J. Craig McArthur

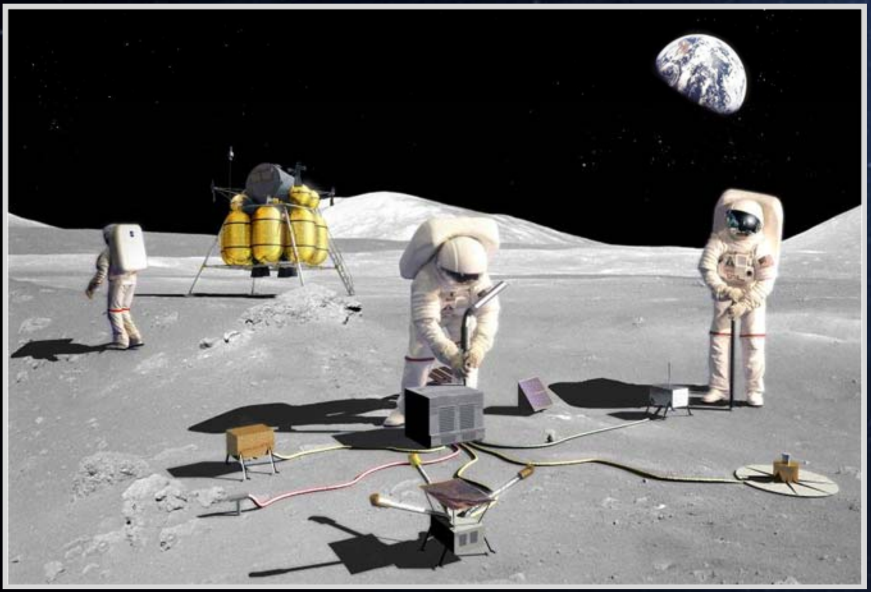
Ares I Upper Stage Deputy Manager

July 23, 2008

Ares I Crew Launch Vehicle Upper Stage Element Overview

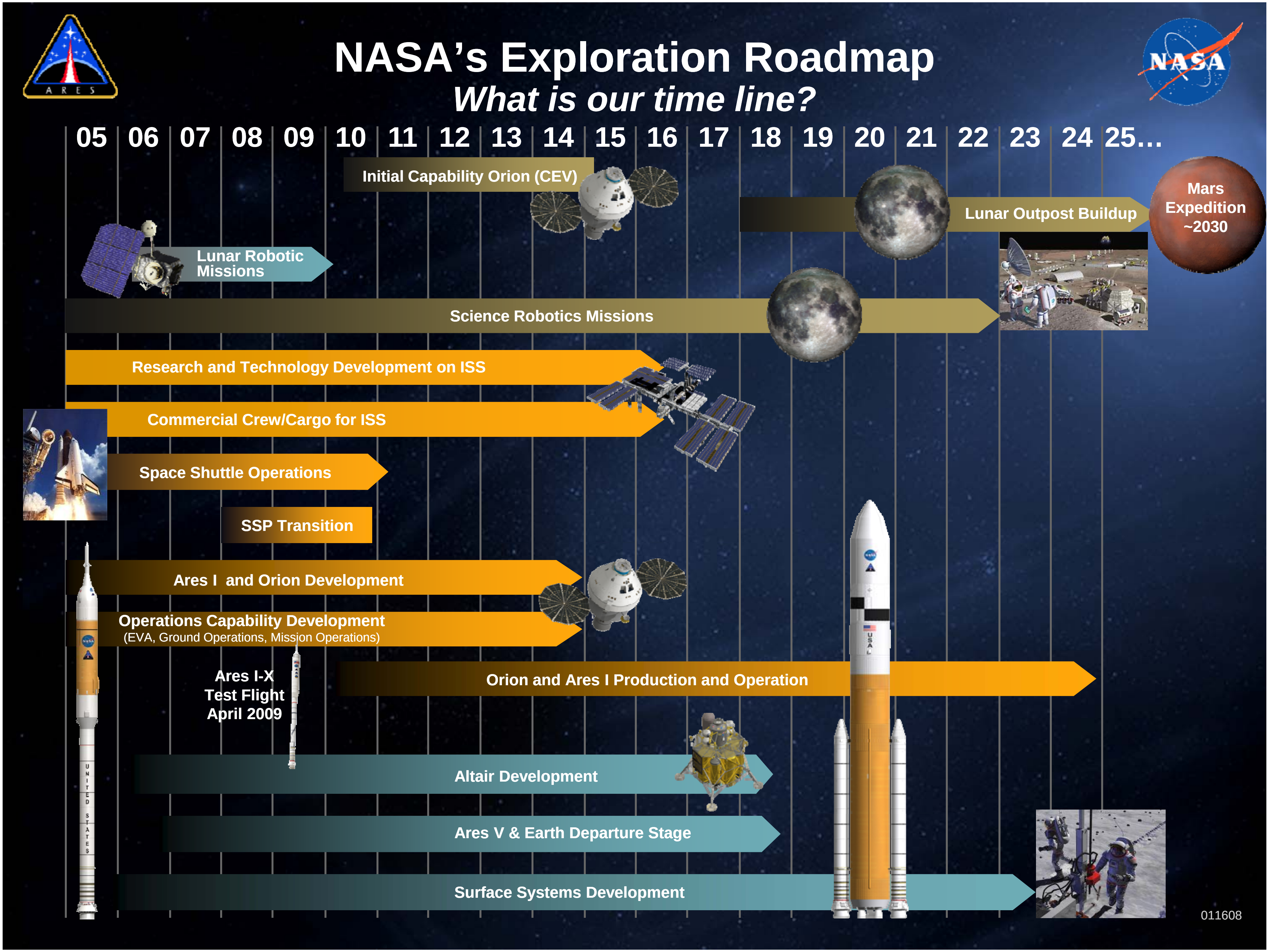
What is NASA's Mission?

- Safely fly the Space Shuttle until 2010
- Complete the International Space Station
- Develop a balanced program of science, exploration, and aeronautics
- Develop and fly the Orion Crew Exploration Vehicle (CEV)
- Return to the Moon no later than 2020
- Promote international and commercial participation in exploration

