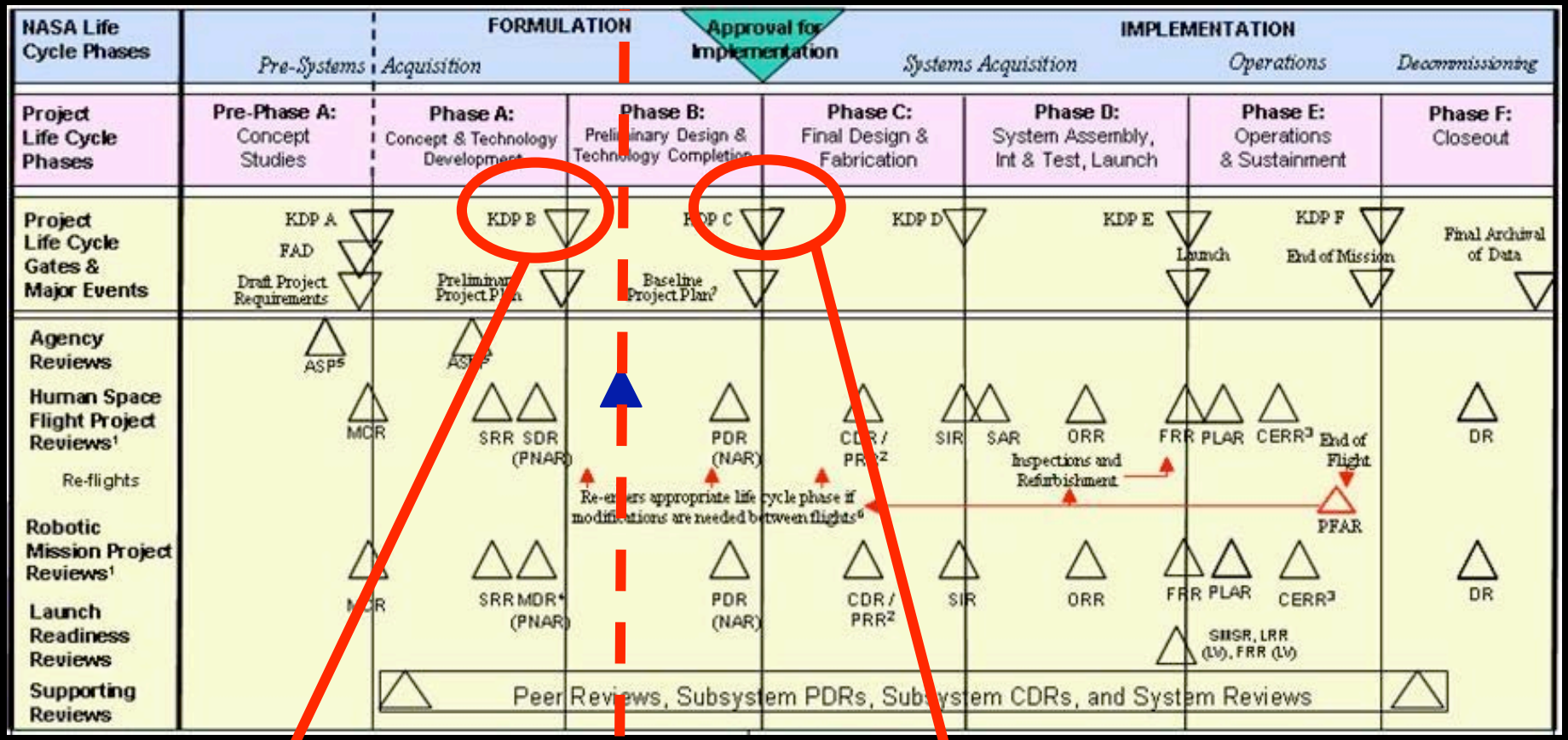
Orion Crew Exploration Vehicle
Overview

Masters Forum
Fred Ouellette
May 2009

NASA Program Life Cycle from 7120.5D

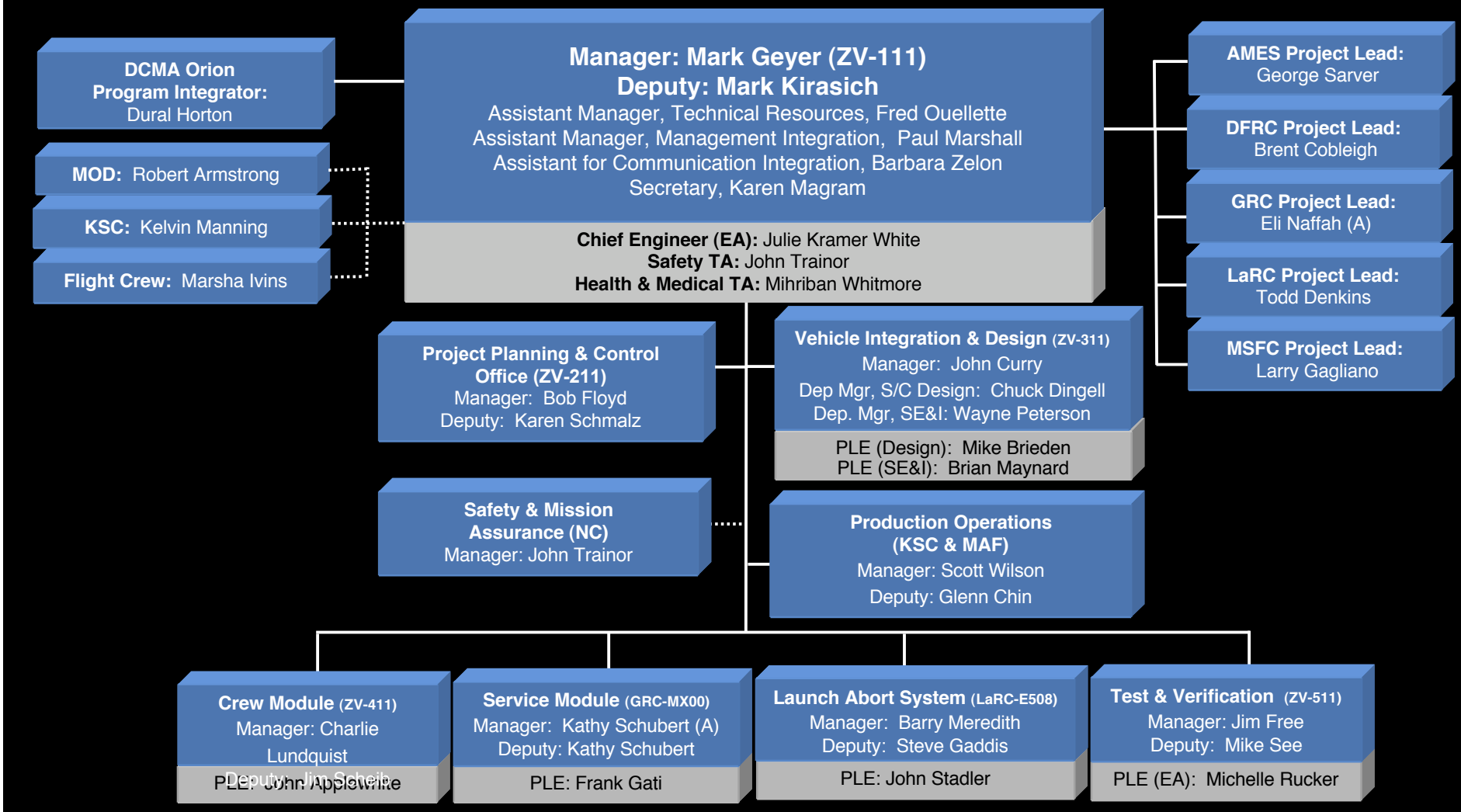


Time Now

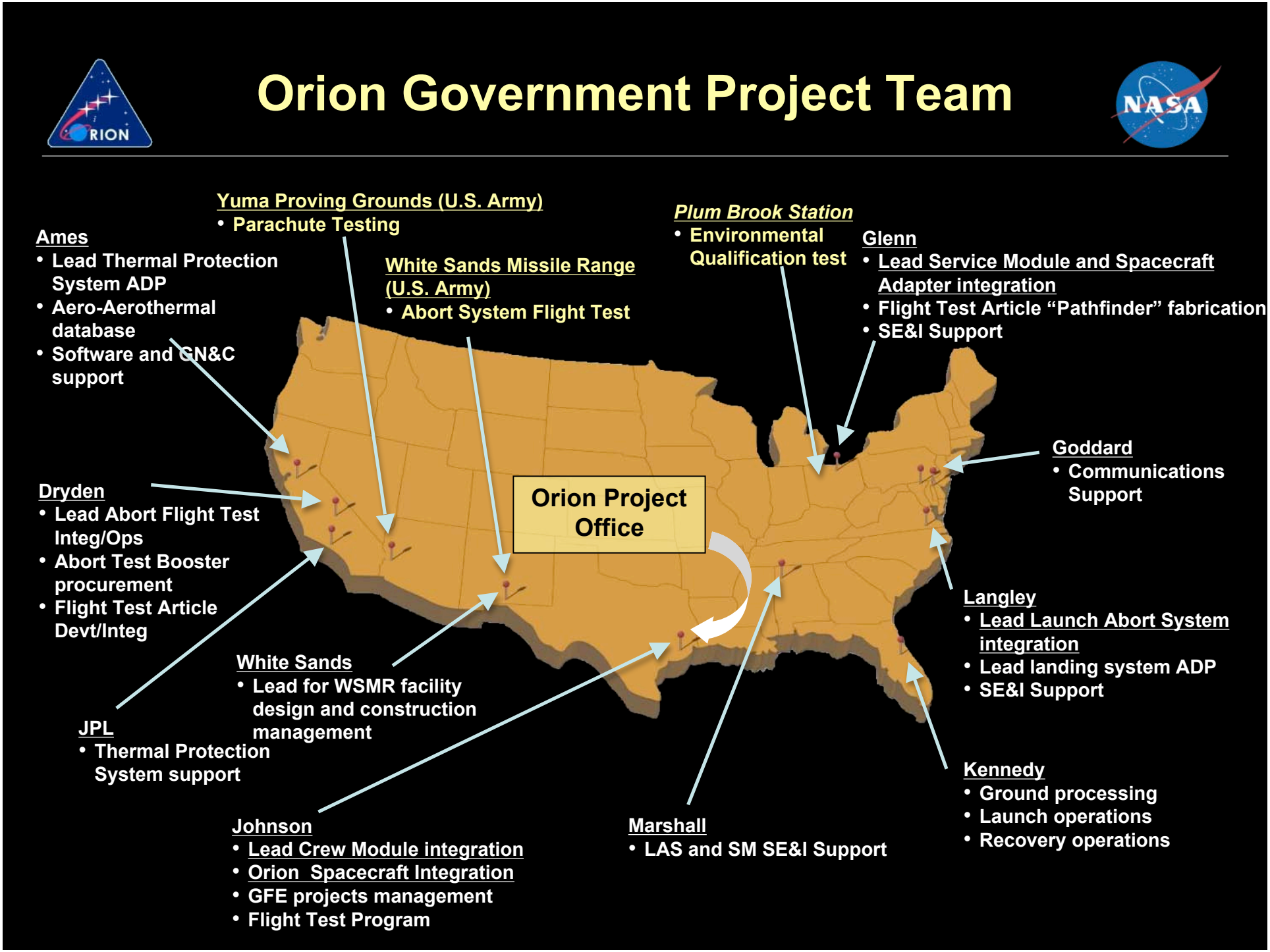
