J. Craig McArthur
Ares I Upper Stage Deputy Manager
September 9, 2008

Ares I Crew Launch Vehicle Upper Stage/Upper Stage Engine Element Overview

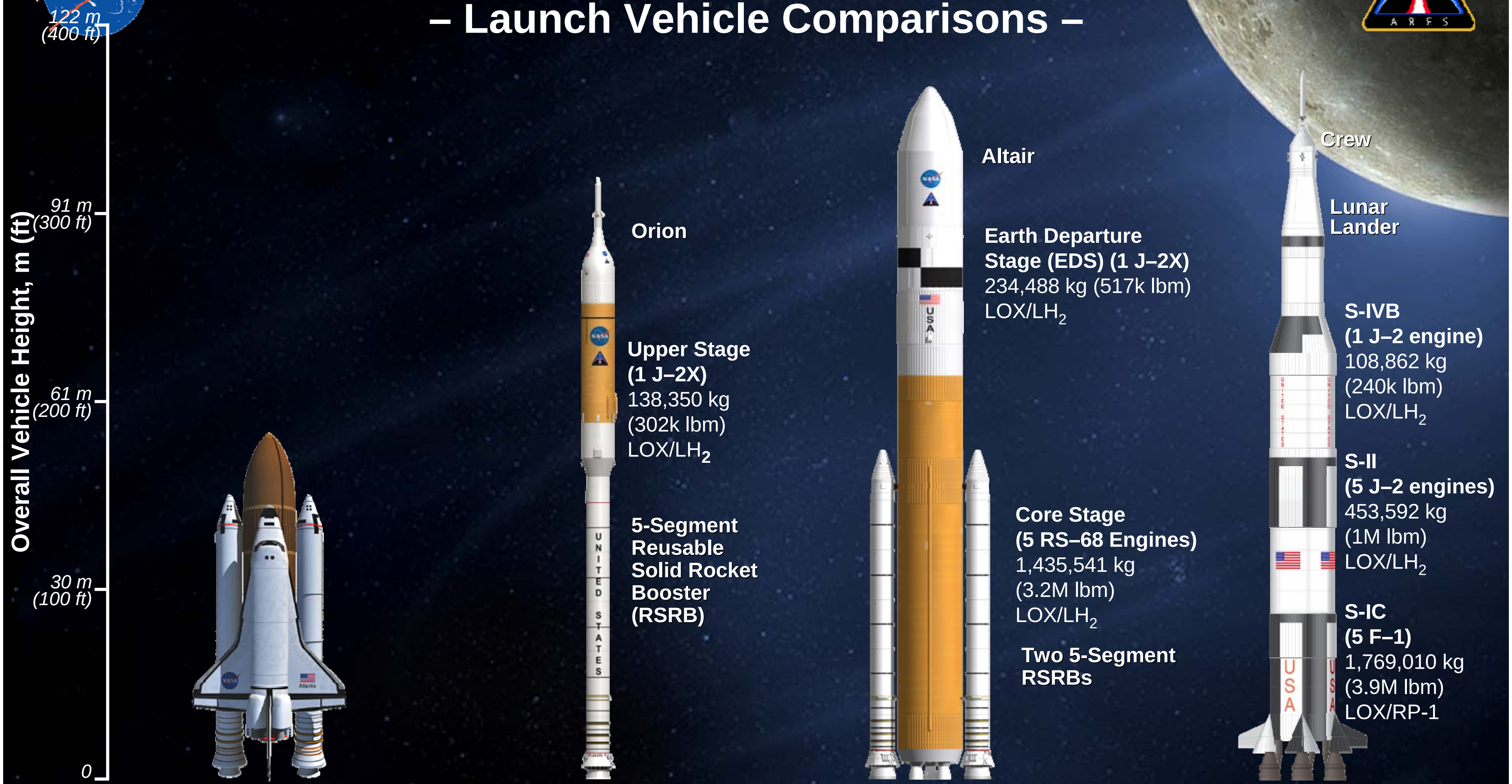
What is the Upper Stage Mission?

