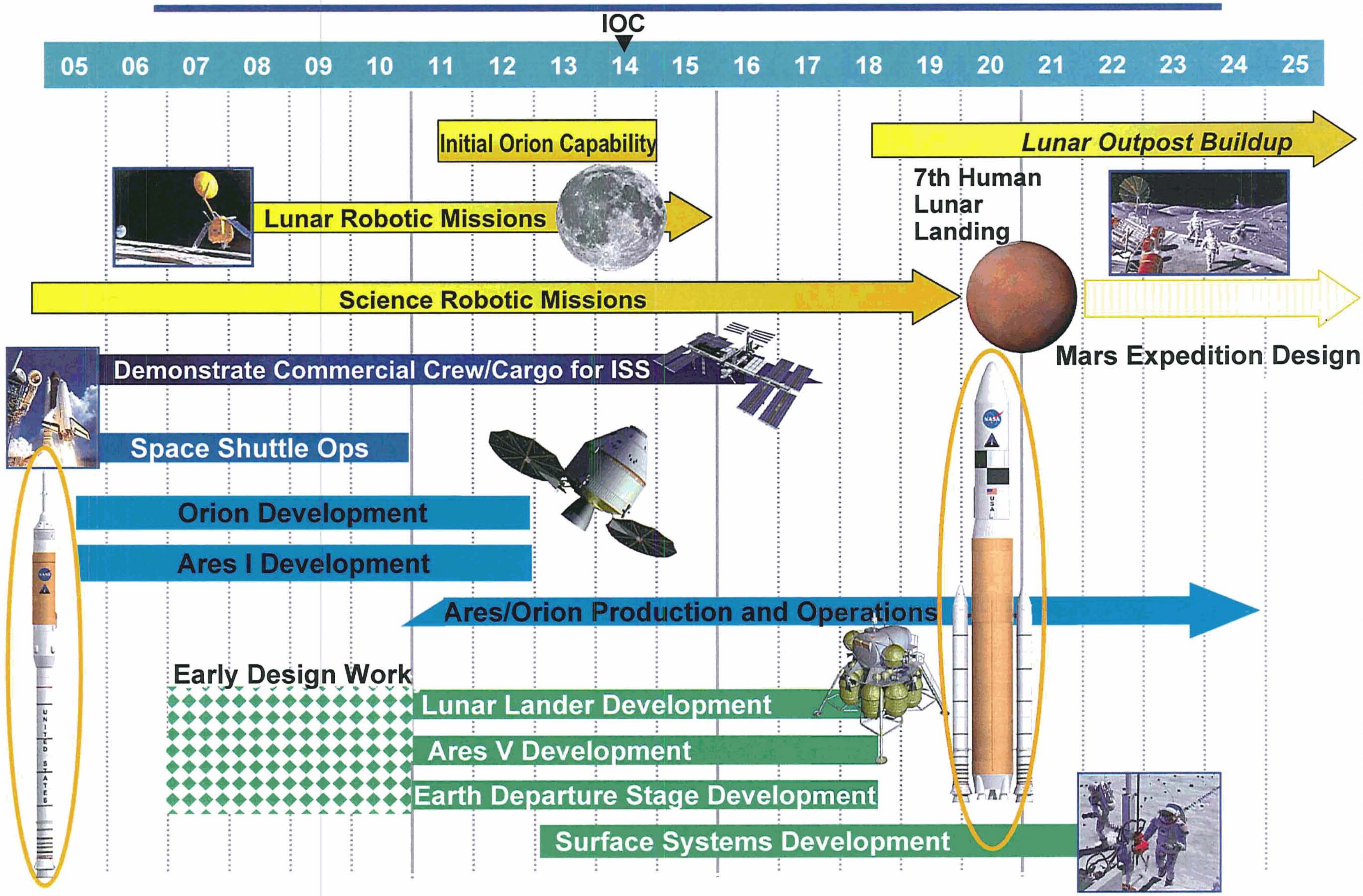
America's Space Transportation Capabilities

- **Space Transportation Architecture**
  - Defined by a term of aerospace experts in 2005
  - Refined through systems engineering studies in 2006
- **Measurable Progress**
  - Ares I Crew Launch Vehicle completed System Requirements Review in 2006
  - Ares V Cargo Launch Vehicle completed early design in 2006

"The next steps in returning to the Moon and moving onward to Mars, the near-Earth asteroids, and beyond, are crucial in deciding the course of future space exploration. We must understand that these steps are incremental, cumulative, and – incredibly powerful in their ultimate effect."

– NASA Administrator Michael Griffin, October 24, 2006

NASA's Exploration Roadmap

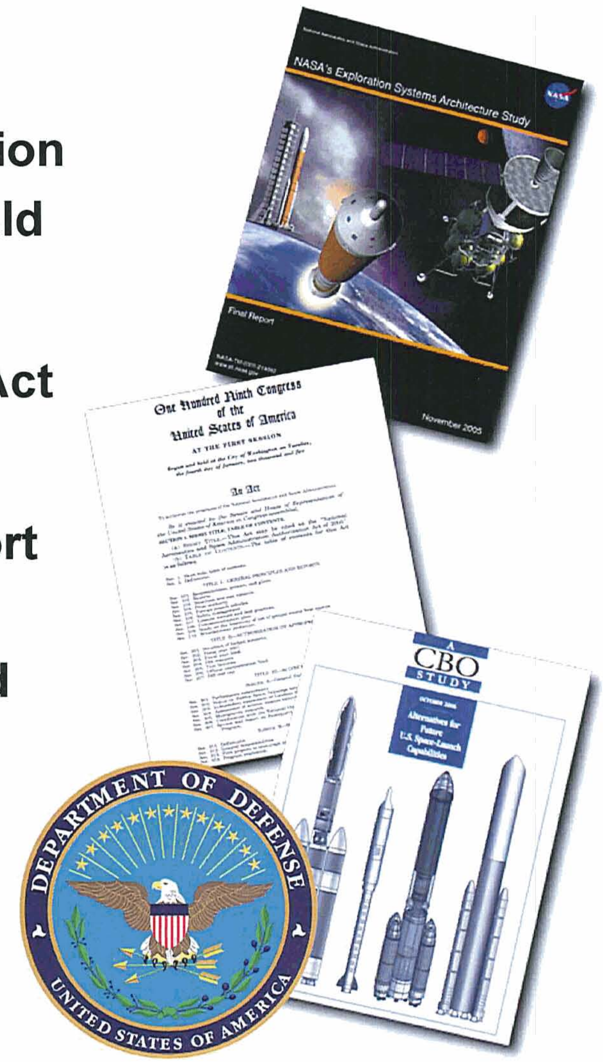


Returning to the Moon for more in-depth study is the next step toward Mars—a planet much like our own.

Launch Architecture Selection Grounded in Expert Analysis

- NASA Exploration Systems Architecture Study (ESAS) in 2005 recommended this approach based on significant analysis.
- Department of Defense (DoD) validated this conclusion in August 2005 (letter to John Marburger* from Ronald Sega** and Michael Griffin***).
- Supported in Law through the NASA Authorization Act of 2005 (Section 502).
- The October 2006 Congressional Budget Office report entitled "Alternatives for Future U.S. Space-Launch Capabilities" is consistent with NASA's analysis and decisions.

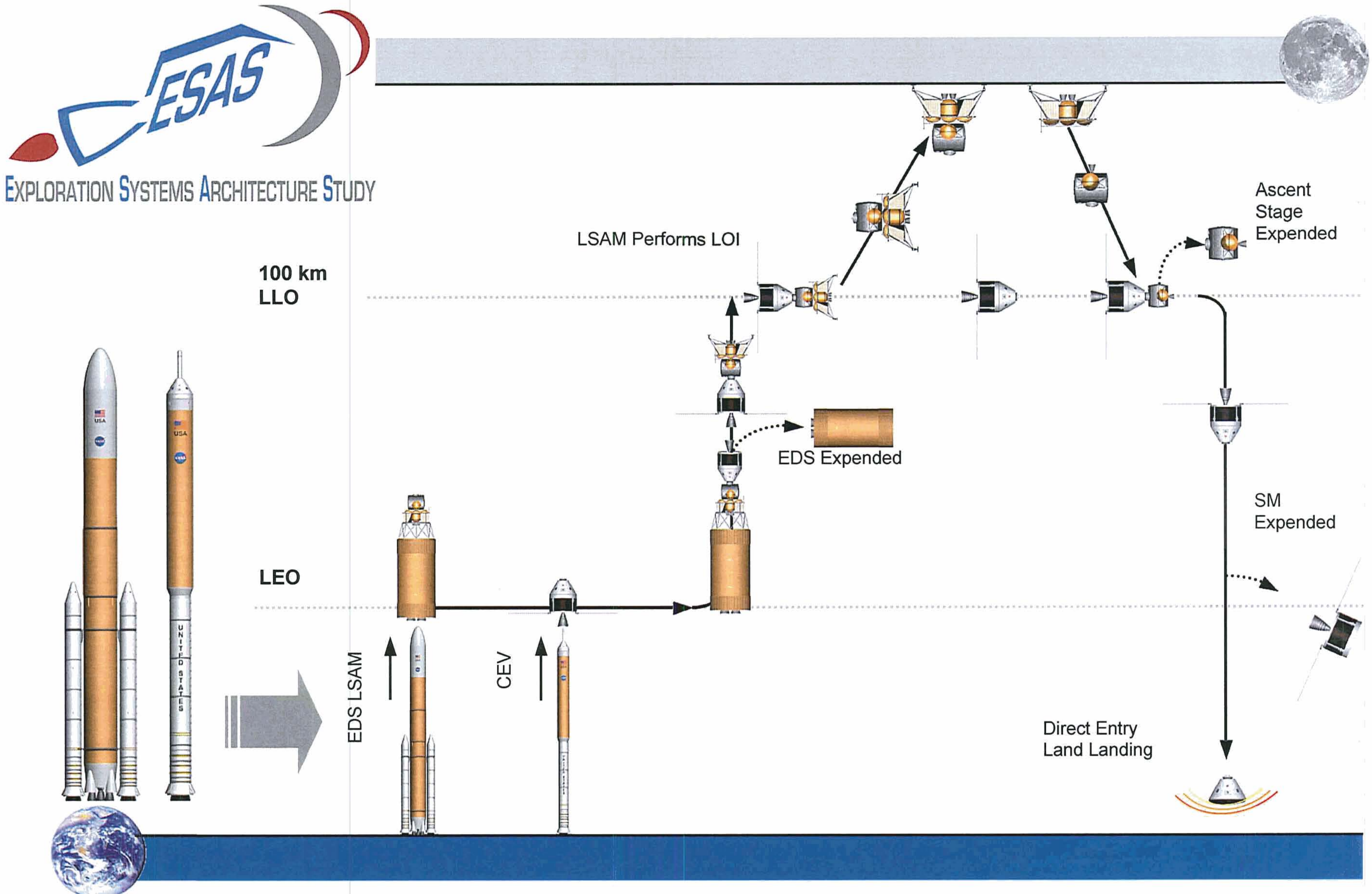
* *Director, White House Office of Science and Technology Policy*
** *Under Secretary of the Air Force*
*** *NASA Administrator*



Several recent studies demonstrate that a Shuttle-derived architecture makes the most sense for NASA from a life-cycle cost, safety, and reliability perspective.

Overall ESAS Lunar Architecture ("1.5 Launch")

Summer 2005



The architecture has not changed—only the hardware has been refined.