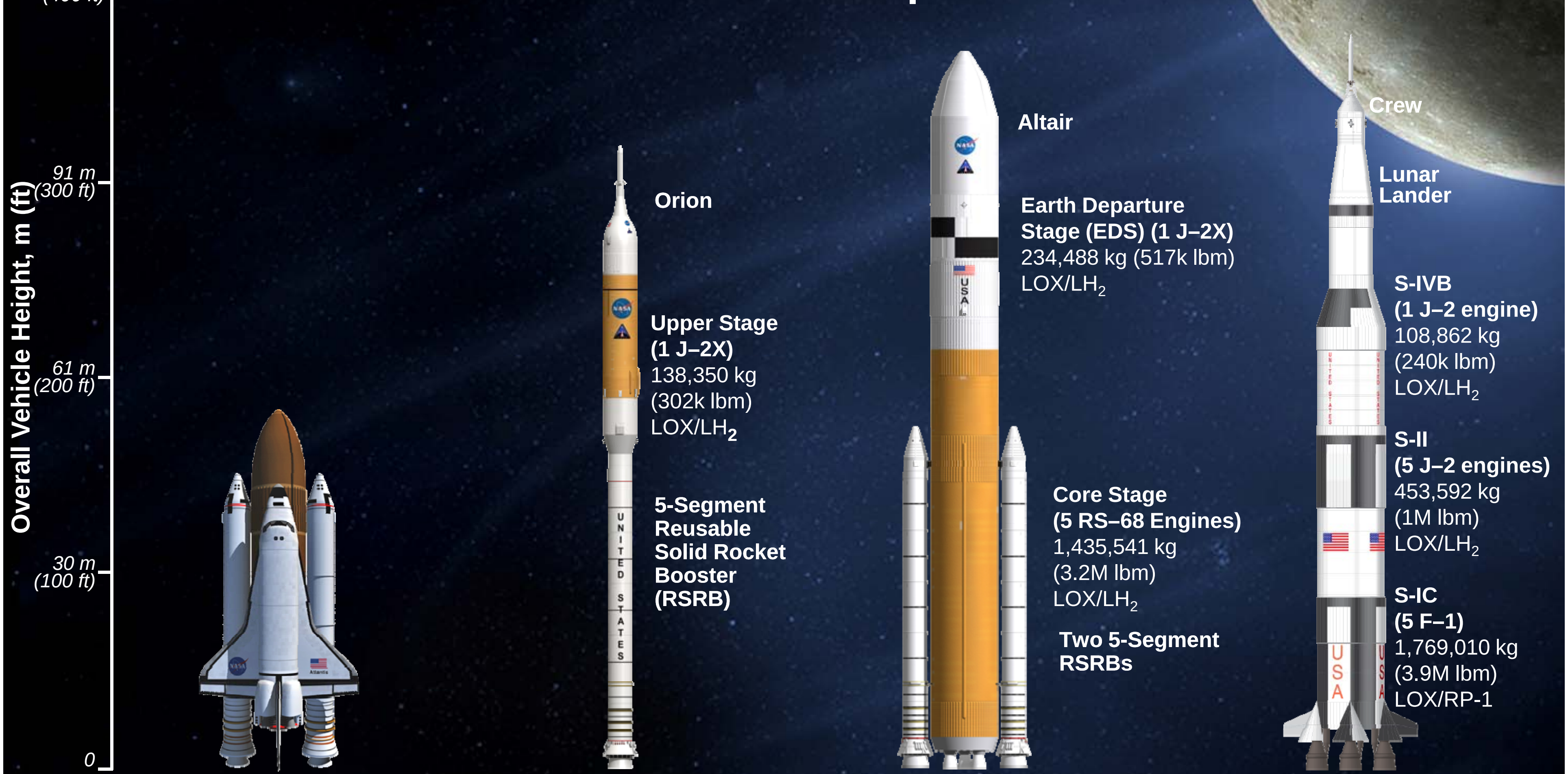


"The next steps in returning to the Moon and moving onward to Mars, the near-Earth asteroids, and beyond, are crucial in deciding the course of future space exploration. We must understand that these steps are incremental, cumulative, and incredibly powerful in their ultimate effect."

– NASA Administrator Michael Griffin
October 24, 2006


NASA's Exploration Roadmap
What is our time line?
05 06 07 08 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25…
Initial Capability Orion (CEV)
Lunar Outpost Buildup
Mars Expedition ~2030
Lunar Robotic Missions
Science Robotics Missions
Research and Technology Development on ISS
Commercial Crew/Cargo for ISS
Space Shuttle Operations
SSP Transition
Ares I and Orion Development
Operations Capability Development
(EVA, Ground Operations, Mission Operations)
Ares I-X Test Flight April 2009
Orion and Ares I Production and Operation
Altair Development
Ares V & Earth Departure Stage
Surface Systems Development
011608

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)

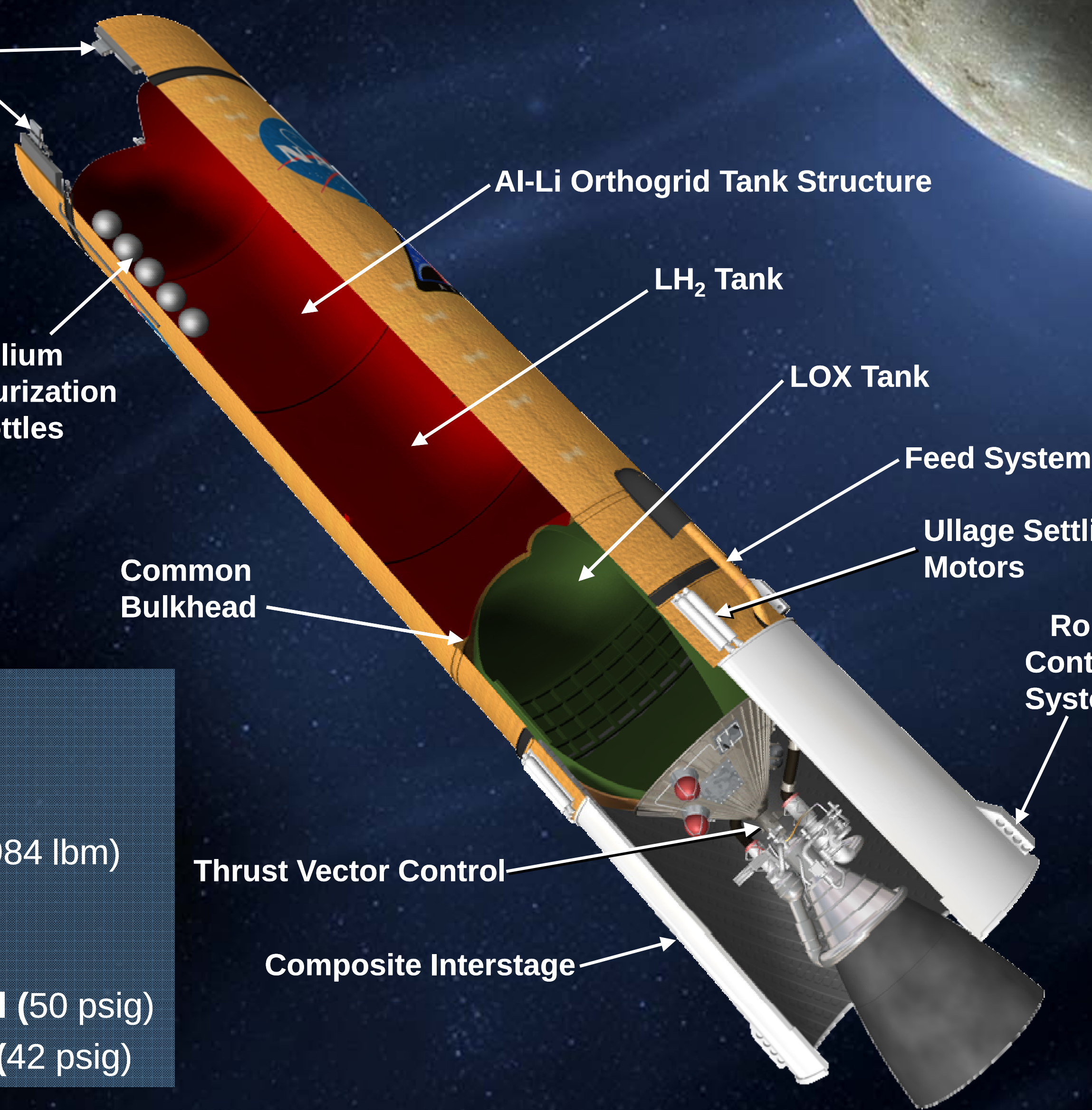
63.6 MT (140.2k lbm) to TLI (with Ares I)
55.9 MT (123k lbm) to Direct TLI
~143.4 MT (316k lbm) to LEO