- 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

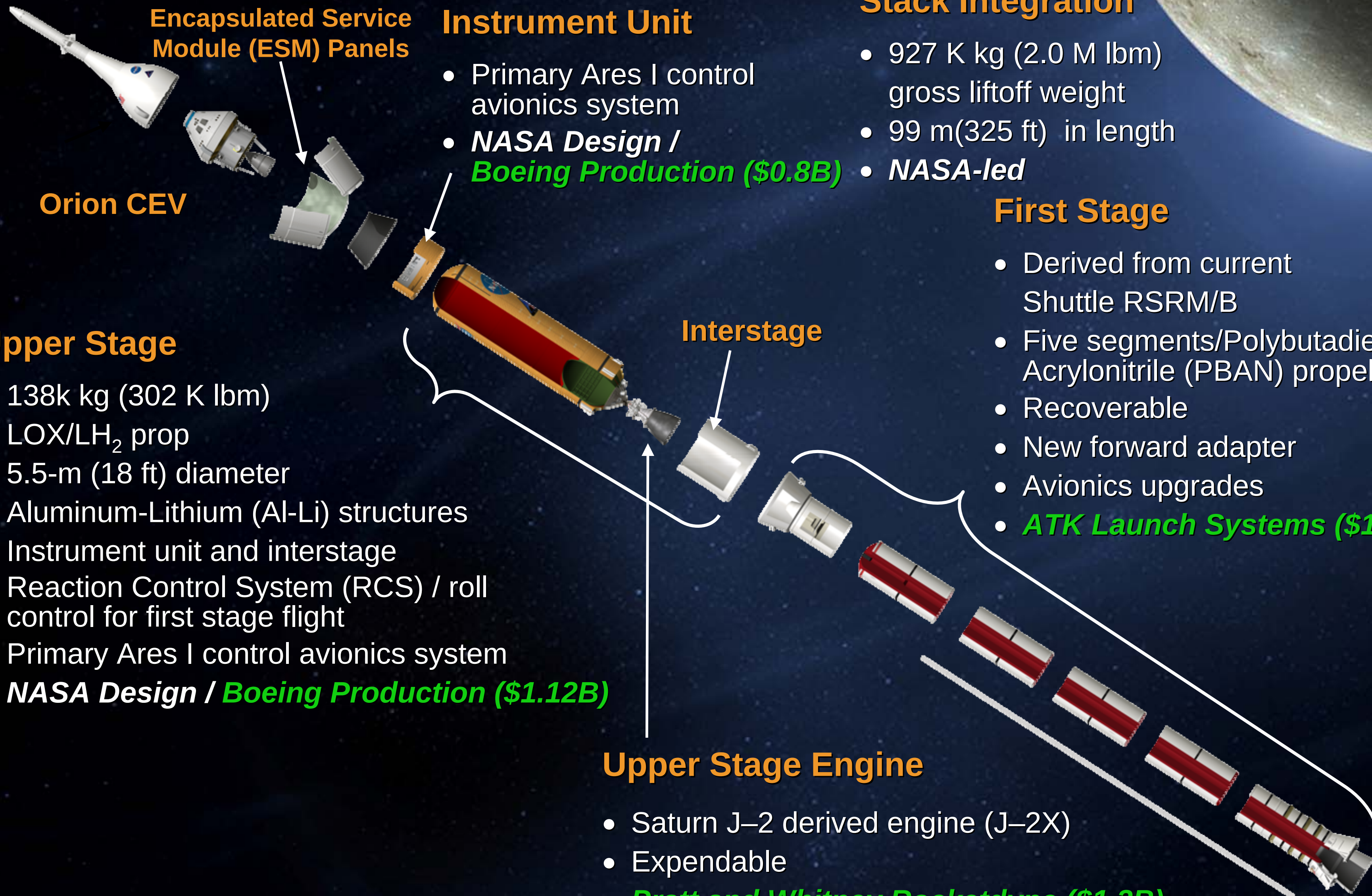
Ares V
Height: 109.7 m (360 ft)
Gross Liftoff Mass:
3,374,910 kg (7.4M lbm)