Completed: April 2008

Projected: 2Q FY10

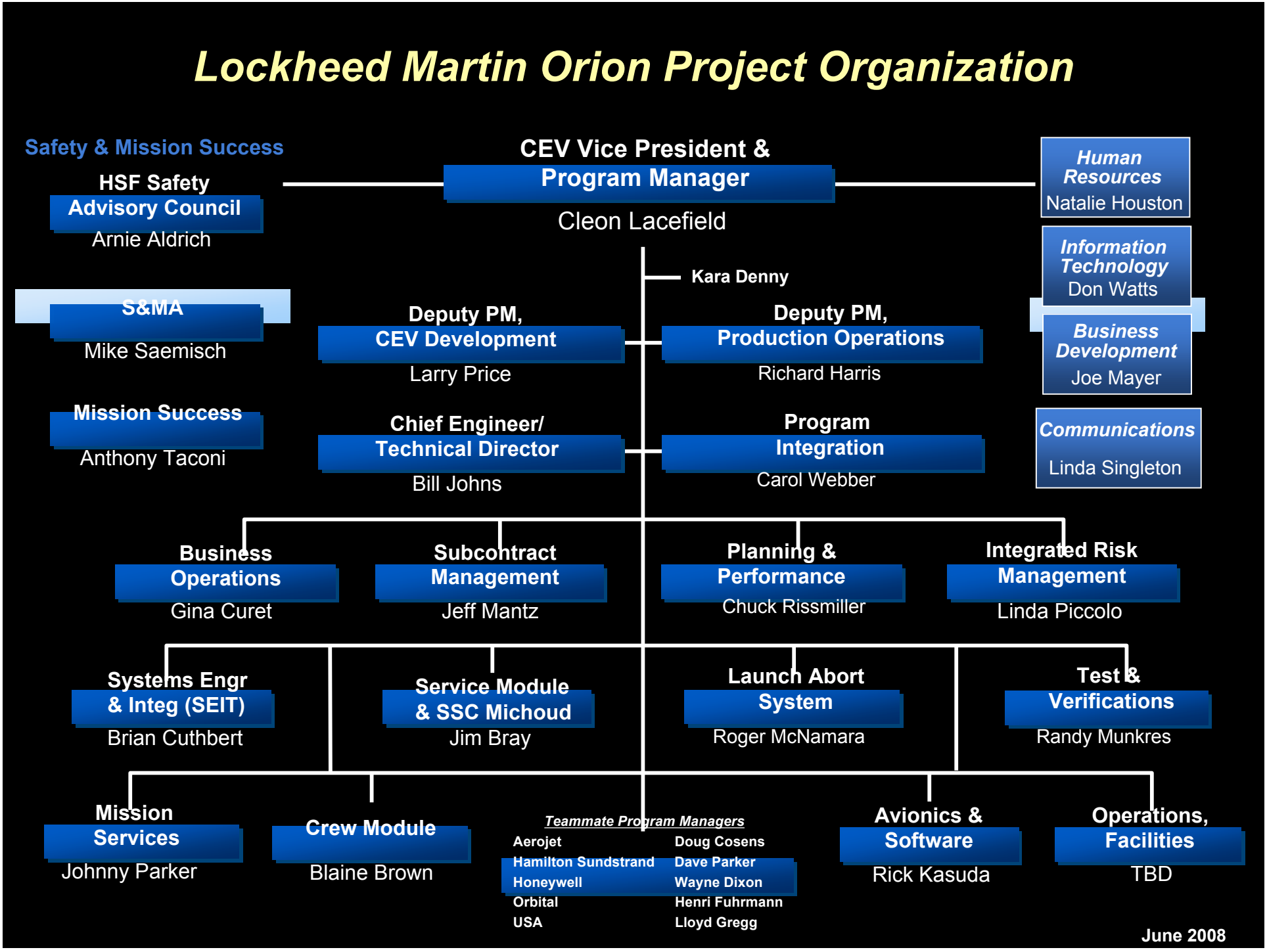
NASA Orion Project Organization



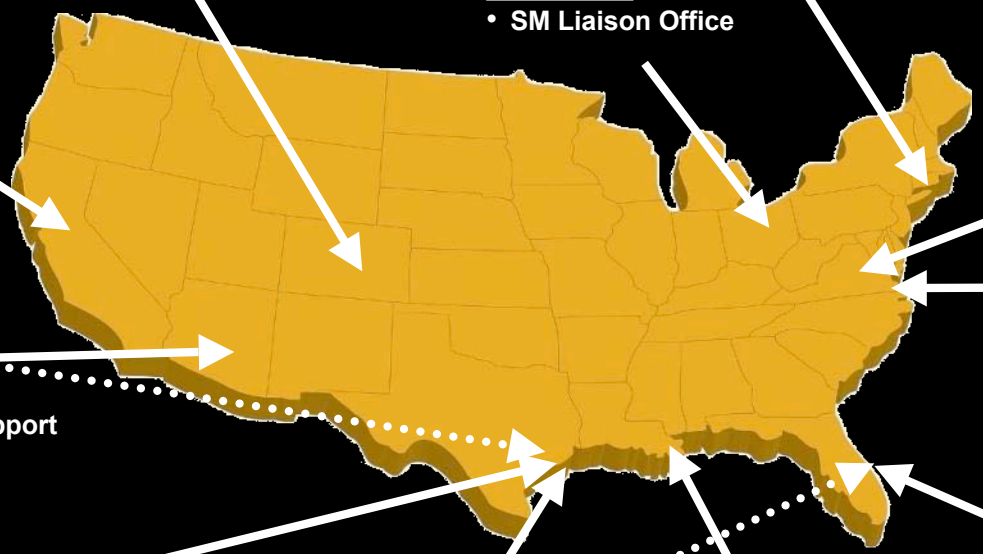
Orion Government Project Team



Lockheed Martin Orion Project Organization



Orion Lockheed Martin Industry Team



LOCKHEED MARTIN
- Systems & Design Engineering Support

Hamilton Sundstrand
A United Technologies Company
- Environmental Control & Life Support
- Active Thermal Control
- System Power Management

AEROJET
- Propulsion

LM GRC
- SM Liaison Office

Orbital
- Launch Abort System
- Safety & Mission Assurance

Honeywell
- Avionics
- Integrated System Health Management
- Crew Interface
- Mission Ground Ops Support

