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Ares I Crew Launch Vehicle Upper Stage/Upper Stage Engine Element Overview
What is the Upper Stage Mission?

- The Ares I Upper Stage is an integral part of the Constellation Program transportation system.
- The Upper Stage will provide guidance, navigation, and control (GN&C) for second stage of ascent flight for the Ares I launch vehicle.
- The Saturn-derived J-2X Upper Stage Engine will provide thrust and propulsive impulse for second stage of ascent flight for the Ares I launch vehicle.
- The Upper Stage is responsible for the avionics system for the entire Ares I.

“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
Building on a Foundation of Proven Technologies
– Launch Vehicle Comparisons –

**Space Shuttle**
- Height: 56.1 m (184.2 ft)
- Gross Liftoff Mass: 2,041,166 kg (4.5M lbm)
- 25 MT (55k lbm) to Low Earth Orbit (LEO)

**Ares I**
- Height: 99.1 m (325 ft)
- Gross Liftoff Mass: 907,185 kg (2.0M lbm)
- 25.6 MT (56.5k lbm) to LEO

**Ares V**
- Height: 109.7 m (360 ft)
- Gross Liftoff Mass: 3,374,910 kg (7.4M lbm)
- 63.6 MT (140.2k lbm) to TLI (with Ares I)
- 55.9 MT (123k lbm) to Direct TLI
- ~143.4 MT (316k lbm) to LEO

**Saturn V**
- Height: 110.9 m (364 ft)
- Gross Liftoff Mass: 2,948,350 kg (6.5M lbm)
- 45 MT (99k lbm) to TLI
- 119 MT (262k lbm) to LEO
Ares I Elements

Upper Stage
- 138k kg (302 K lbm) LOX/LH₂ prop
- 5.5-m (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 / Boeing Production ($1.12B)

Instrument Unit
- Primary Ares I control avionics system
- NASA Design / Boeing Production ($0.8B)

Stack Integration
- 927 K kg (2.0 M lbm) gross liftoff weight
- 99 m (325 ft) in length
- NASA-led

First Stage
- Derived from current Shuttle RSRM/B
- Five segments/Polybutadiene Acrylonitrile (PBAN) propellant
- Recoverable
- New forward adapter
- Avionics upgrades
- ATK Launch Systems ($1.8B)

Upper Stage Engine
- Saturn J–2 derived engine (J–2X)
- Expendable
- Pratt and Whitney Rocketdyne ($1.2B)
Ares I Upper Stage

Propellant Load: 138k kg
Total Mass: 156 K kg
Dry Mass: 17.5 k kg (38.6 k lbm)
Dry Mass (Interstage): 4075 kg (8,984 lbm)
Length: 25.6 m (84 ft)
Diameter: 5.5 m (18 ft)
LOX Tank Pressure: 344.7 k Pascal (50 psig)
LH₂ Tank Pressure: 289.6 k Pascal (42 psig)
Upper Stage Engine Key Requirements and Design Drivers

Nominal Vacuum Thrust
- Nominal = 294,000 lbs
- Open-loop control

Operational Life = 4 starts and 2,000 seconds (post-delivery)

Engine Gimbal
- 4-degree square
- drives design of flexible inlet ducts and gimbal block

Mixture Ratio
- Nominal = 5.5
- Open-loop control

Health and Status Monitoring and Reporting
Data Collection for Post-Flight Analysis
Engine Failure Notification
- drives towards controller versus sequencer
- drives software development and Validation and Verification (V&V)

Altitude Start and Orbital Re-Start
- Start at > 100,000 feet (ft.)
- Second start after 5 days on orbit

Secondary Mode Operation
- Thrust = ~82%
- MR = 4.5
- Vacuum Thrust 242,000 lbs

Natural and Induced Environments
- first-stage loads on Ares I
- in-space environments for Ares V

Minimum Vacuum Isp = 448 sec
- drives size of nozzle extension
- drives increased need for altitude simulation test facility
- Nozzle Area Ratio 92:1
The J-2X Heritage: Avoiding Clean-Sheet Design

Gimbal Block
- Based on J-2 & J-2S design
- Potential upgrade to more modern, demonstrated materials

Flexible Inlet Ducts
- Based on J-2 & J-2S ducts
- Adjusted to meet J-2X performance
- Altered to meet current NASA design standards

Open Loop Pneumatic Control Valves
- Similar to J-2 and J-2S design
- Sector ball design traceable to XRS-2200 and RS-68

Main Injector
- Based on RS-68 design to meet Isp
- Augmented Spark Igniter

HIP-bonded Main Combustion Chamber
- Based on RS-68 demonstrated technology

Metallic Nozzle Extension
- New Design

Turbomachinery
- Based on J-2S MK-29 design
- Beefed up to meet J-2X performance
- Altered to meet current NASA design standards
- Helium Spin Start

Gas Generator
- Based on RS-68 design
- Scaled to meet J-2X needs
- Pyrotechnic Igniter

Engine Controller
- Based on RS-68 design and software architecture

Tube-Wall Regeneratively-Cooled Nozzle Section
- Based on J-2/J-2S and long history of RS-27 success (Delta II/III)

Heat Exchanger
- Based on J-2 experience on Saturn S-IVB Stage
What progress have we made?