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



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)***

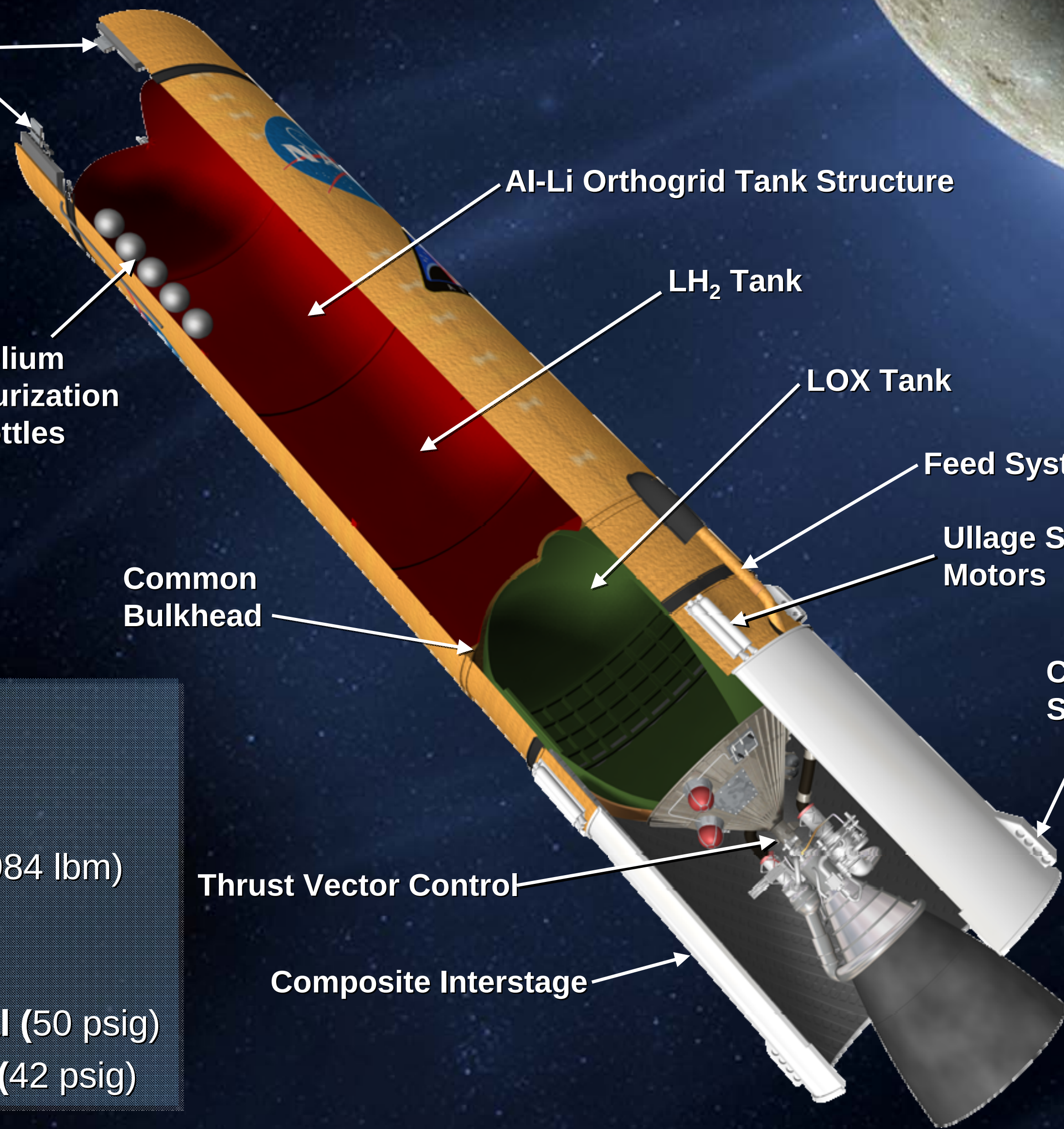
Upper Stage

- 138k kg (302 K lbm) LOX/LH_2 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)***

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)
LH_2 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)

Mixture Ratio

- Nominal = 5.5
- *Open-loop control*

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

Engine Gimbal

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

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)

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

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

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

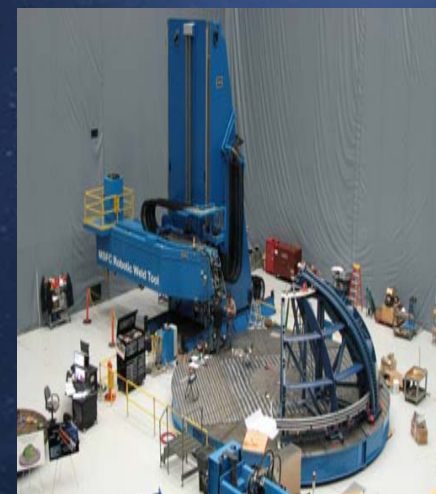
HIP-bonded Main Combustion Chamber
- Based on RS-68 demonstrated technology