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

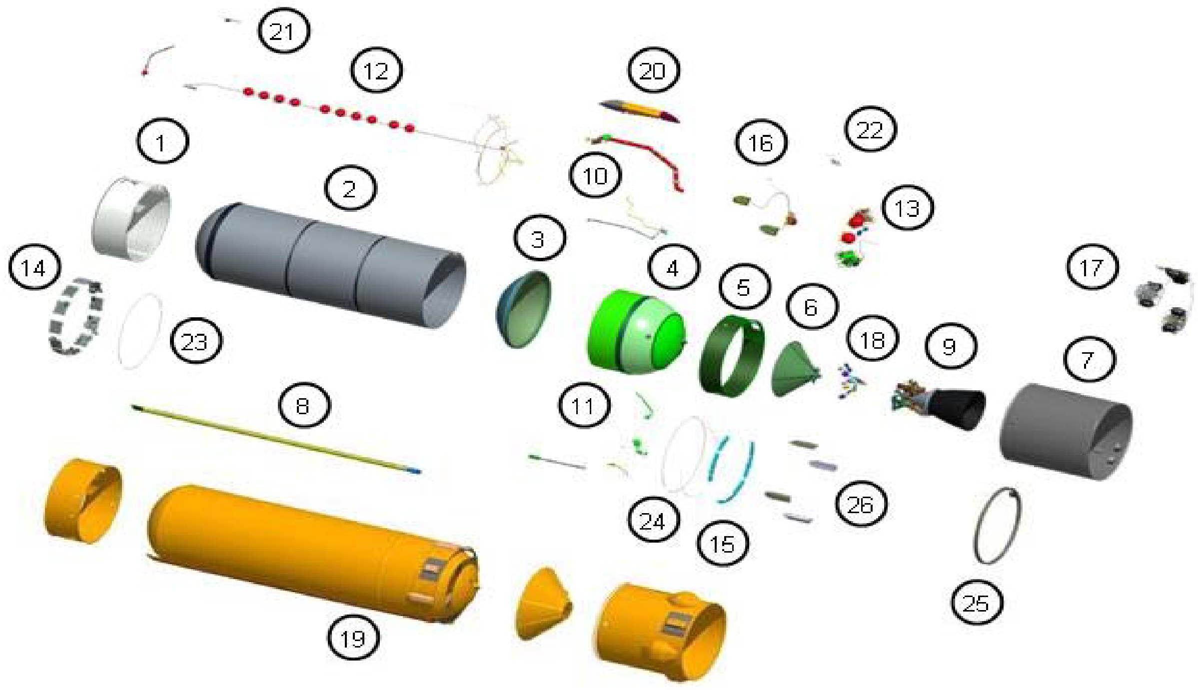
DAC 2 TR 5

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 Primary Products

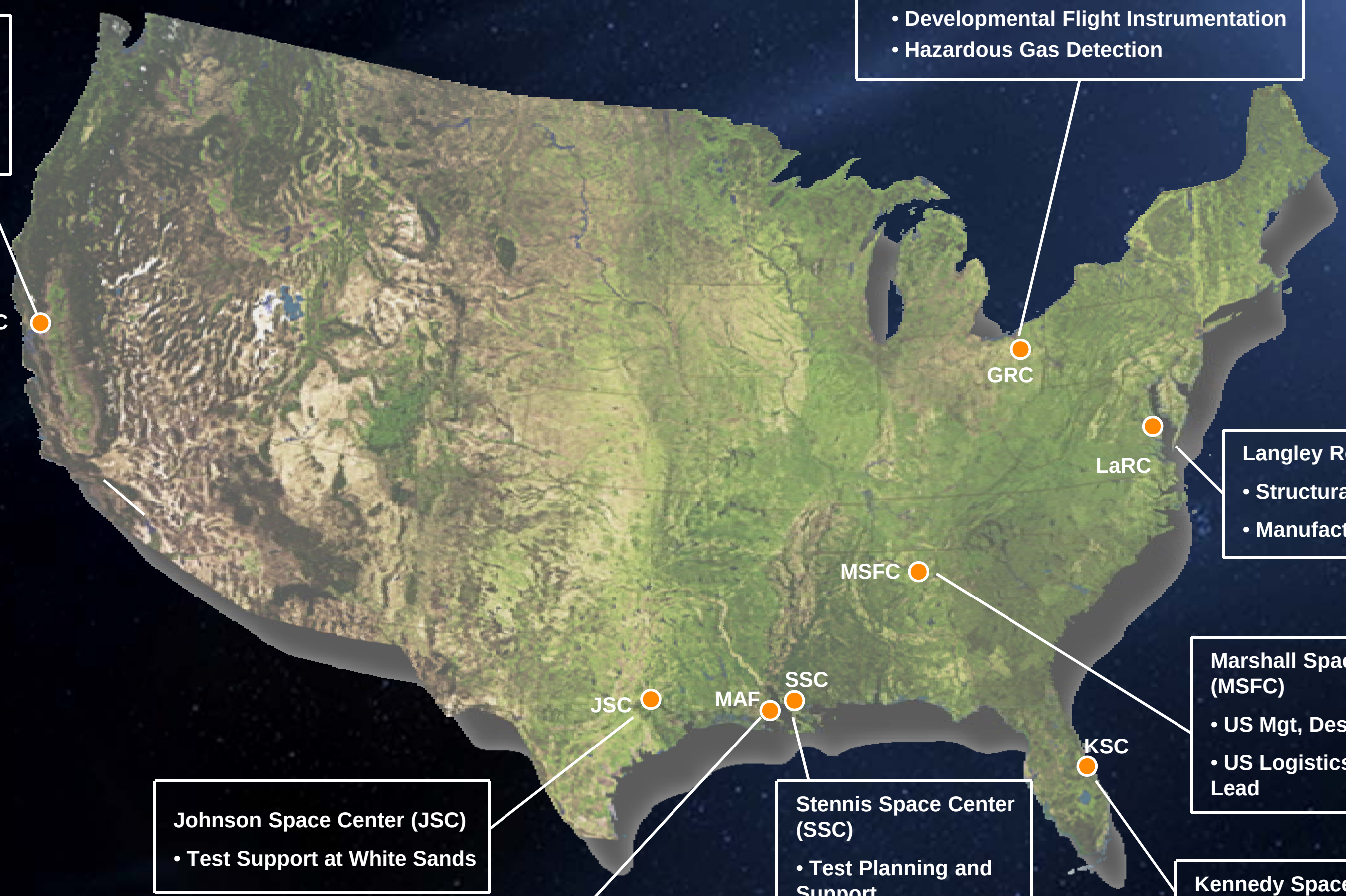


1. Instrument Unit (IU)
2. Liquid Hydrogen (LH2) Tank
3. Common Bulkhead
4. Liquid Oxygen (LO2) Tank
5. Aft Skirt
6. Thrust Cone
7. Interstage
8. System Tunnel
9. Upper Stage Engine
10. LH2 System
11. LO2 System
12. Pressurization & Pneumatic System (cryogenic)
13. Pressurization & Pneumatic System (ambient)
14. IU Avionics
15. Aft Skirt Avionics
16. Upper Stage Reaction Control System (ReCS)
17. First Stage Roll Control System (RoCS)
18. Thrust Vector Control
19. Thermal Protection System
20. LH2 Feedline Fairing
21. IU Umbilical Panel
22. Aft Skirt Umbilical Panels
23. IU Purge & Hazardous Gas Detection System
24. Aft Skirt Purge & Hazardous Gas Detection System
25. Interstage Purge System
26. Ullage Settling Motors

Ares I Upper Stage Development Approach

Glenn Research Center (GRC)
- TVC
- Electrical Power System
- Developmental Flight Instrumentation
- Hazardous Gas Detection

Ames Research Center (ARC)
- Avionics & Software Support



Langley Research Center (LaRC)
- Structural Design Support
- Manufacturing Support

Marshall Space Flight Center (MSFC)
- US Mgt, Design, and Integration
- US Logistics and Operations Lead

Johnson Space Center (JSC)
- Test Support at White Sands

Stennis Space Center (SSC)
- Test Planning and Support

Kennedy Space Center (KSC)
- Ground Umbilicals Development