ESAS Launch System Selection Summary

- **Continue to rely on the Evolved Expendable Launch Vehicle (EELV) fleet for scientific and International Space Station (ISS) cargo missions in the 5-20 metric ton range to the maximum extent possible**
- **The *safest, most reliable, and most affordable* way to meet exploration launch requirements is a 25 metric ton system derived from the current Shuttle solid rocket booster and liquid propulsion system**
  - Ares I: 4 Segment Reusable Solid Rocket Motor (RSRM) with Space Shuttle Main Engine (SSME)-powered upper stage
  - Ares V: 5 Segment RSRM, 5xSSME-powered core stage, J-2X powered Earth departure stage
  - Capitalizes on human-rated systems and 85% of existing facilities.
  - The most straightforward growth path to later exploration requires super heavy launch
- **125 metric ton lift capacity required to minimize on-orbit assembly and complexity — increasing mission success**
  - A clean-sheet-of-paper design incurs high expense and risk
  - EELV-based designs require development of *two* core stages plus boosters–increasing cost and decreasing safety/reliability
  - Current Shuttle lifts 100 metric tons to orbit on every launch

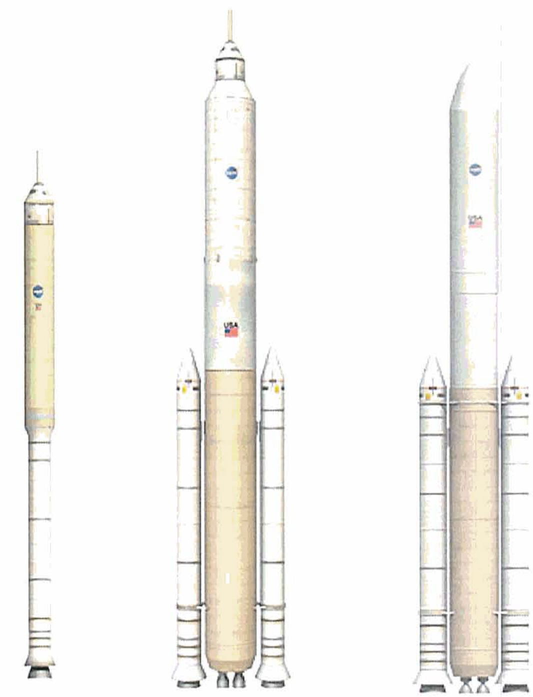
Ares I

Ares V

Current plans build on these recommendations.

Improving on the ESAS Launch Vehicle Recommendations

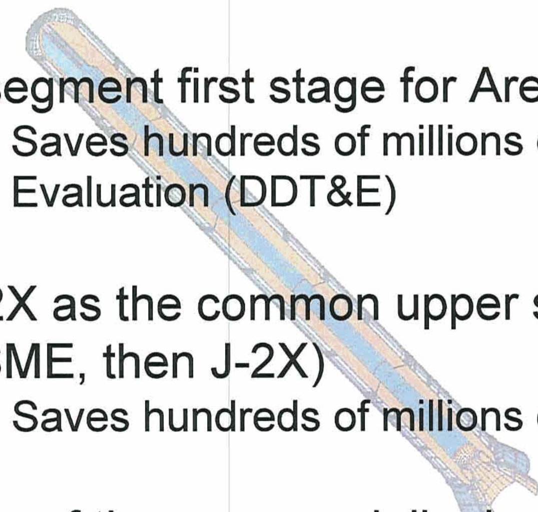
- ESAS was a "point of departure" exploration architecture
- Post-ESAS analysis demonstrated there was a more streamlined way to assure U.S. access to Low-Earth Orbit (LEO) and regain access to the Moon
- NASA decided to reduce the total number of propulsion developments required to enable the Ares launch vehicle family.



Better focuses the architecture on exploration as the primary mission, vs. ISS and then exploration.

Improving on the ESAS Launch Vehicle Recommendations (cont'd)

- **Current approach focuses on developing key systems sooner:**



  - 5 segment first stage for Ares I and V (vs. 4, then 5 segment)
    - Saves hundreds of millions of dollars in Design, Development, Test, and Evaluation (DDT&E)
  - J-2X as the common upper stage engine for both Ares I and Ares V (vs. SSME, then J-2X)
    - Saves hundreds of millions of dollars in DDT&E
  - Use of the commercially developed RS-68 engine as the core engine for Ares V (vs. SSME)
    - Saves several billions of dollars through 2020

Progress made on the Ares I is now a significant and direct "down payment" on the Ares V. Selecting common hardware reduces cost and gets us closer to enabling a lunar transportation system.

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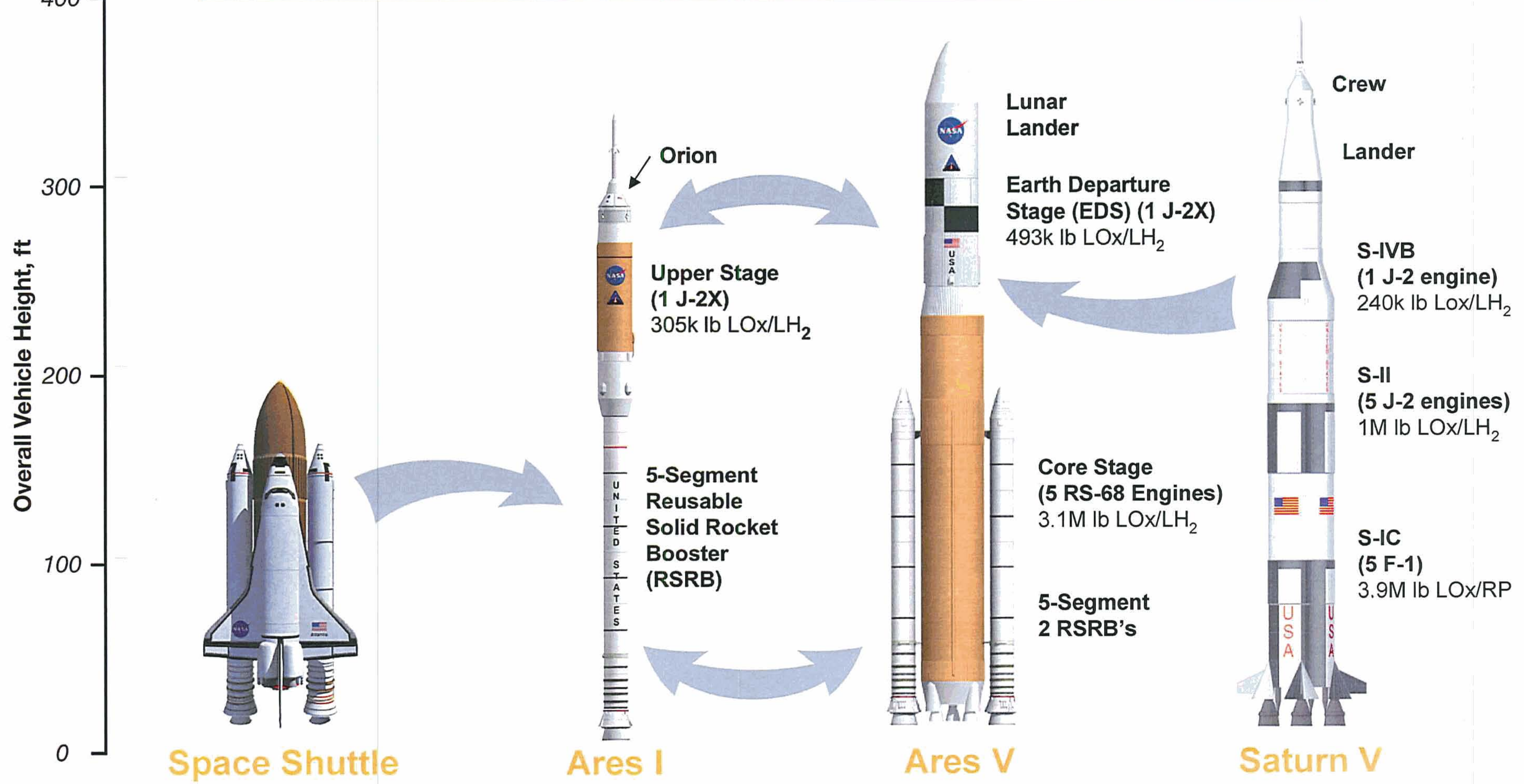
Launch Systems Comparison

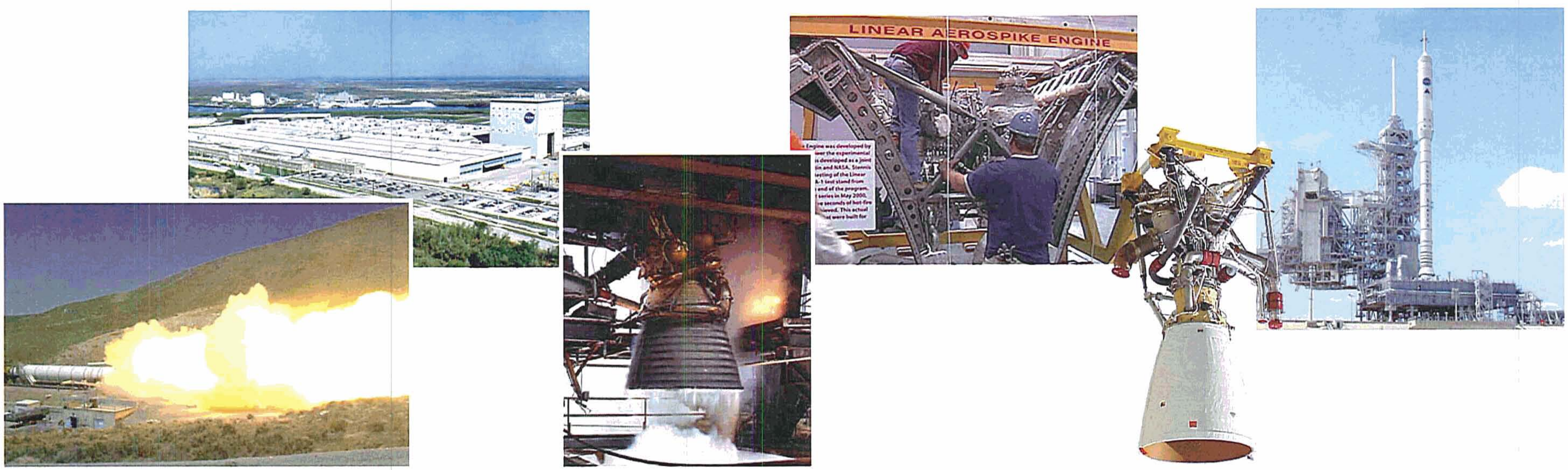


Space Shuttle	Ares I	Ares V	Saturn V
Height: 184.2 ft	**Height:** 328 ft	**Height:** 361 ft	**Height:** 364 ft
Gross Liftoff Mass: 4.5M lb	**Gross Liftoff Mass:** 2.0M lb	**Gross Liftoff Mass:** 7.3M lb	**Gross Liftoff Mass:** 6.5M lb
55k lbm to LEO	50k lbm to LEO (effective)	119k lbm to TLI 134k lbm to TLI in Dual-Launch Mode with Ares I 285k lbm to LEO	99k lbm to TLI 262k lbm to LEO

New systems build on 50 years of experience.

Ares: Building on Proven Capabilities

- A 5-segment solid rocket motor was test fired in October 2003
- The J-2X engine's predecessor made its debut during America's first round of Moon missions, and its turbomachinery was tested as part of the more recent X-33 Program
- The Upper Stage will be assembled at the Michoud Assembly Facility (MAF), home of the Shuttle External Tank (ET), using some of the same materials
- The RS-68 engine, which powers the Delta IV, will boost the Ares V core stage
- Using experienced human spaceflight workforce to process the Ares at the Kennedy Space Center (KSC) using many Shuttle capabilities, such as booster processing and assembly, the Vehicle Assembly Building, and Launch Complex 39



Using unique, experienced capabilities in a streamlined manner.