Metallic Nozzle Extension
- New Design

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



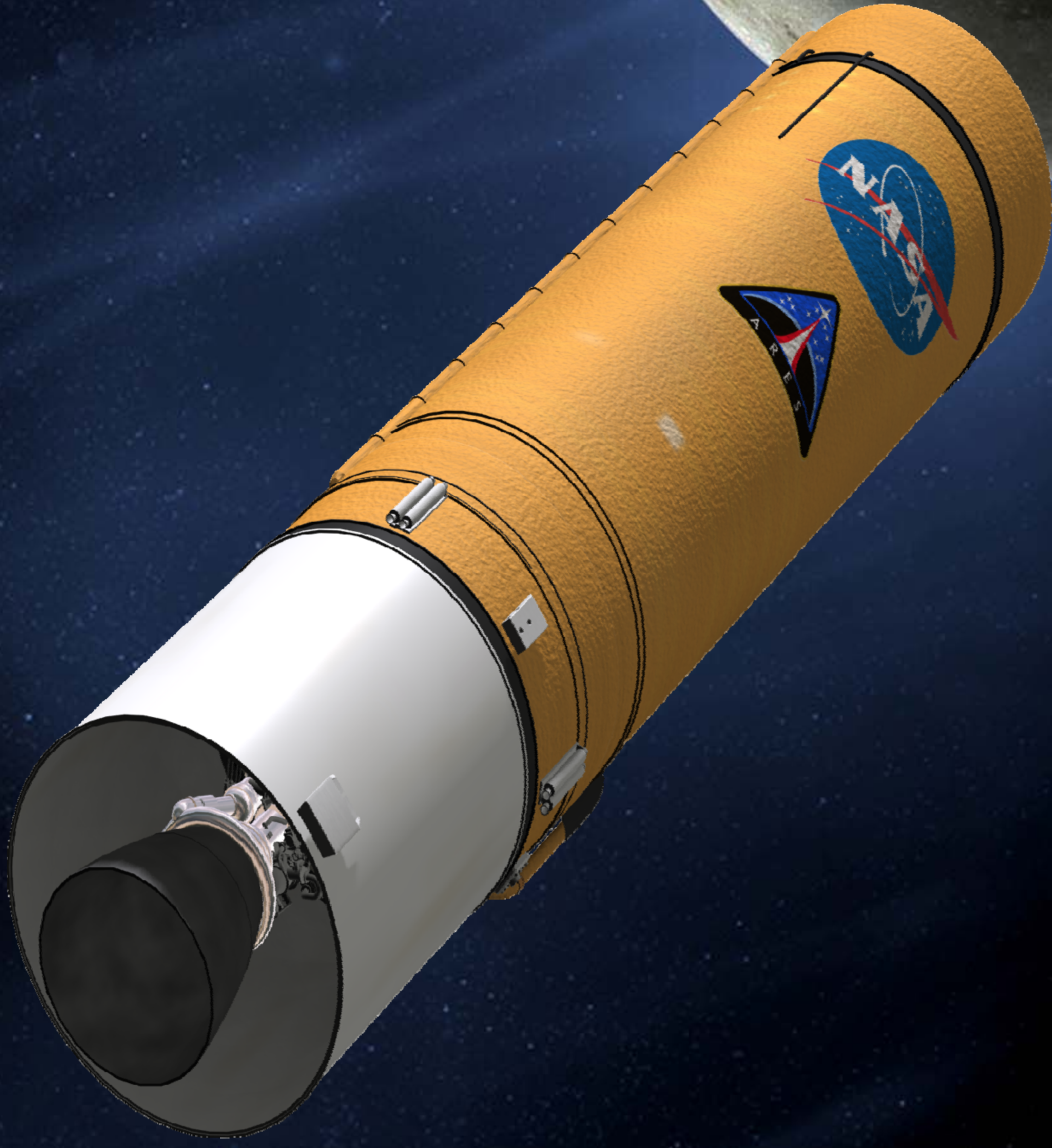
♦ Technical Accomplishments

- 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

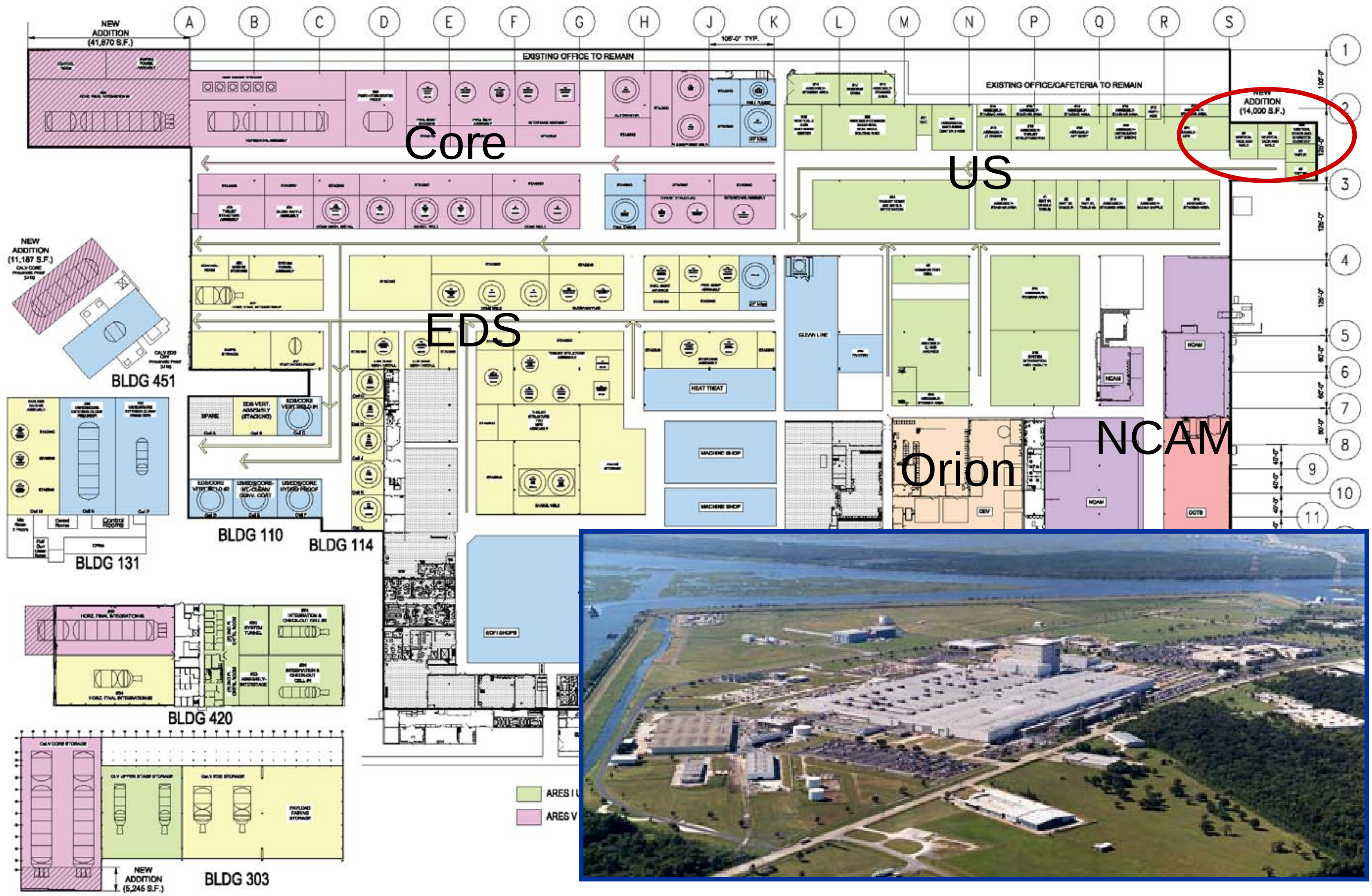
For more information go to www.nasa.gov/ares