- Propellant Systems Development @ MPTA Test Site
- Logistics and Operations Support

Michoud Assembly Facility (MAF)
- Facility Services and Planning Support to ILS and Manufacturing & Assembly IPTs

What progress have we made?

♦ US Programmatic Milestones

- Completed US System Requirements Review and System Definition Review, and currently in the midst of 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

♦ US 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 Subsystem Highlights

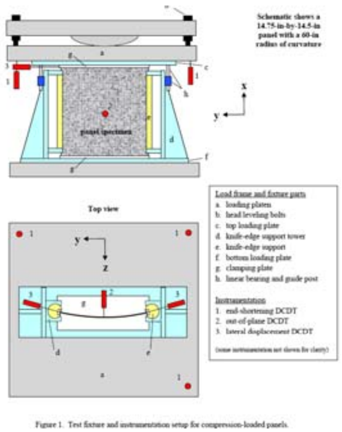
- **Small Solids**
  - Separation analysis and trade study
  - Heavy weight motor test
  - Propellant tailoring and testing
  - PDR Kickoff
- **Structures and Thermal**
  - Final Layout Out Reviews
  - Panel test analysis
- **Main Propulsion System**
  - Terminal drain analysis
  - Ullage collapse analysis
  - Bench testing of Saturn Components
  - Cryo regulator testing
- **Reaction Control System**
  - Producibility upgrades (DFMA Thruster)
  - Water Hammer Testing in the CDA
- **Thrust Vector Control System**
  - Hydraulic Breadboard Test
  - PDR Kickoff
- **Avionics and Software**
  - Boeing Integration
  - Specification Development
  - Software Reviews
  - Industry Day with Supply Chain

SD01 Panel Test

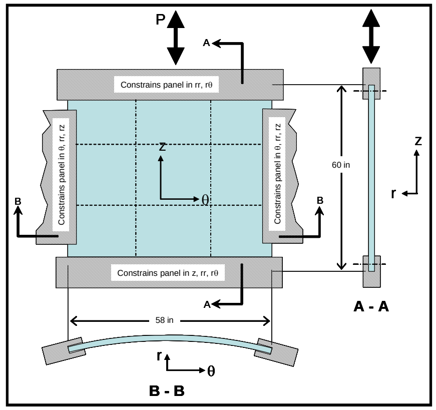
TVC Breadboard 1-axis Test Rig

Test Stand Adapter for Small Solids USM Heavy Wall Motor test

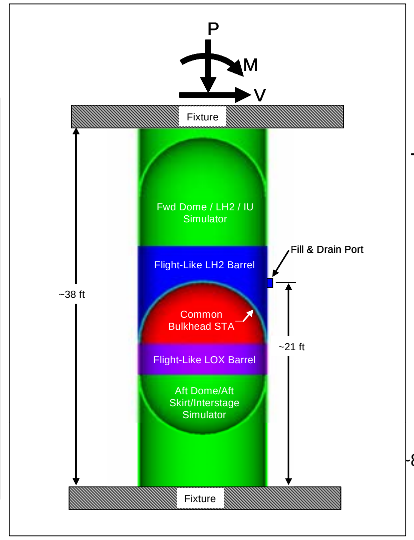
Structural Testing



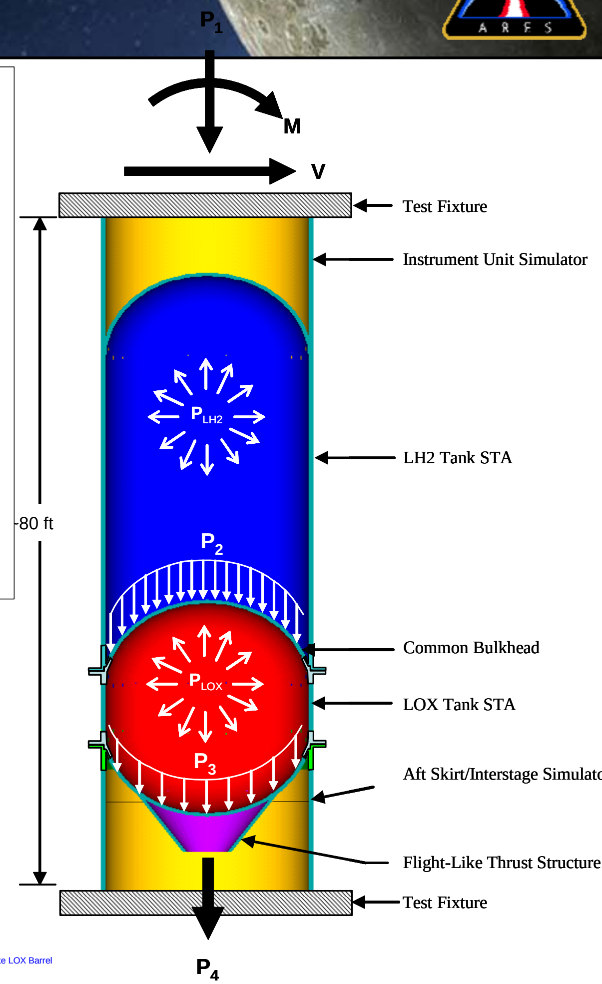
SD01- AL-Li Small Panel
SD02- AL-Li Large Panel