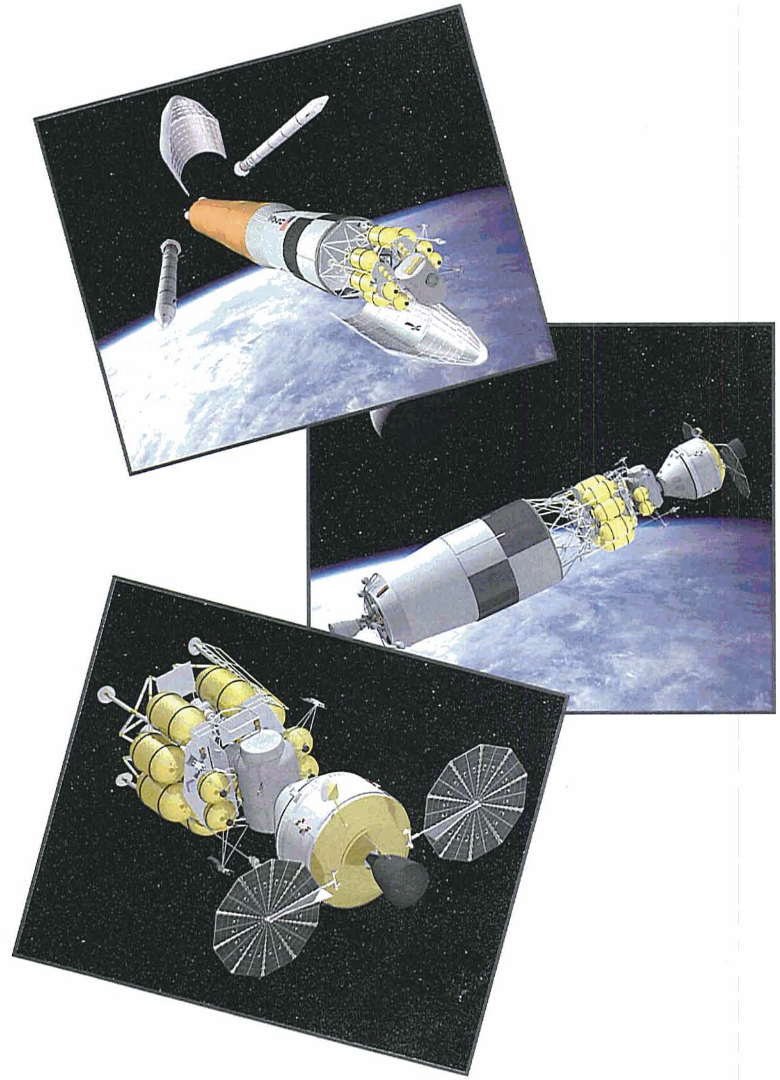
A Robust Launch System Approach

- **Performance**
  - Ares I: Delivers 50k lbm to LEO (effective) / 58k lbm (gross)
  - Ares V: Delivers 285k lbm to LEO / 134k lbm to Trans-Lunar Injection (with Ares I)
- **Flight Control**
  - While Ares is a long and slender vehicle, it is within the control dynamics experience base of previous programs, most notably the Saturn V
    - ~8x margin on the vehicle structural response to control frequency ratio
  - Results indicate a ~2x margin on first stage thrust vector control (angle and rate) and ~1.7x capability over predicted roll torque
- **Weather**
  - Designing for a 95% launch availability
  - Using conservative assumptions for natural environments, such as winds aloft
- **Structures and Loads**
  - Within the design of the existing Shuttle motor case, joints, and aft skirt
  - Upper Stage/interstage is being designed for the loads
- **Safety and Reliability**
  - Current estimates project Loss of Mission > 1:500
    Loss of Crew > 1:2000

Designing for safe, reliable, and cost-effective operations.

Design Philosophy for Mission Success

- **Keep it simple**
  - Simplify interfaces
  - Make it robust
- **Focus on reliability, maintainability, and supportability early to improve safety and reduce long-term operations costs**
- **Apply validated engineering tools, models, and data to new vehicle configurations**
- **Capture and apply Lessons Learned**



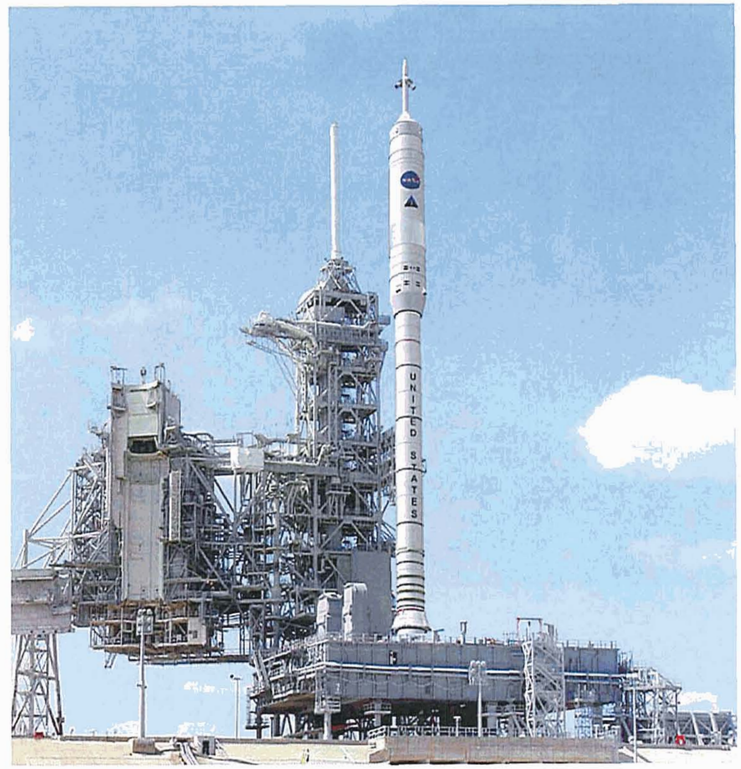
Sustaining long-term exploration depends on responsive, cost-effective launch vehicles.

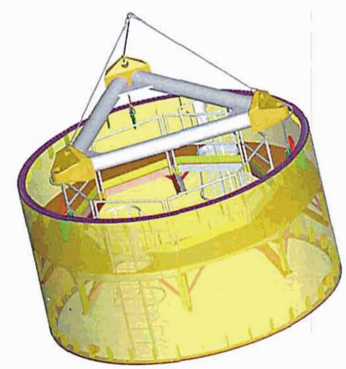
Ares I-X Development Flight Test

April 2009

- Demonstrate control of a dynamically similar, integrated Ares I Crew Launch Vehicle(CLV)/Orion Crew Exploration Vehicle (CEV)
  - Baseline trajectory closely matches Ares I through Mach 4 and key separation conditions
- Perform an in-flight separation/staging event between a similar First Stage and a representative Upper Stage
- Demonstrate assembly and recovery of a new Ares I-like First Stage element at KSC
- Demonstrate First Stage separation sequencing, and quantify First Stage atmospheric entry dynamics and recovery parachute performance
- Characterize magnitude of integrated vehicle roll torque throughout First Stage flight

Early flight testing in real-world environments validates laboratory and ground-based research.

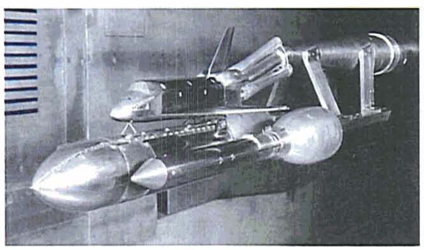


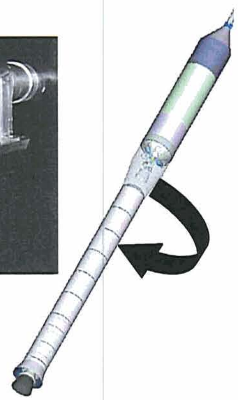


Ares I-X: Risk Reduction Flight Test

- **Vehicle Aerodynamics, Environments**
  - Wind Tunnel testing
  - CFD predictions.
  - Stability derivatives and control authority requirements.

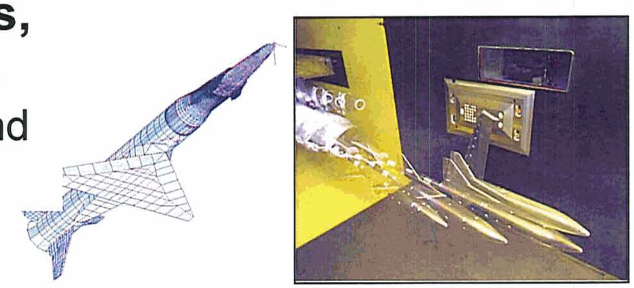
- **Structural Integration**
  - Analysis of load paths, dynamics.
  - Component-level modal testing.
  - Aeroelasticity Wind Tunnel Test and Analysis.
  - On-the-Pad Loads Test.





Flight Validation of Integrated Aero, Structures, and Performance Models

Comparison of prediction, ground test, and flight data

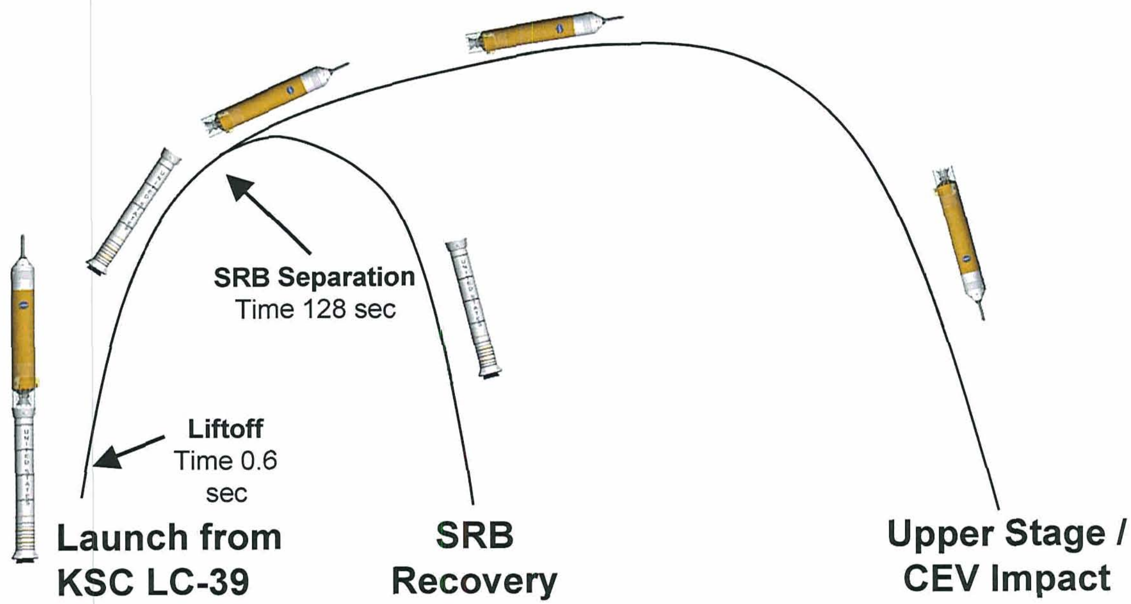


- **First Stage Performance**
  - Propulsion performance.
  - Flight control laws.
  - Models for plume effects and ignition over-pressure.

- **Stage Separation**
  - Static CFD with multiple codes.
  - Time-dependent CFD.
  - Quasi-static Wind-Tunnel testing for interference aero.

Flight Test Data will help characterize uncertainties on CLV Design Margins.