Upper Stage Low Cost Strategy

- **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

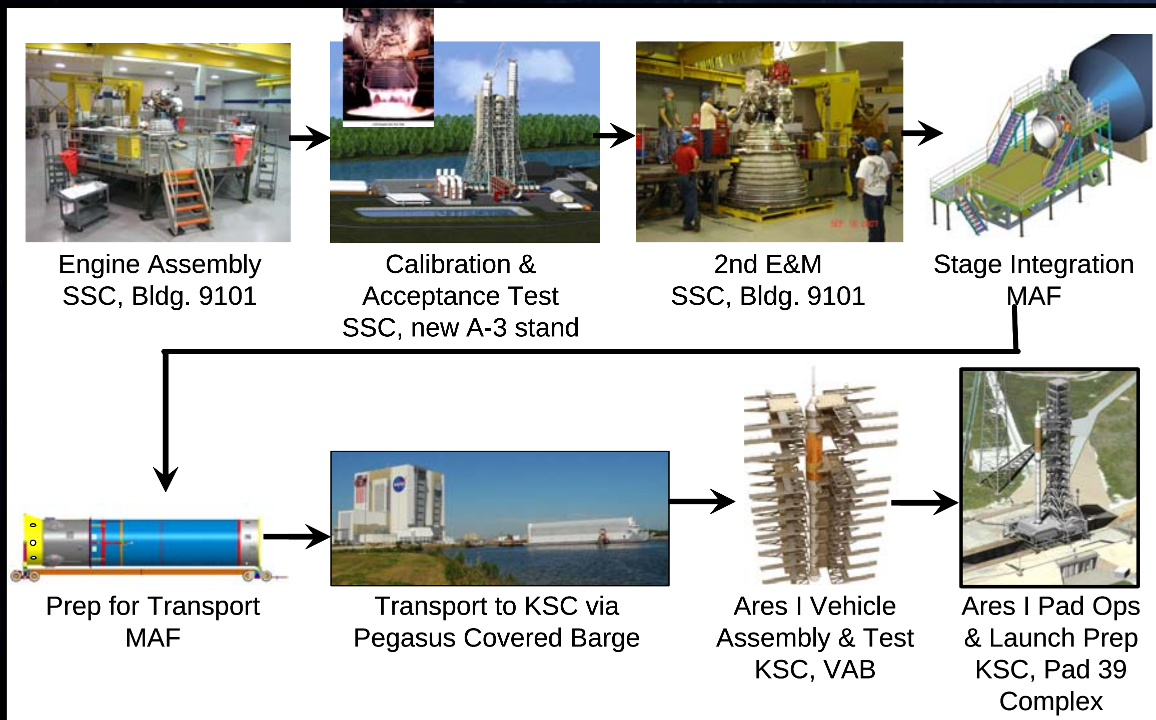
♦ **SSC Test Stand A-2**
- Development and certification engine testing
- Pseudo-altitude testing with passive diffuser
- Engine performance verification
- Engine configuration – no nozzle ext & stubby ext
- No engine gimballing
- Engine "Acceptance Series" type testing
- Transfer from SSME to J-2X in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

Test Facilities (cont'd)