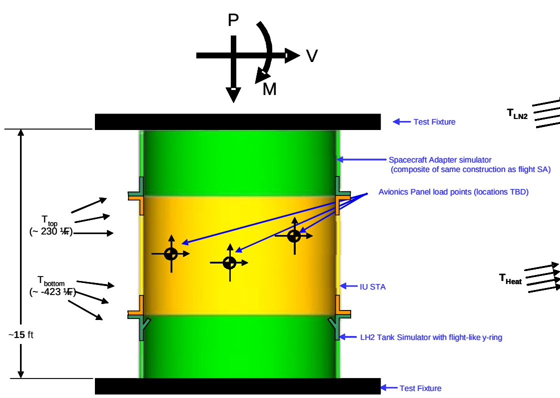
SD06-SD07-SD08
Composite Panel Test



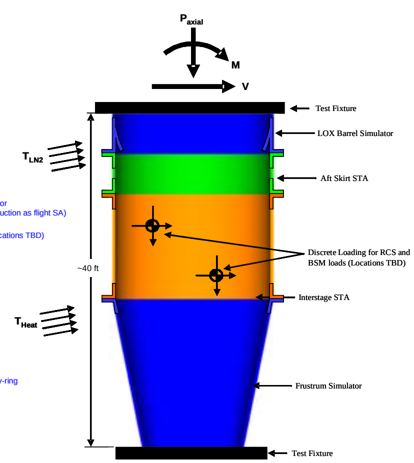
SD03- Common
Bulkhead Dev Test



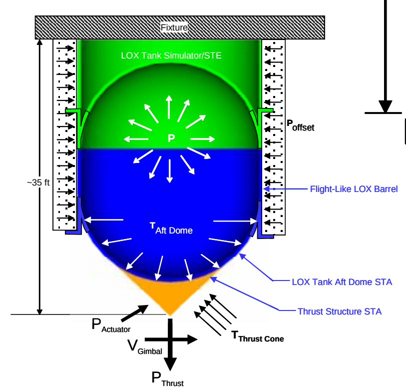
SQ02A- Core US
Qualification & Life Test