Ares I-X Flight Test



Approach:

- Utilize aged flight or test hardware from the Shuttle SRB project.
- Utilize mass simulators for the Upper Stage, CEV, and LAS.
- Utilize a mass simulator to represent the Upper Stage engine.
- Match the CLV design as much as possible but freeze design at certain point.
- Recover First Stage and safely expend other hardware.
- Will plan conservatively on roll control package
- Launch from LC 39 at KSC with ascent monitoring responsibility

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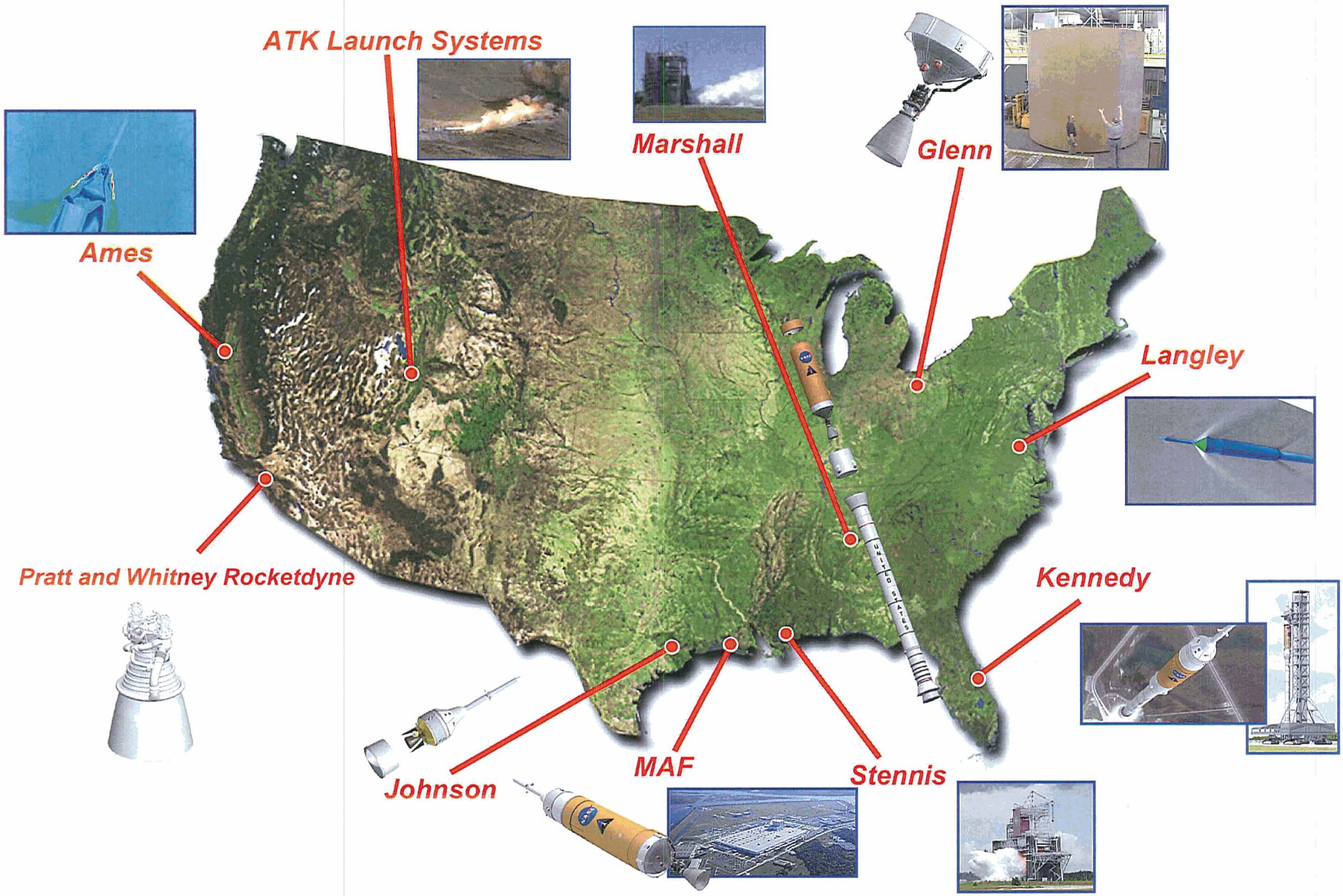
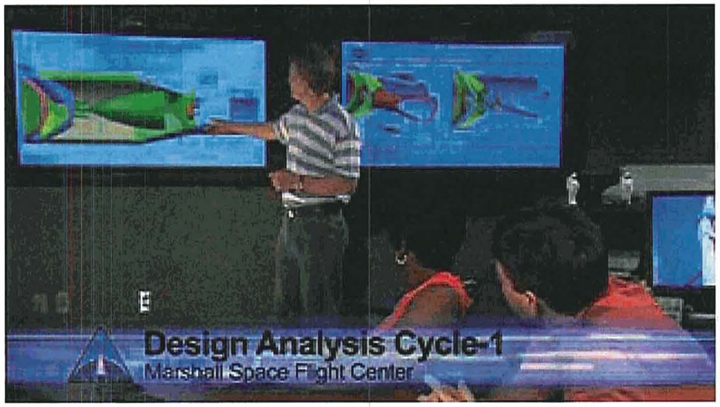
Our Nationwide Ares Team



Vehicle Integration



Design Analysis Cycle 1 (DAC-1) Complete, DAC-2 Underway – Marshall Space Flight Center (MSFC)

Certificate of Completion
Ares I System Requirements Review (SRR)
Internal Board

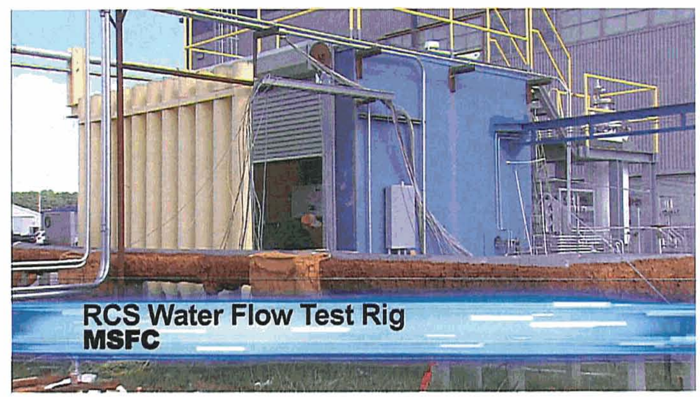
December 19, 2006

- Accomplished success criteria to complete the SRR objectives
- Identified open issues and developed closure plans
- The Ares I Project has demonstrated readiness to proceed to Preliminary Design Review (PDR)

Steve Cook, Ares Project Manager	Neil Otte, Ares Chief Engineer	Craig McArthur, Ares Core Stage Manager	Skip Hatfield, Orion Project Representative (JSC)
Dan Dumbacher, Ares Project Deputy Manager	Jim Reuter, Ares Vehicle Integration Manager	Jim Taylor, Flight & Integrated Test Manager	Dennis Webb, Mission Operations Directorate Representative (JSC)
Chris Hardcastle, Constellation Program Representative	Rick Burt, Ares First Stage Booster Manager	Chris Guidi, Headquarters Representative	Tip Talone, Ground Operations Project Representative (KSC)
Alex Priskos, Engineering Director	Danny Davis, Ares Upper Stage Manager	Eric Boe, Crew Representative (JSC)	David Martin, Shuttle Propulsion Representative
Roy Malone, Safety & Mission Assurance Director	Mike Kynard, Ares Upper Stage Engine Manager		

Conducted Successful Ares SRR

Monopropellant RC Thruster Testing



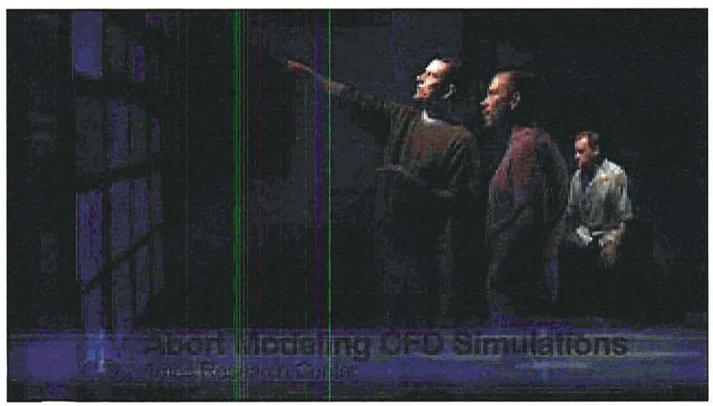
RCS Water Flow Test Rig – MSFC

The Nationwide Team is actively engaged and making valuable progress.

Vehicle Integration

Ares I Wind Tunnel Tests – Boeing & Langley Research Center

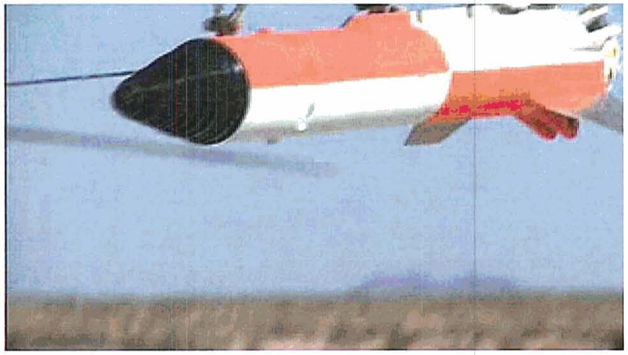
High Fidelity Truncated Model Testing – MSFC



Abort Model CFD Simulations – Ames Research Center

Early testing is informing trade studies and design decisions.

First Stage Development & Testing



Pilot Parachute Testing –
Yuma Proving Ground
New Mexico

Development of new First Stage Hardware –
ATK Utah

New Nozzle Hardware – Votaw Precision Technologies

Measurement of Roll Torque –
ATK Utah

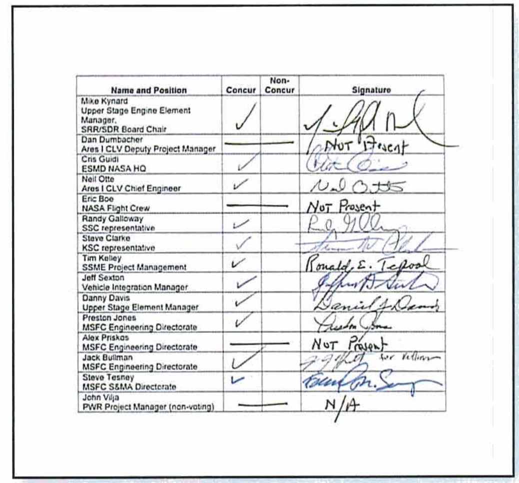
Conducted Successful First Stage SRR

Heritage hardware from the Space Shuttle is being adapted for new applications.

Upper Stage Engine

Dismantle of X-33 J-2S Turbo Machinery – Stennis Space Center (SSC)

Test Stand A-I Handover to Ares – SSC



Name and Position	Concur	Non-Concur	Signature
Mike Kynard Upper Stage Engine Element Manager, SRR/SDR Board Chair	✓		
Dan Dumbacher Ares I CLV Deputy Project Manager	—		Not Present
Cris Guidi ESMD NASA HQ	✓		
Neil Otte Ares I CLV Chief Engineer	✓		
Eric Boe NASA Flight Crew	—		Not Present
Randy Galloway SSC representative	✓		
Steve Clarke KSC representative	✓		
Tim Kelley SSME Project Management	✓		
Jeff Sexton Vehicle Integration Manager	✓		
Danny Davis Upper Stage Element Manager	✓		
Preston Jones MSFC Engineering Directorate	✓		
Alex Priskos MSFC Engineering Directorate	—		Not Present
Jack Bullman MSFC Engineering Directorate	✓		
Steve Tesney MSFC S&MA Directorate	✓		
John Vilja PWR Project Manager (non-voting)	—		N/A

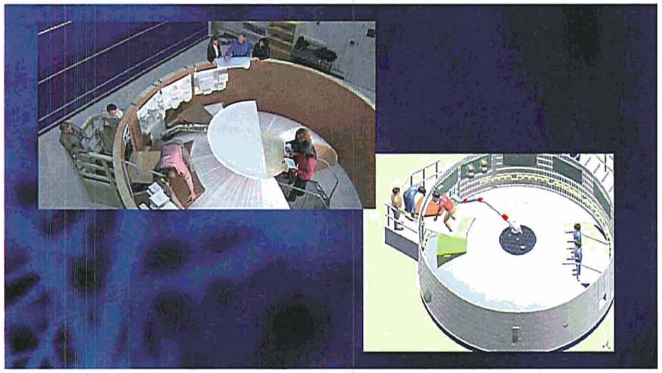
Conducted Successful Upper Stage Engine SRR/SDR

J-2X Component Development – MSFC

J-2X Powerpack Assembly/Disassembly

Saturn V engines form a foundation of legacy knowledge.