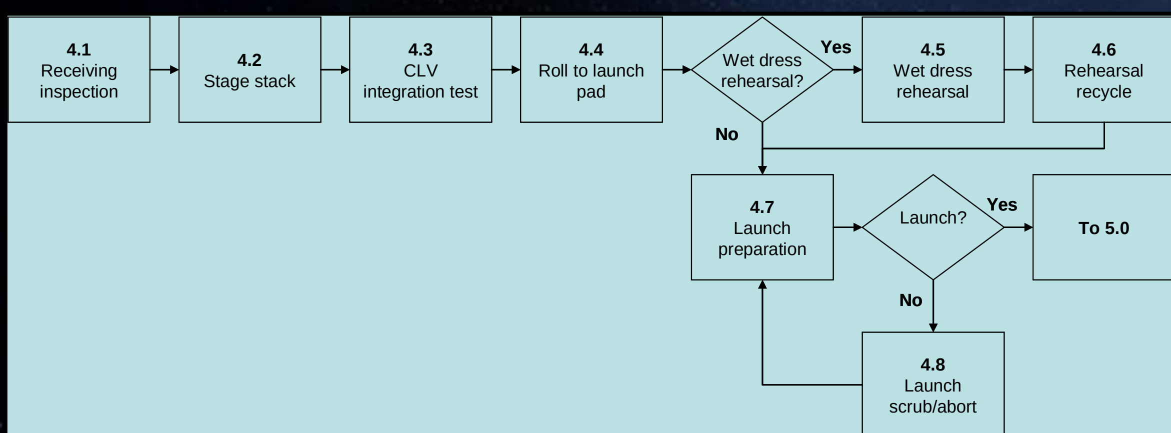
- **SSC A-3 Test Stand**
  - Development and certification engine testing
  - Performance at simulated altitude (80,000 ft – 100,000 ft)
  - Engine configuration – no nozzle ext, stubby extension, and full nozzle extension
  - Nozzle extension development and certification (4 units)
  - Engine gimballing
  - 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