SQ01- IU Qualification Test

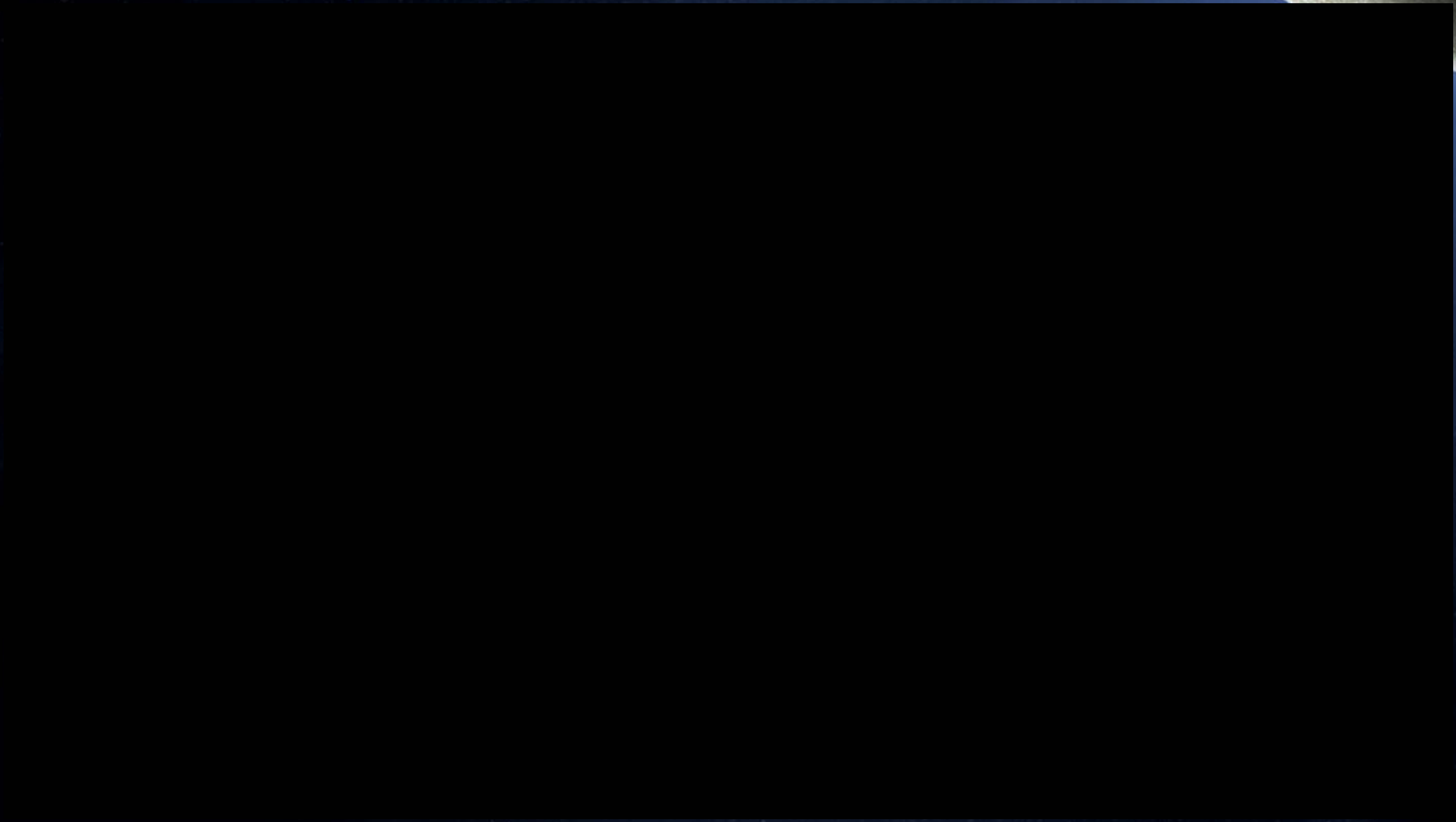


SQ05, SQ06- Interstage
Qualification Test

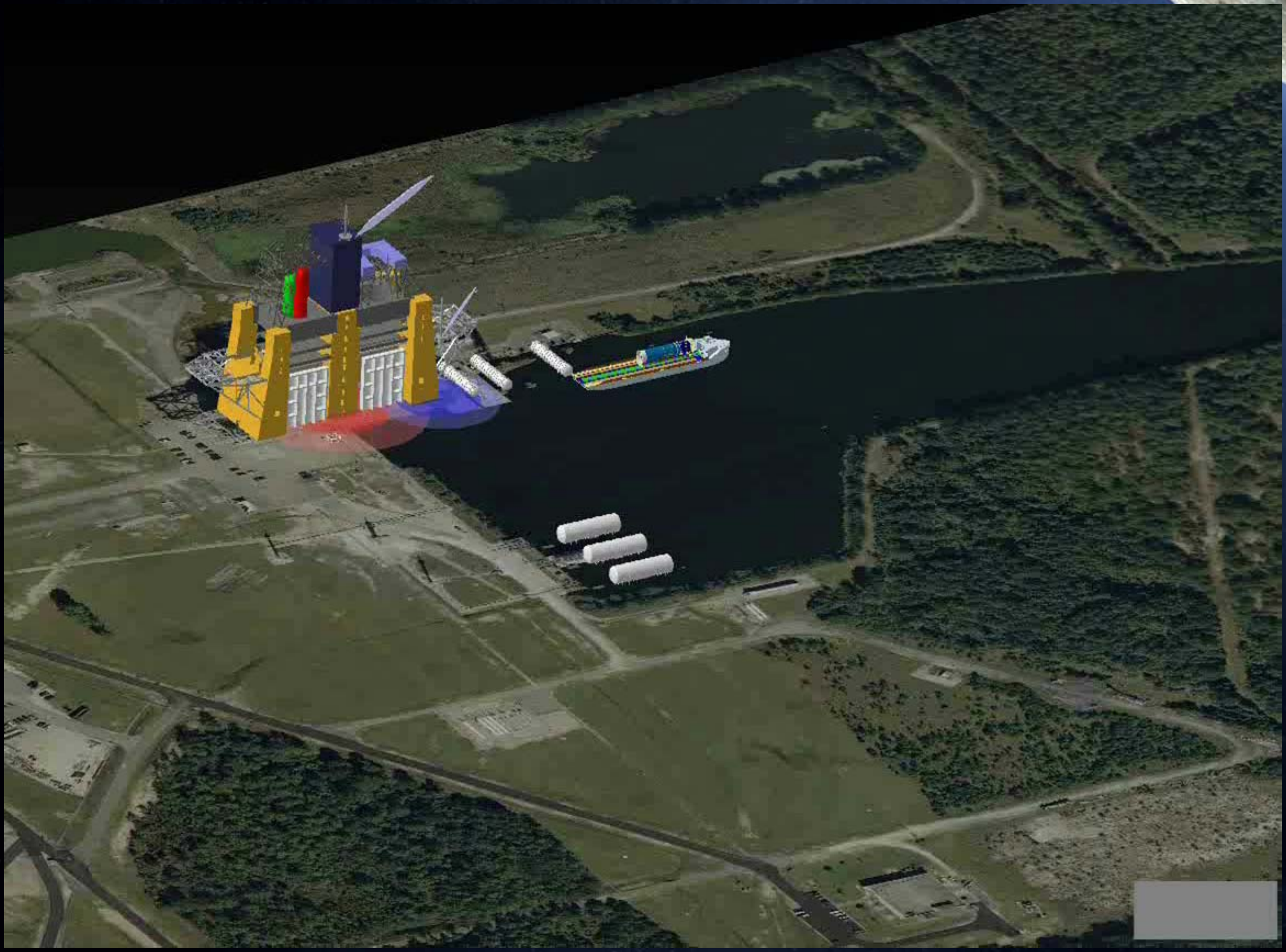


SD05, SQ07- LOX Tank Aft
Dome with Thrust
Structure and Aft Skirt

Common Bulkhead Processing



Stage Installation at Stennis Space Center



Boeing Producibility Team

Boeing has been selected as USPC and the IUAC

- Producibility and Design Support
- Manufacturing
- Operations
- Sustaining Engineering