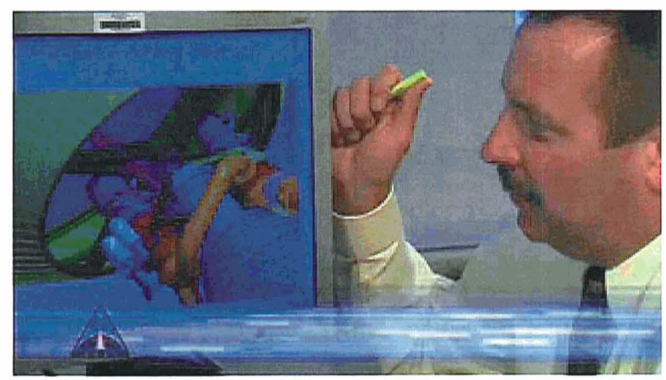
Upper Stage



Mock-up of Ares I Instrument Unit with CAD Imagery

Ares - 1 Upper Stage Manufacturing Flow – MSFC

Friction Stir Welding Development – MSFC

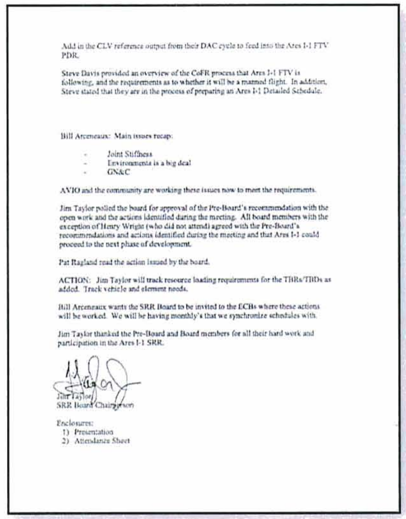


J-2X Actuator Design

NASA is designing and will partner with industry for manufacturing.

Flight & Integrated Test

Ares I-X Roll Control System – MSFC



Add in the CLV reference output from their DAC cycle to feed into the Ares I-1 FTV PDR.

Steve Davis provided an overview of the CoFR process that Ares I-1 FTV is following, and the requirements as to whether it will be a manned flight. In addition, Steve stated that they are in the process of preparing an Ares I-1 Detailed Schedule.

Bill Arceneaux: Main issues recap:

- Joint Stiffness
- Environments is a big deal
- GN&C

AVIO and the community are working these issues now to meet the requirements.

Jim Taylor polled the board for approval of the Pre-Board's recommendation with the open work and the actions identified during the meeting. All board members with the exception of Henry Wright (who did not attend) agreed with the Pre-Board's recommendations and actions identified during the meeting and that Ares I-1 could proceed to the next phase of development.

Pat Ragland read the action issued by the board.

ACTION: Jim Taylor will track resource loading requirements for the TBRs/TBDs as added. Track vehicle and element needs.

Bill Arceneaux wants the SRR Board to be invited to the ECBs where these actions will be worked. We will be having monthly's that we synchronize schedules with.

Jim Taylor thanked the Pre-Board and Board members for all their hard work and participation in the Ares I-1 SRR.

Jim Taylor
SRR Board Chairperson

Enclosures:
1) Presentation
2) Attendance Sheet

Successful
Ares I-X SRR

Fabrication of the Ares I-X
Flight Hardware

Ares I-X Systems Integration Lab –
Lockheed Martin

Ares I-X Avionics / Solid Rocket Booster (SRB) Thrust Vector Control (TVC) Test – MSFC

First test flight is in April 2009.

Ares I and Ares V Events (2Q/3Q 2007)

- **Upper Stage (Ares I)**
  - SRR Kickoff – February 20-21
  - SRR Preboard – March 27
  - SRR Board – April 3
  - Flight Software Readiness Review – June 14
  - Upper Stage Instrument unit RFP release – TBD
  - Upper Stage Instrument RFP award – TBD
  - Upper Stage Production Contract award – Late 2007
- **J-2X Upper Stage Engine (Ares I and Ares V)**
  - Power Pack #1A CDR – March 21-22
  - Preparations for Engine Systems Testing Continues
- **Ares I-X Test Flight**
  - PDR – May 18
  - First Stage and Vehicle Avionics Design & Fabrication Underway
  - Upper Stage Simulator Fabrication Continues
- **RS-68 Core Stage Engine (Ares V)**
  - Procurement Strategy Meeting – February 12
- **Vehicle Integration**
  - Constellation Program (CxP) PBS – May 23
  - Software Requirements Review – June 14

Common hardware between the Ares I and Ares V promotes engineering and business synergy.

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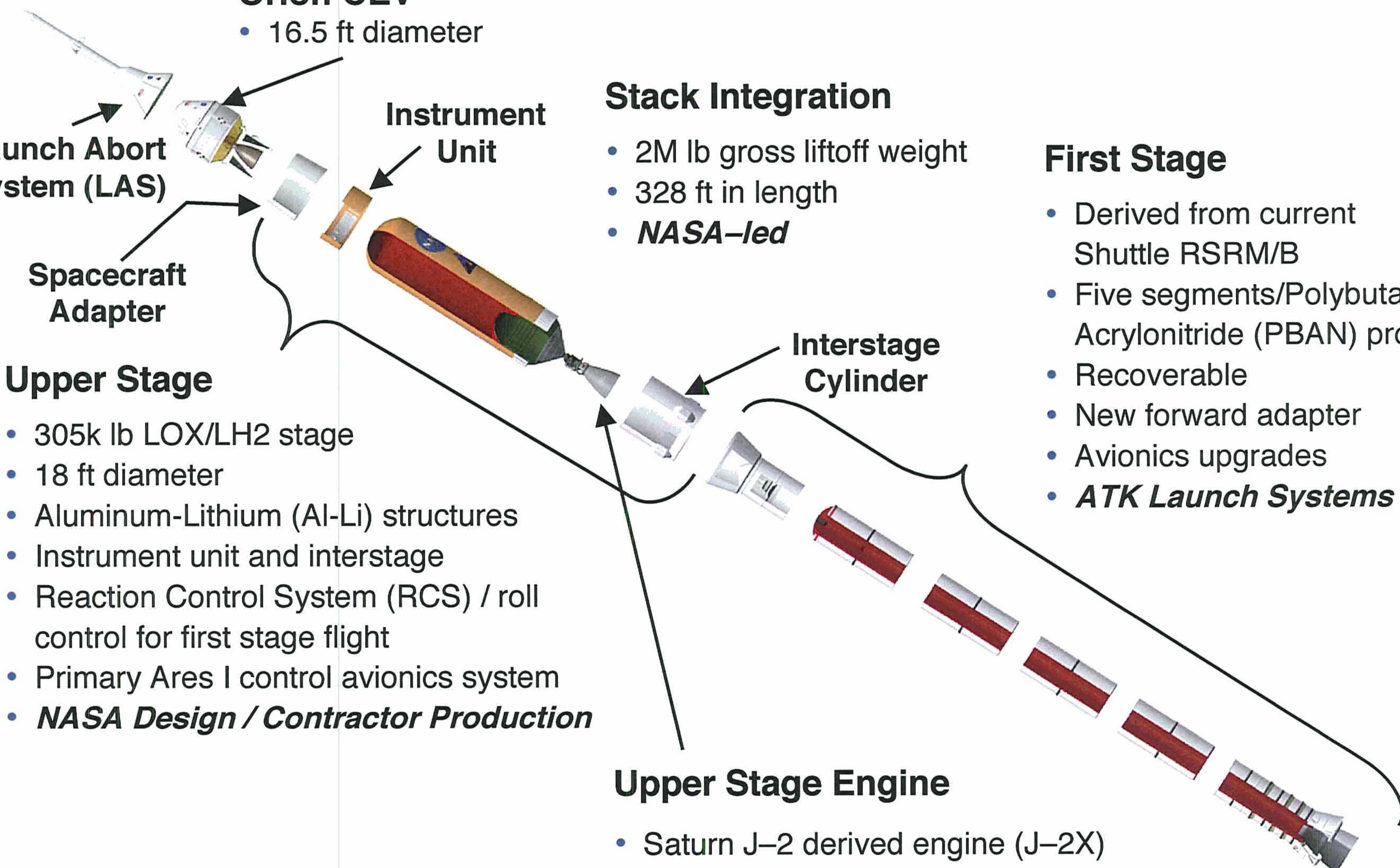
Ares I Elements



Orion CEV
- 16.5 ft diameter

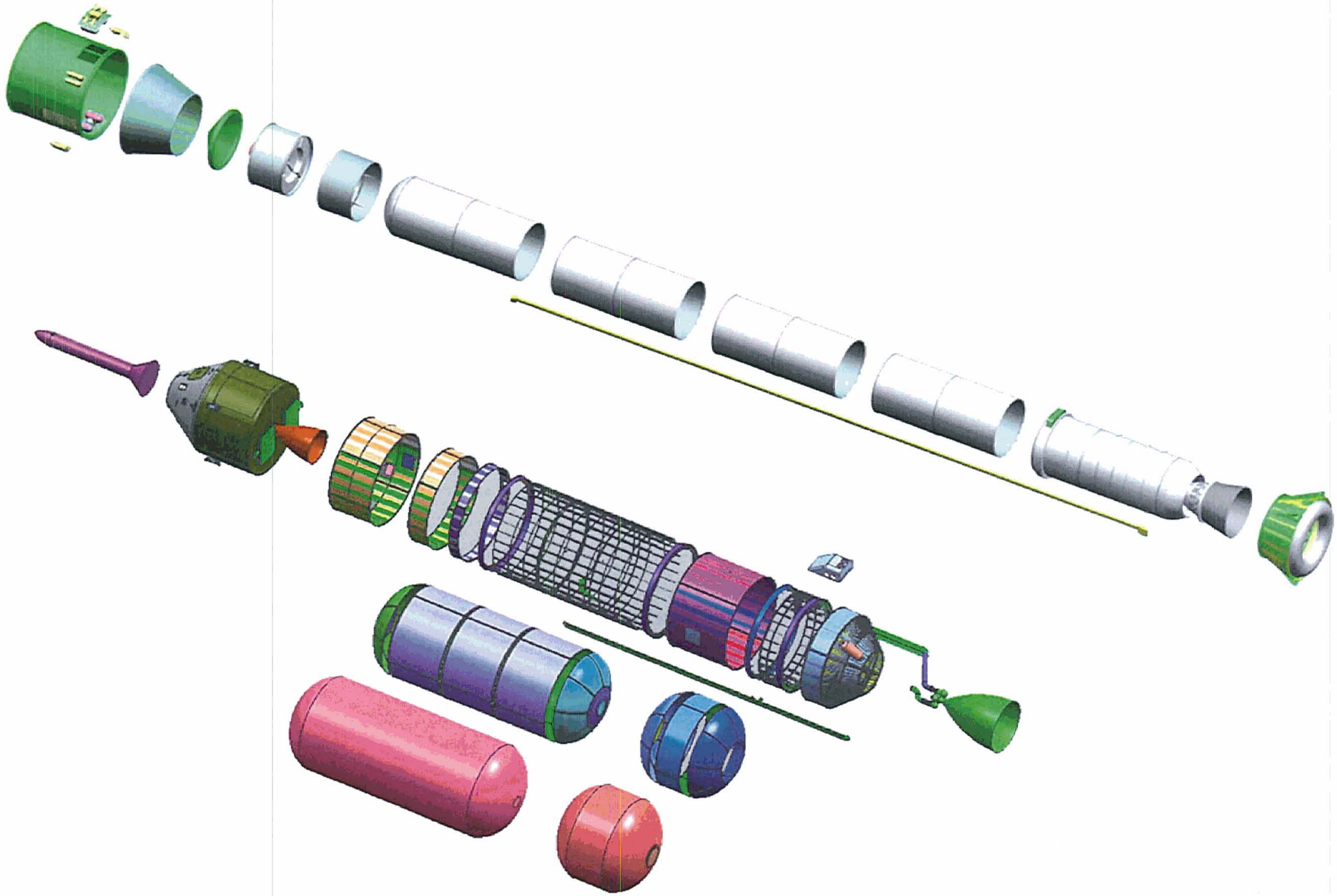
Stack Integration
- 2M lb gross liftoff weight
- 328 ft in length
- ***NASA–led***