♦ Programmatic Milestones
  - Completed US System Requirements Review and System Definition Review, and Preliminary Design Review
  - Contracts awarded for building the upper stage and instrument unit
  - Request for Proposal released for Manufacturing Support and Facility Operations Contract (MSFOC) at Michoud Assembly Facility

♦ Technical Accomplishments
  - Robotic Weld Tool now in operation at MSFC
  - US TVC Testing
  - US Structural Test Panels
  - Avionics Computer Test
  - First foam spray for cryogenic systems
  - First Heavy Weight Motor Test and first Ullage Settling Motor Igniter Hot-Fire
  - Al-Li 2014 dome qualification article

For more information go to www.nasa.gov/ares
Upper Stage acquisition strategy maximizes price competition
- Minimal proprietary items
  - NASA in-house design with commercial production
- Large supplier base for components
  - Boeing approach maintains competition from large supplier base
- Procure Sustaining Engineering and Operations using IDIQ (buy it by the yard)

Total cost of ownership is addressed early in the design cycle
- Safety emphasized in all phases of design and production
- Value Stream Mapping of the entire manufacturing, test, and operations flow
  - Design Production and Ops flows along with the Upper Stage product
- Design for Production and Operations
  - Boeing provides "Producibility" input to the NASA Design Team
- Optimized Manufacturing and Production Plans
  - Design for low cost manufacturing to minimize "monuments" in the production flow
- Operation Concept Analysis - to minimize "monuments" in the operations flow
  - Depots (no depot at KSC or SSC)
  - Support equipment (flexible support equipment)
  - Workforce (no standing army)
Ares I and V Production at Michoud Assembly Facility (MAF)
Test Facilities To Support J-2X Development

♦ SSC Test Stand A-1
- Powerpack testing
- Engine systems development testing
- Transferred from SSME to J-2X November 2006
- Refurbished in 2007
- Powerpack IA testing completed in 2008

♦ SSC Test Stand A-2
- Development and certification engine testing
- Pseudo-altitude testing with passive diffuser
- Engine performance verification
- Engine configuration – no nozzle ext & stubby ext
- No engine gimballing
- Engine “Acceptance Series” type testing
- Transfer from SSME to J-2X in July 2009/Testing begins April 2010
SSC A-3 Test Stand

- Development and certification engine testing
- Performance at simulated altitude (80,000 ft – 100,000 ft)
- Engine configuration – no nozzle ext, stubby extension, and full nozzle extension
- Nozzle extension development and certification (4 units)
- Engine gimballing
- Engine Performance verification
- Vertical position hot-fire testing
- May 2007 Authority to Proceed
- Fall 2008 structural steel erected
- June 2010 Ready to Test
J-2X Testing
Operational Flow

4.1 Receiving inspection

4.2 Stage stack

4.3 CLV integration test

4.4 Roll to launch pad

Wet dress rehearsal?

Yes

4.5 Wet dress rehearsal

4.6 Rehearsal recycle

No

4.7 Launch preparation

4.8 Launch scrub/abort

Launch?

Yes

To 5.0

No

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Launch?

Yes

To 5.0

No

Sample flow from the J-2X Concept of Operations

Graphic representation of overall J-2X Concept of Operations
Merged Manufacturing Flow

- Manufacturing Value Stream Map
  - Vertical Tack and Weld
  - Horizontal TPS Application
- Producability Summit
- Manufacturing Plan
- Manufacturing Floor Plan at Michoud
- Tooling Design and Fabrication

**Common Test Cell**

**Critical Path**

**Vertical Tank Assembly**

**Common Bulkhead**

**Metrics**
- NASA Baseline: 420 days
- Boeing Contract: 347 days
- Merged VSM: 320 days
- With learning: <300 days

Boeing, working with NASA, Reduced Assembly Flow Over 100 days
Manufacturing & Assembly Weld Tools

Vertical Weld Tool (VWT)
Barrel-Barrel, Conventional FSW

Robotic Weld Tool (RWT)
MSFC Bldg 4755

gore-gore, dome-y ring, dome-fitting
Self-Reacting Friction Stir Welding (FSW)

Vertical Circumferential Weld Tool
Concept
Conclusion

♦ Building on the heritage of the Apollo and Space Shuttle Programs, the Ares I US and USE teams are utilizing extensive lessons learned to place NASA and the United States into another great era of space exploration
  - Ares I team must build beyond its current capability to ferry astronauts and cargo to Low Earth Orbit
  - To reach for Mars and beyond, the team must first reach for the moon
  - We are using the best of NASA to design the stage, and the best of industry to build the stage

♦ NASA, Boeing, and PWR teams are now integrated, working together, and making good progress
  - Designing and building the Ares I Upper Stage to minimize:
    - Cost risks
    - Technical risks
    - Schedule risks

“This Nation has tossed its cap over the wall of space, and we have no choice but to follow it.”

-- President John F. Kennedy, 1962