Program Manager – Jim Chilton

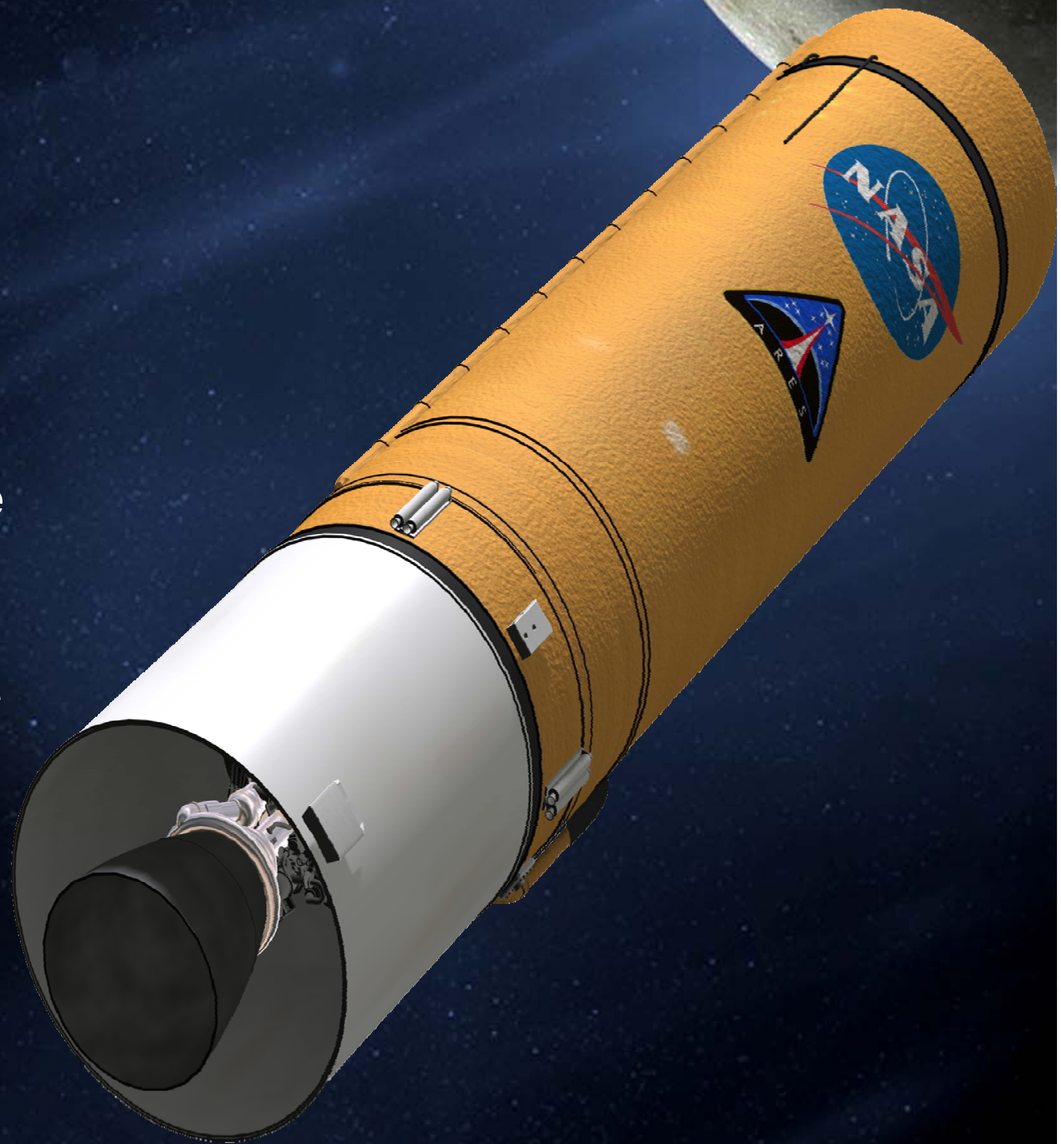
- IUAC Manager – Dwight Potter

Team is engaged with the NASA Design Team (NDT)

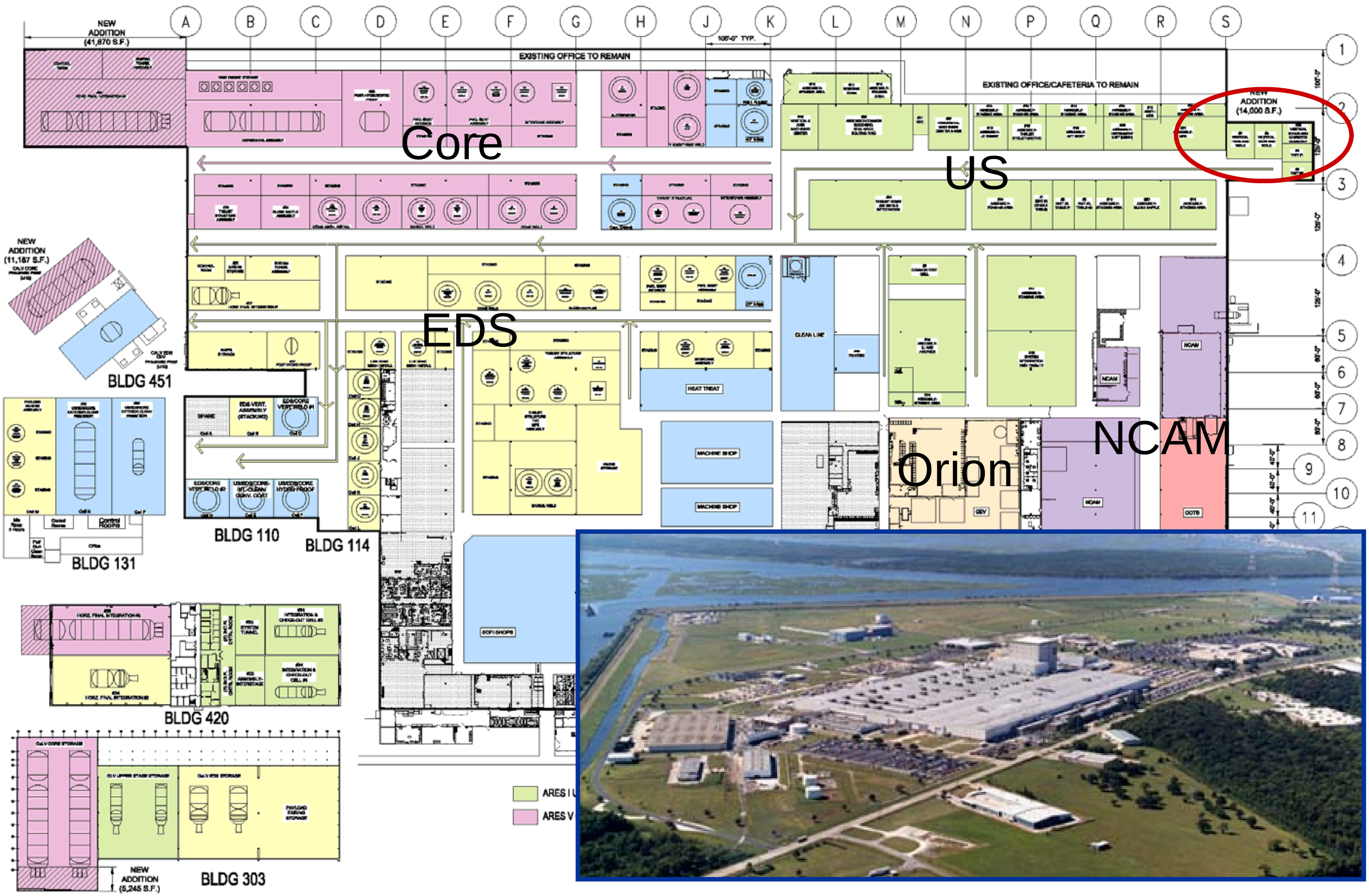
- Manufacturing Value Stream Mapping
- Producibility Summit
- Tooling Design Support
- Schedule Development
- Component Cost Updates
- Test Article Planning Support
- Special Studies

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)