First Stage
- Derived from current Shuttle RSRM/B
- Five segments/Polybutadiene Acrylonitride (PBAN) propellant
- Recoverable
- New forward adapter
- Avionics upgrades
- ***ATK Launch Systems***

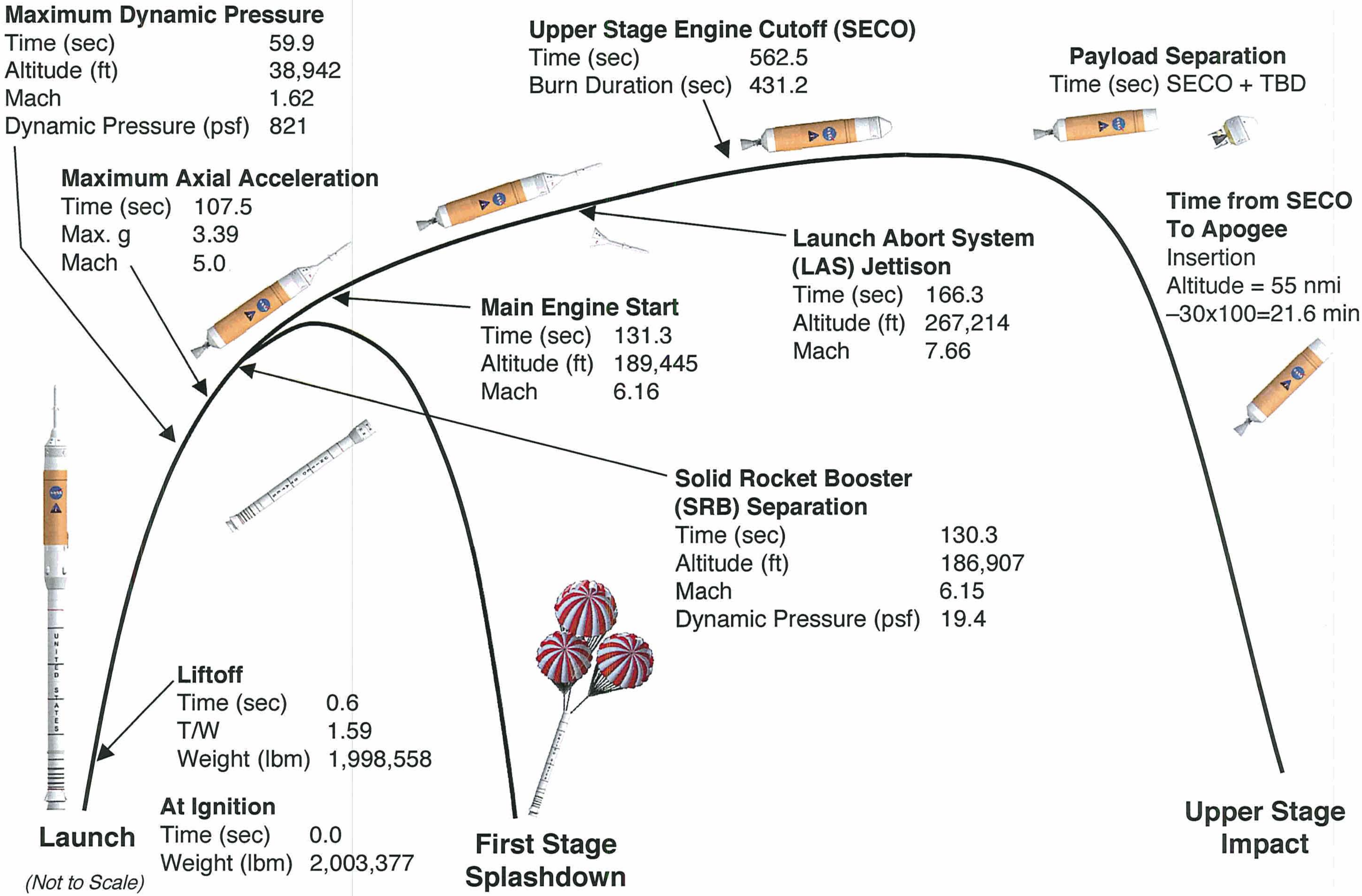
Upper Stage
- 305k lb LOX/LH2 stage
- 18 ft diameter
- Aluminum-Lithium (Al-Li) structures
- Instrument unit and interstage
- Reaction Control System (RCS) / roll control for first stage flight
- Primary Ares I control avionics system
- ***NASA Design / Contractor Production***

Upper Stage Engine
- Saturn J–2 derived engine (J–2X)
- Expendable
- ***Pratt and Whitney Rocketdyne***

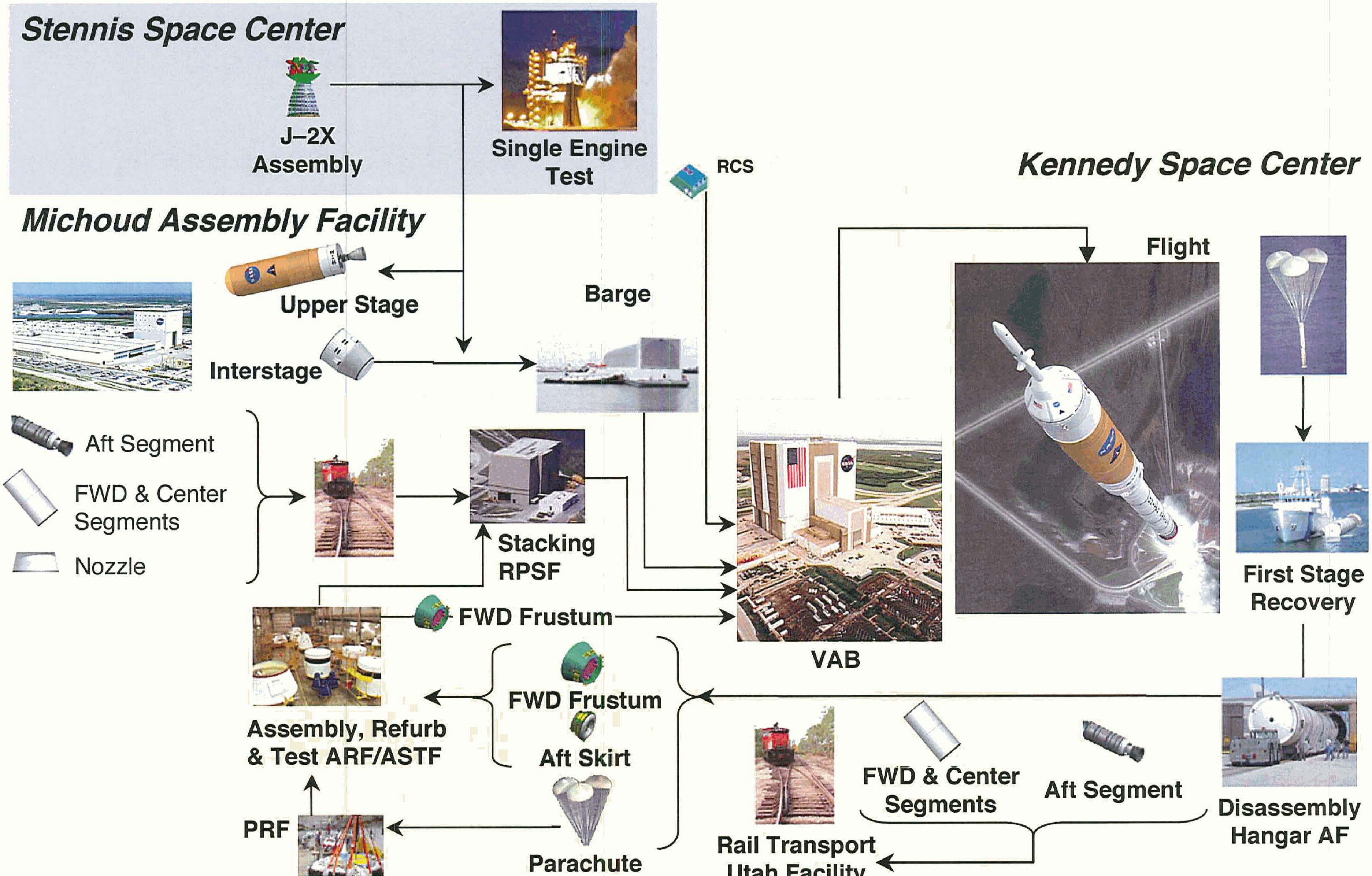
Ares I Configuration



Lunar Mission Profile



Concept of Operations



Reducing complexity for cost-effective launch solutions.