Graphic representation of overall J-2X Concept of Operations

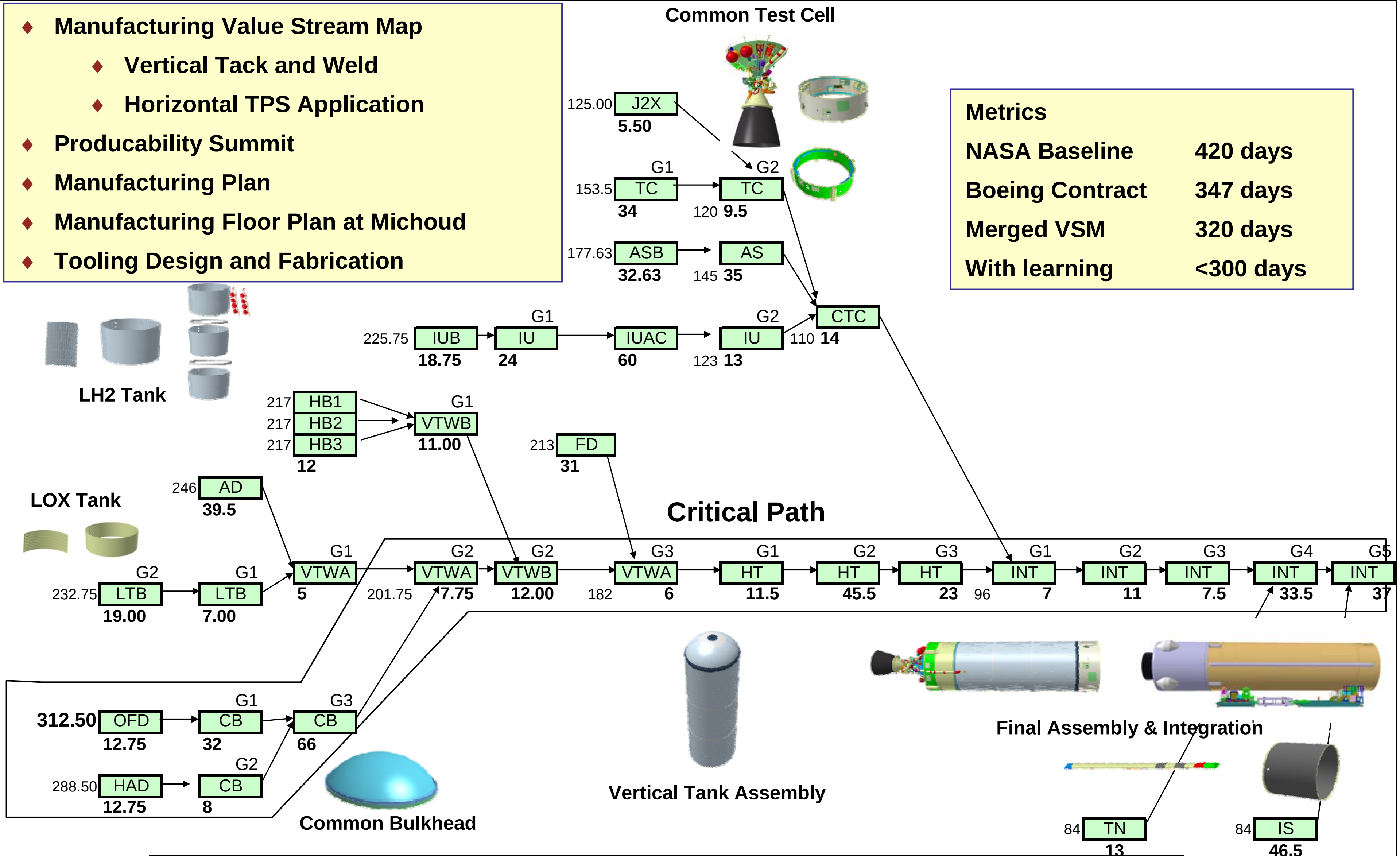


Sample flow from the J-2X Concept of Operations

Merged Manufacturing Flow

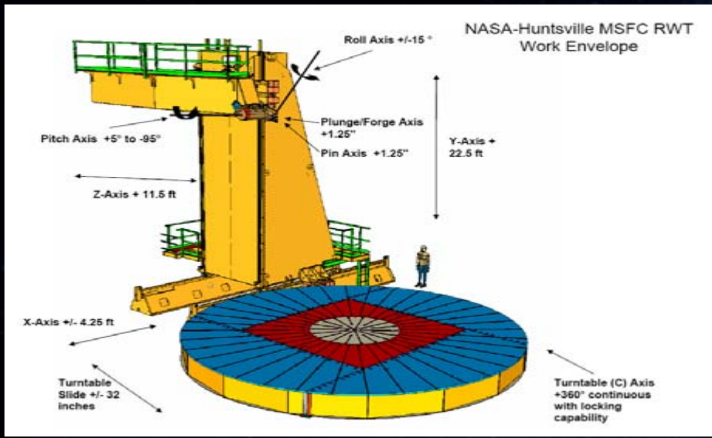
- Manufacturing Value Stream Map
  - Vertical Tack and Weld
  - Horizontal TPS Application
- Producability Summit
- Manufacturing Plan
- Manufacturing Floor Plan at Michoud
- Tooling Design and Fabrication