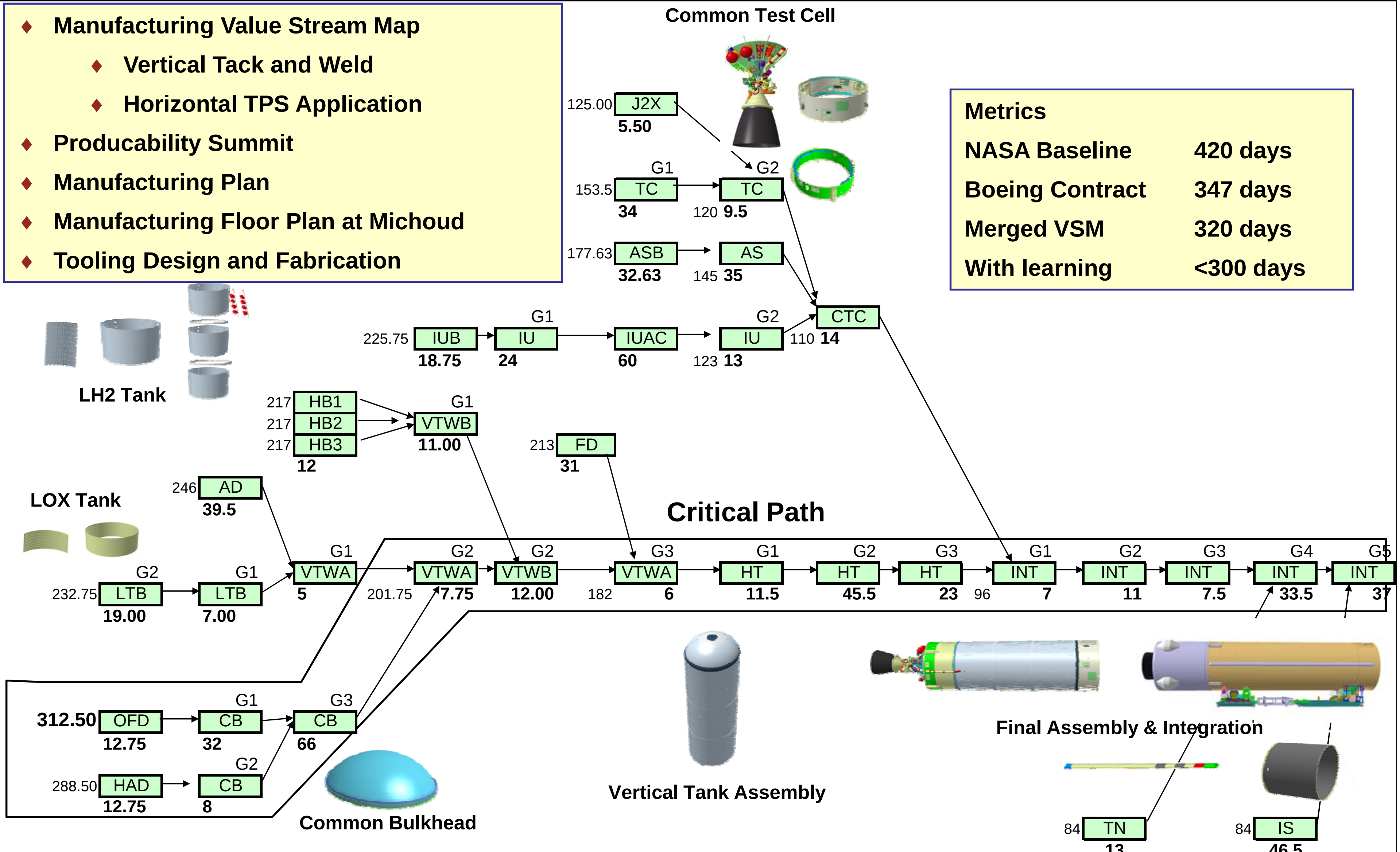
Ares I and V Production at Michoud Assembly Facility (MAF)



Merged Manufacturing Flow

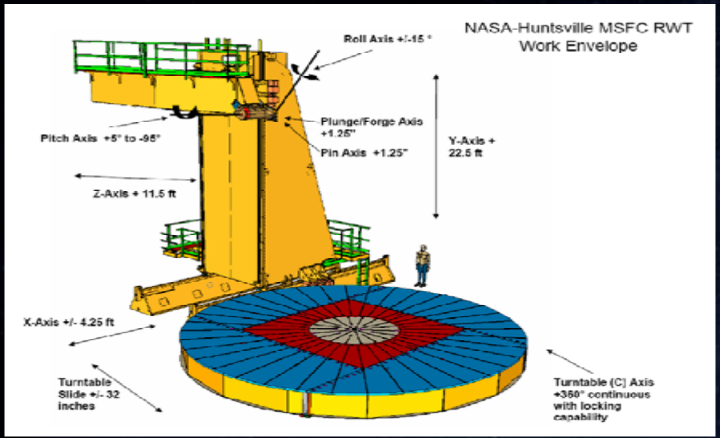
- Manufacturing Value Stream Map
  - Vertical Tack and Weld
  - Horizontal TPS Application
- Producability Summit
- Manufacturing Plan
- Manufacturing Floor Plan at Michoud
- Tooling Design and Fabrication

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

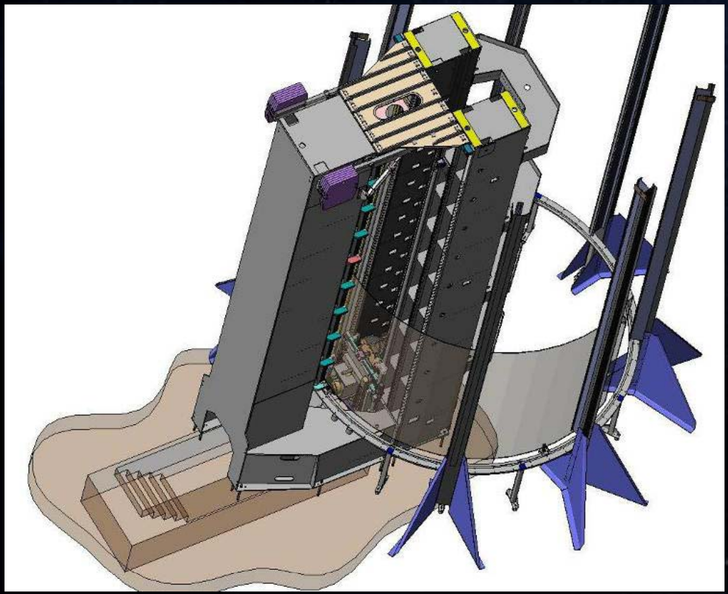
Manufacturing & Assembly Weld Tools



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

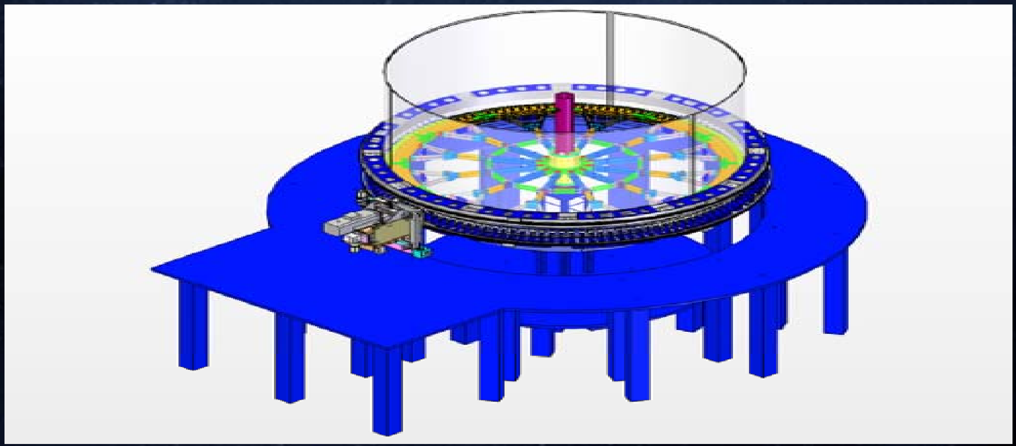
gore-gore, dome-y ring, dome-fitting

Self-Reacting Friction Stir Welding (FSW)



Vertical Weld Tool (VWT)

Barrel-Barrel, Conventional FSW



Vertical Circumferential Weld Tool Concept

Conclusion

- **Building on the heritage of the Apollo and Space Shuttle Programs, the Ares I Upper Stage team is 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 and Boeing Upper Stage teams are now integrated, working together, and making good progress**
  - Designing and building the Ares I Upper 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***