Designing for Operations

- **Operations Include Manufacturing, Logistics, Transportation, Flight Processing, Engineering & Program Support, & Refurbishment Activities**

- **Design-for-Operations Objective is to Reduce System Support Costs**
  - Both Hardware and Non-hardware Costs
  - Trade-off Between Recurring and Non-recurring Costs

- **80% of Operations Costs Are Determined During the Concept Development Phase**
  - We are in the Phase of Highest Leverage
  - One of our Emphases is on Understanding the EELV's Design and Operation Approaches and Application to Human Systems

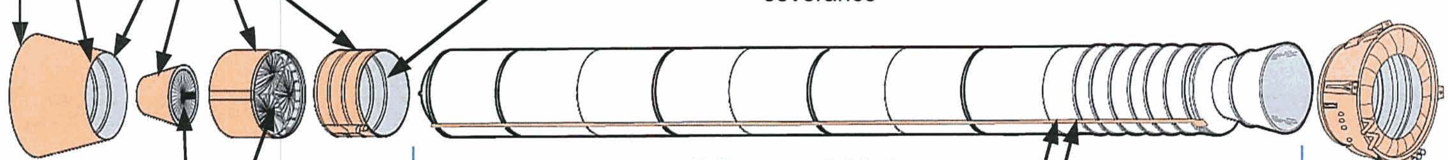
- **Design Teams Include Manufacturing, Operations, and Safety Personnel Working Together to Implement a System-Level Operations Approach**

- **We have completed SRR and are Beginning the Design-for-Operations Process with the Hardware and Process Designers**

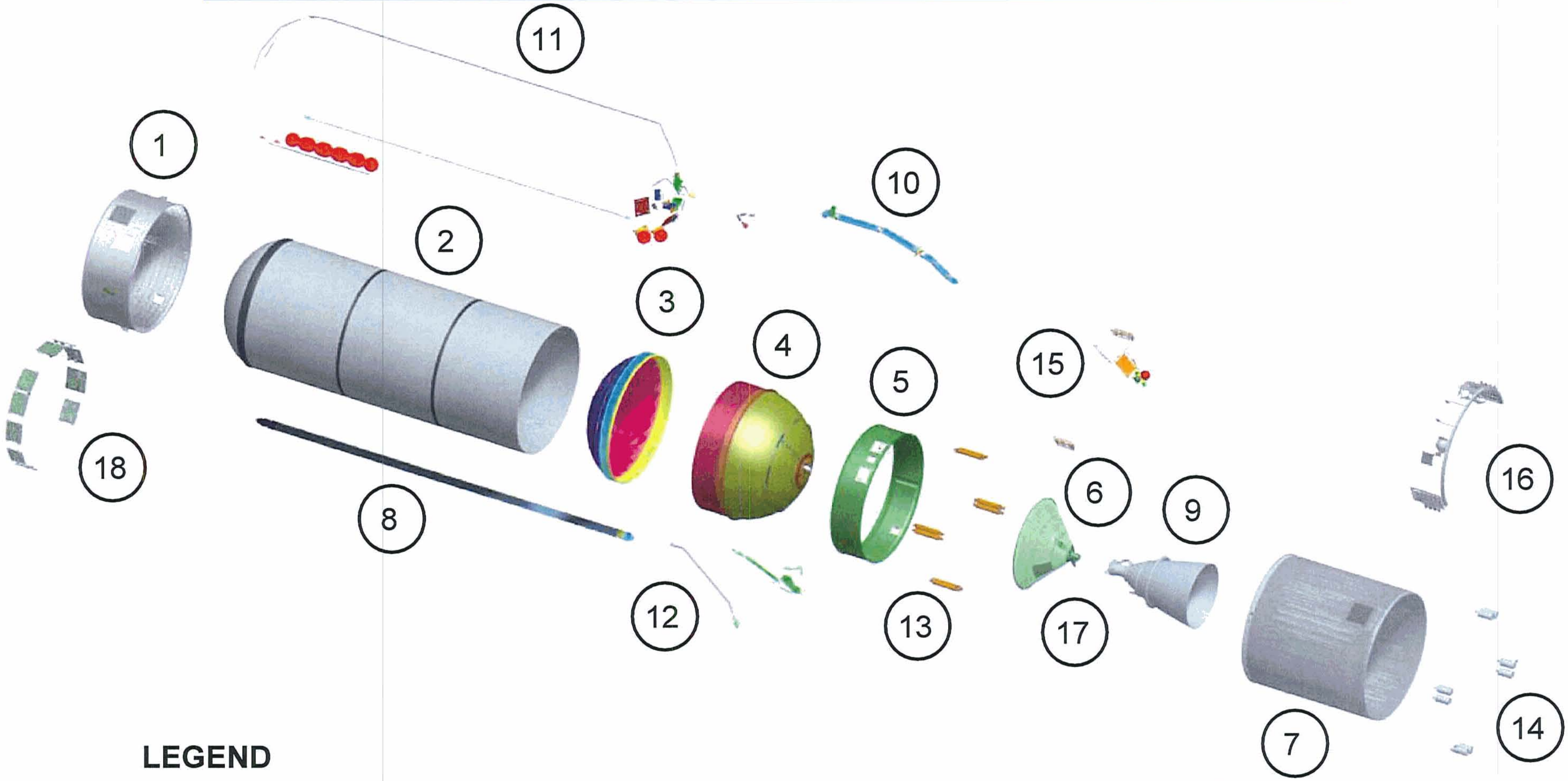
Ares Design-for-Operations Manager and Team reach across and into the Project.

First Stage System and Subsystems Description

Component	Ares I	
	Same as Shuttle RSRB	New
Aft Skirt	X	
Thrust Vector Control	Same hardware, New Avionics	
Motor		Same casing and propellant, New segment, nozzle, and propellant geometry
Systems Tunnel		Extended to all 5 segments
Range Safety		Extended to all 5 segments
Recovery		X
Forward Structures		X
Avionics and Electrical		X



Upper Stage Configuration



LEGEND

1	Instrument Unit	7	Interstage	13	Ullage Settling Motors
2	Liquid Hydrogen Tank	8	System Tunnel	14	Booster Deceleration Motors
3	Common Bulkhead	9	Upper Stage Engine	15	Upper Stage RCS
4	Liquid Oxygen Tank	10	Hydrogen System	16	First Stage RCS
5	Aft Skirt	11	Pressurization System	17	Thrust Vector Control
6	Thrust Cone	12	Oxygen System	18	Upper Stage Avionics

Upper Stage Engine (J-2X)

Loss of Mission Risk for Ares I = 1 in 1250

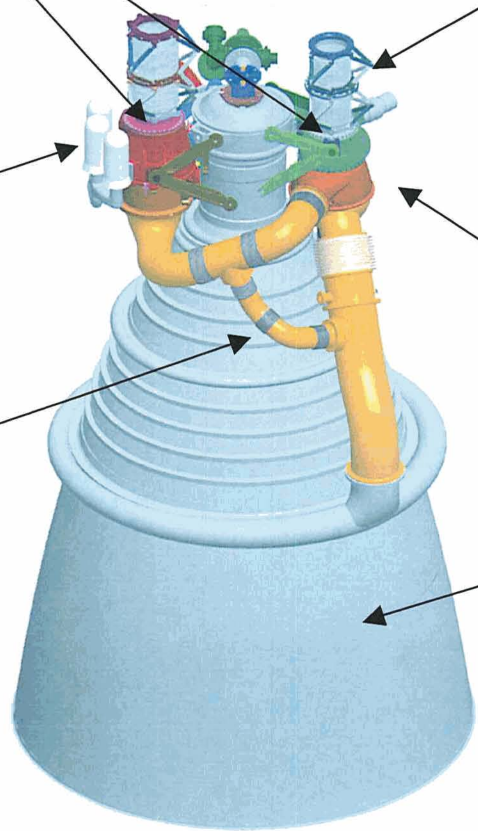
Catastrophic Risk = 1 in 8000

Operational Life = 4 starts and 2000 seconds (post-delivery)

Nominal Vacuum Thrust
- Nominal = 294k
- Precision = ±3%
- *Open-loop control*

Mixture Ratio
- Nominal = 5.5
- Precision = ±2%
- *Open-loop control*

Engine Gimbal
- 4-degree square



Altitude Start and Orbital Re-Start
- Start at > 100,000 ft.
- Second start after 95 days on orbit

Health and Status Monitoring and Reporting
Data Collection for Post-Flight Analysis
Engine Failure Notification

Secondary Mode Operation
- Thrust = ~80%
- MR = ~ 4.5

Minimum Vacuum Isp = 448 sec

Engine Mass = 5360 lbm

Engine Size = 120" D X 185" L

Fault Tolerance: Prescribed level for specific functions & 2-Fault Tolerant (FT) for catastrophic hazards & 1-FT for critical functions

Agenda

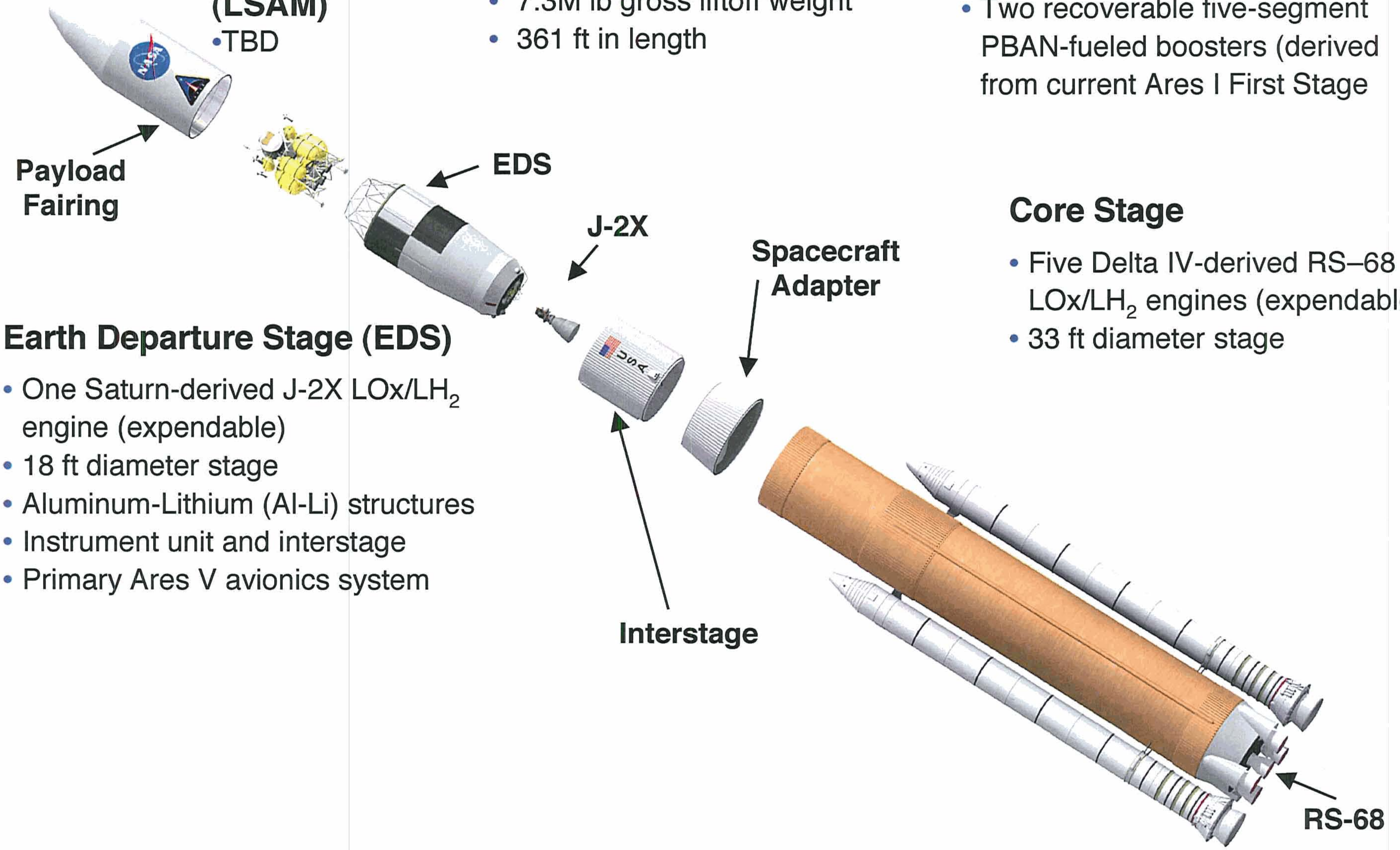
- U.S. Launch Vehicle Relevance and Design Evolution
- Ares Launch Vehicle Development
- Progress to Date
- Ares I Technical Description
- ▶ Ares V Technical Description
- Summary