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

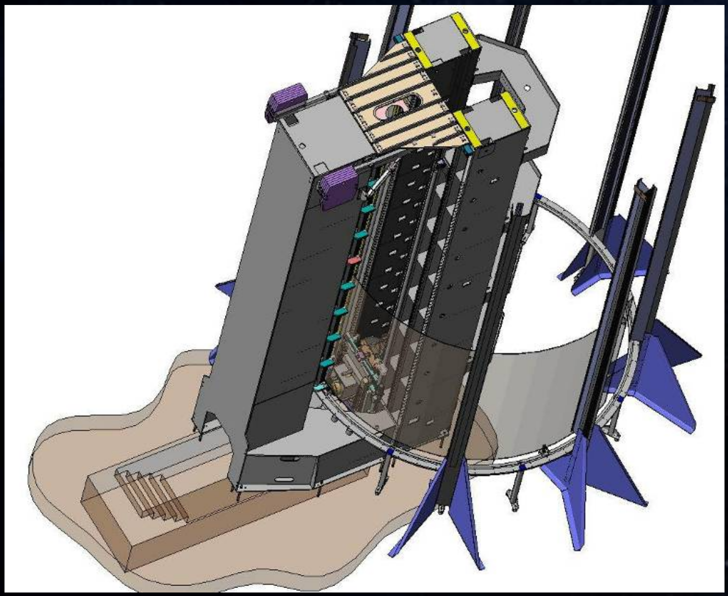
Manufacturing & Assembly Weld Tools



Robotic Weld Tool (RWT) **MSFC Bldg 4755**

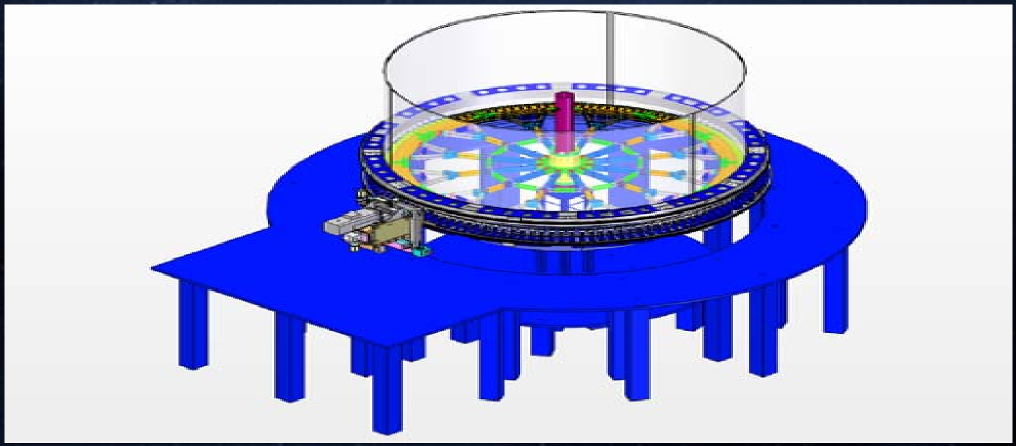
gore-gore, dome-y ring, dome-fitting

Self-Reacting Friction Stir Welding (FSW)



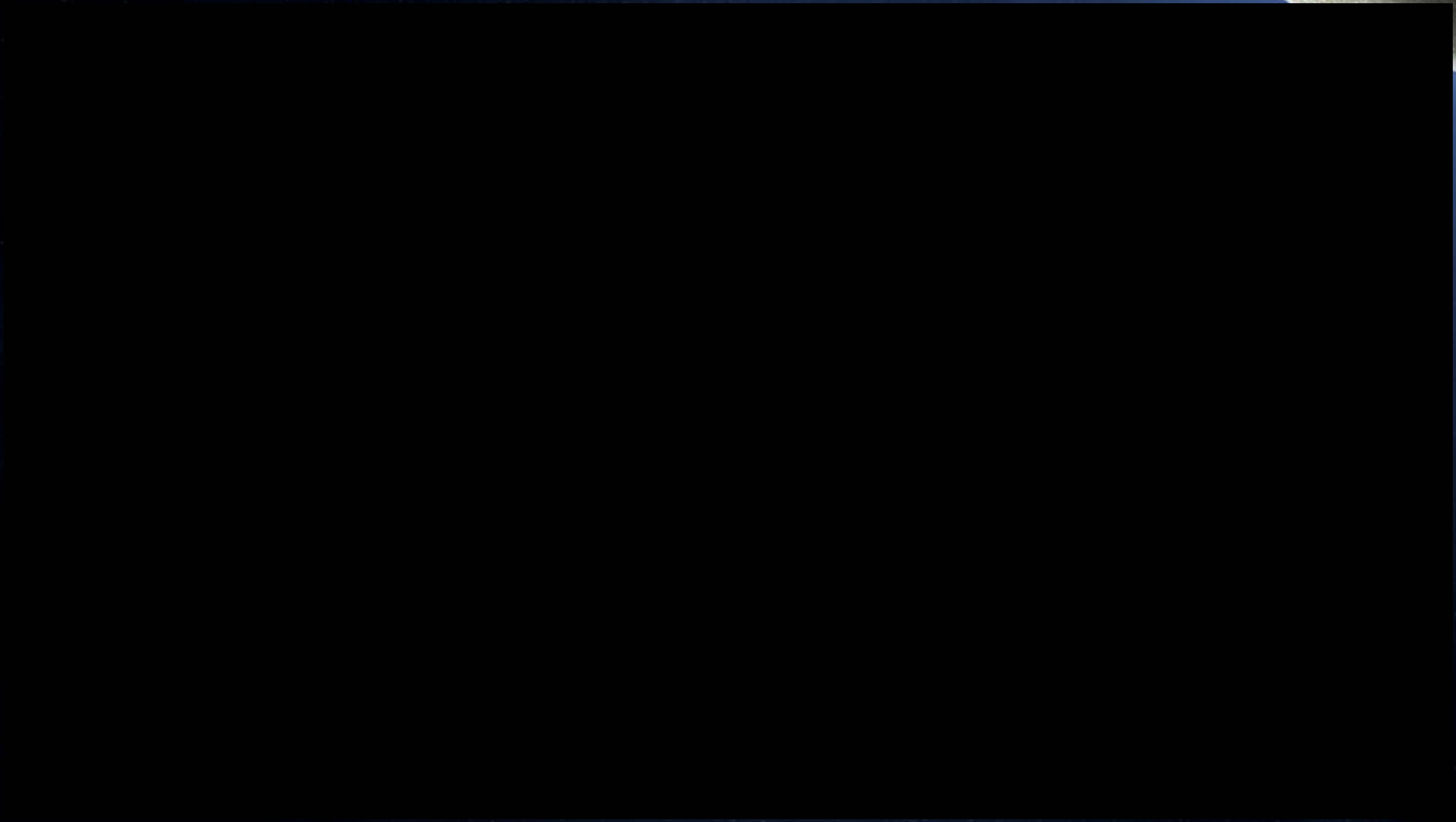
Vertical Weld Tool (VWT)

Barrel-Barrel, Conventional FSW



Vertical Circumferential Weld Tool Concept

Common Bulkhead Processing



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