Ares V Configuration

Lunar Surface Access Module (LSAM)
- TBD

Stack Integration
- 7.3M lb gross liftoff weight
- 361 ft in length

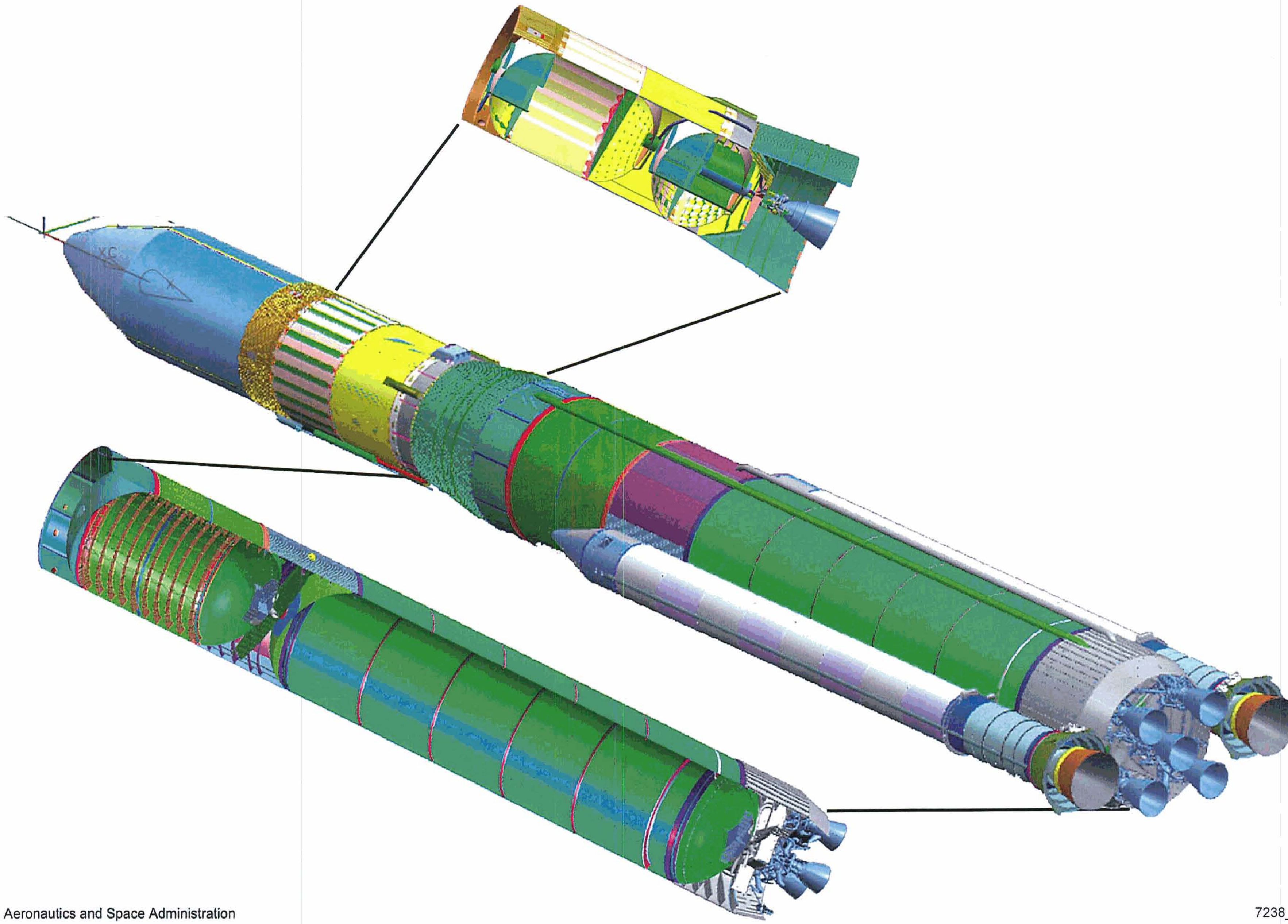
First Stage
- Two recoverable five-segment PBAN-fueled boosters (derived from current Ares I First Stage



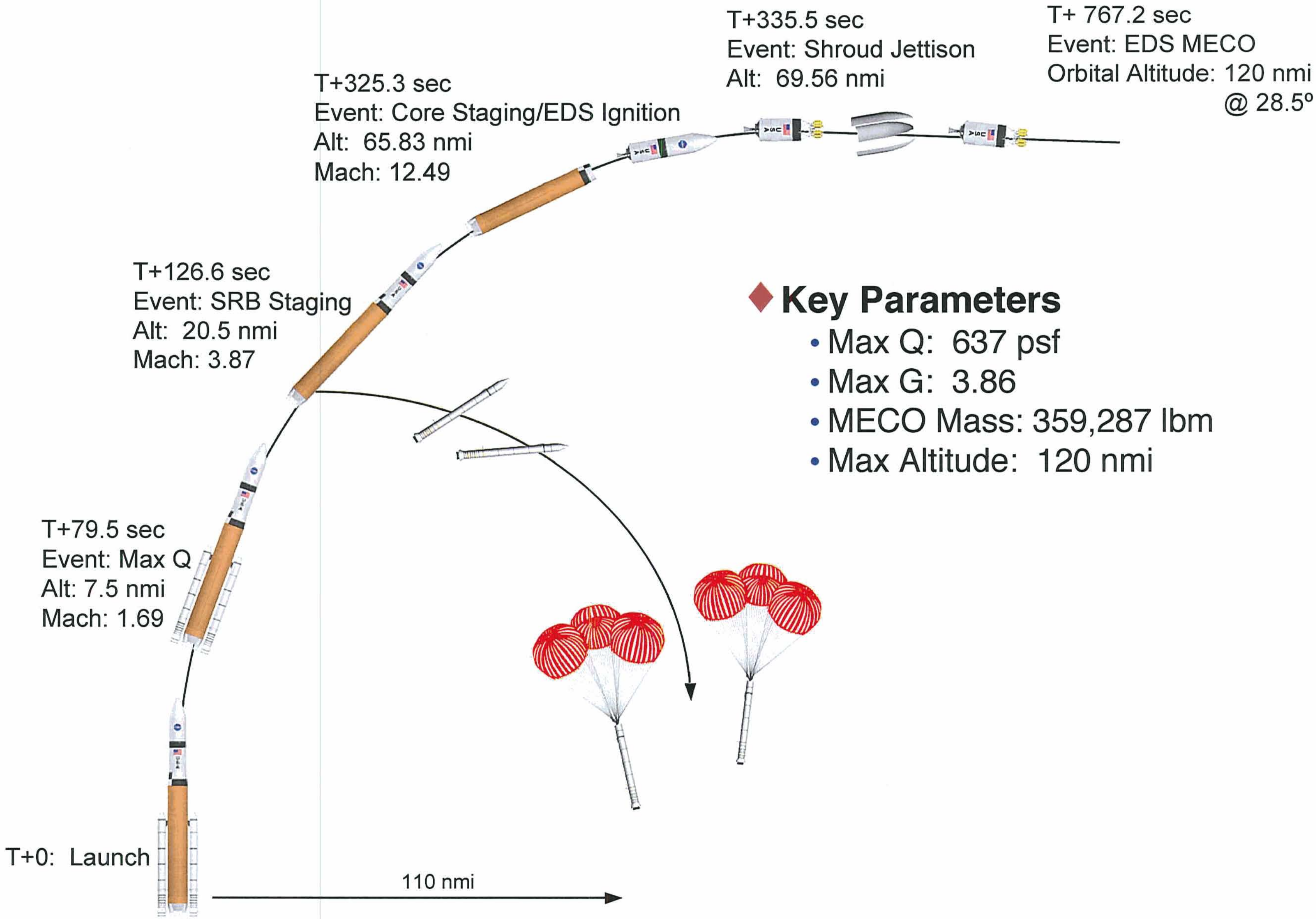
Core Stage
- Five Delta IV-derived RS–68 LOx/LH_2 engines (expendable)
- 33 ft diameter stage

Earth Departure Stage (EDS)
- One Saturn-derived J-2X LOx/LH_2 engine (expendable)
- 18 ft diameter stage
- Aluminum-Lithium (Al-Li) structures
- Instrument unit and interstage
- Primary Ares V avionics system

Ares V Configuration



Ares V Ascent Profile



◆ Key Parameters

- Max Q: 637 psf
- Max G: 3.86
- MECO Mass: 359,287 lbm
- Max Altitude: 120 nmi

Agenda

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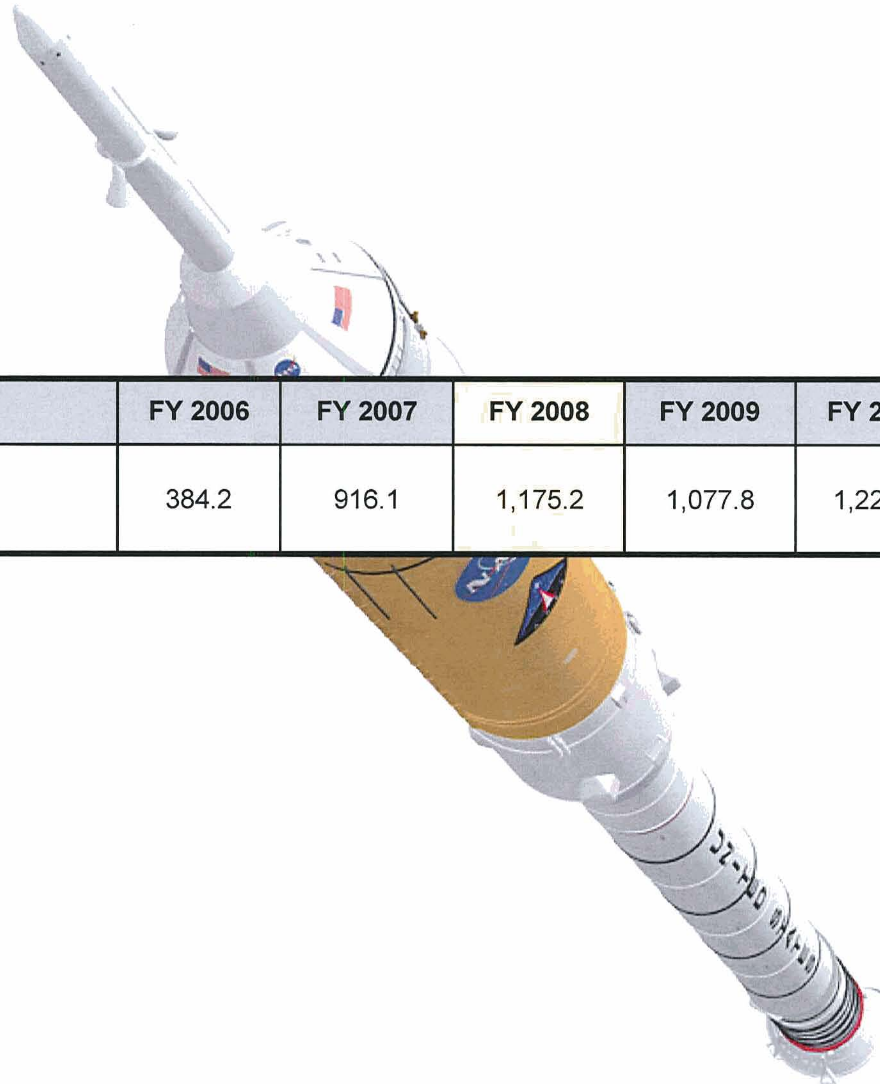
Budget Run-out by Year for Ares Development



Budget Authority ($ millions)	FY 2006	FY 2007	FY 2008	FY 2009	FY 2010	FY 2011	FY 2012
Crew Launch Vehicle	384.2	916.1	1,175.2	1,077.8	1,220.0	1,817.2	1,334.9

Ares Launch Vehicles

- **Provide the best possibility of meeting stakeholder, Congressional law, and customer requirements within the funding available and timeframe desired**
  - Smart evolution from ESAS baseline
  - Maximum leveraging of existing human-rated systems and infrastructure
  - Synergistic collaboration between the retiring Shuttle program and emerging Constellation projects
  - Hardware commonality reduces development and operations costs
- **Robust vehicle concept validated through a rigorous systems engineering design analysis cycle**
- **Operability, reliability, and safety are getting significant early attention**
- **Team is making great progress—System Requirements Review (SRR) completed and heading to Preliminary Design Review (PDR)**

First test flight in April 2009.