LM LaRC
- LAS Liaison Office

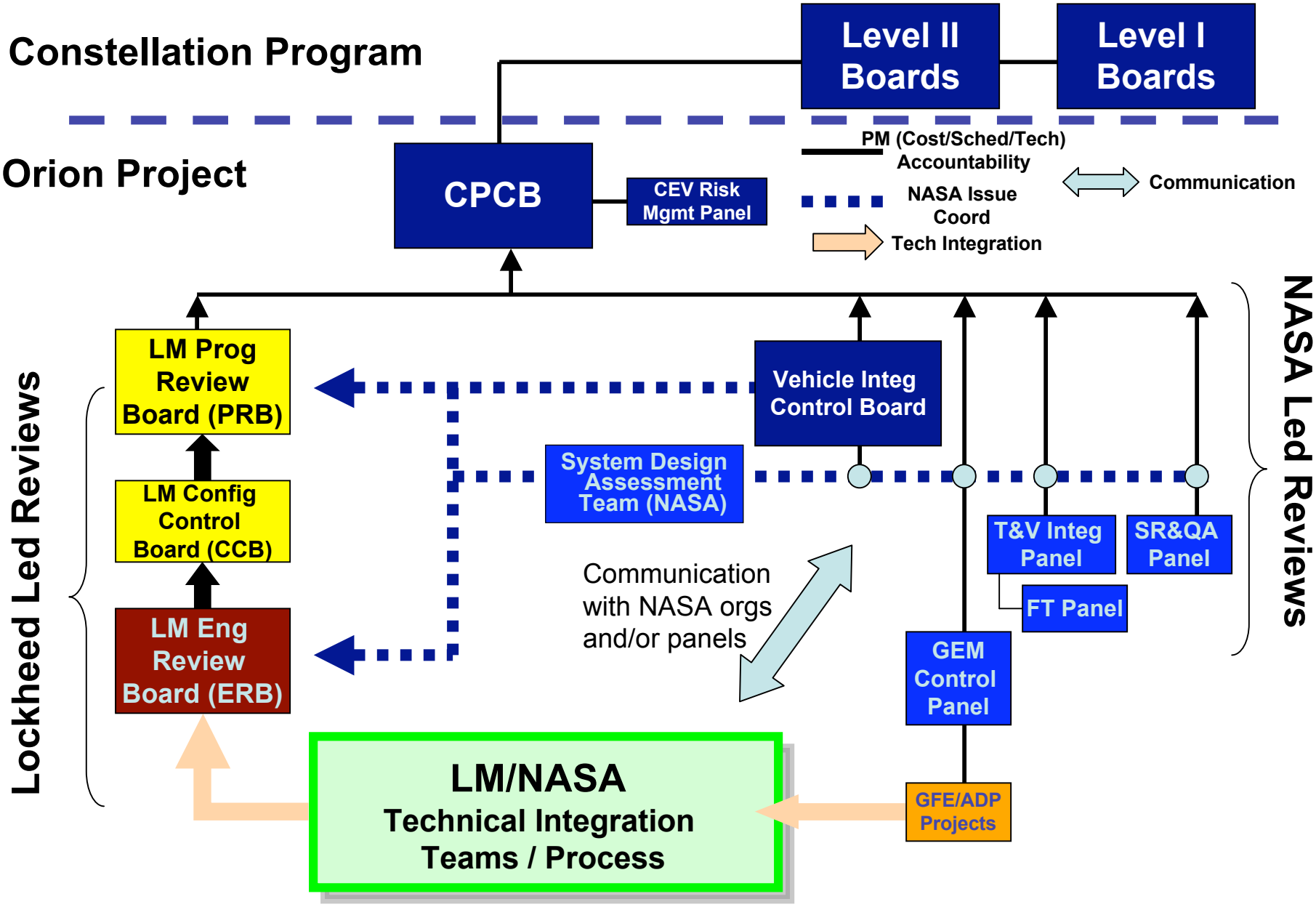
LOCKHEED MARTIN
KSC
- Final Assembly
- Checkout
- Acceptance Test
- Sustaining Engineering
- Spacecraft Refurbishment

LOCKHEED MARTIN
- Program Management
- Systems Integration
- Crew Module Development
- Service Module Development
- Qualification Test
- Software Development

USA
United Space Alliance
- Operator Interfaces
- Ground Processing
- Mission Flight Planning
- Software Development

LOCKHEED MARTIN
Michoud
- CM and SM Structures

CEV Project Boards and Panels Structure



Government Furnished Equipment (GFE) and Advanced Development Projects (ADP) Roles

- **Several Non-Prime efforts are managed out of Orion project office**
  - **GFE projects (LIDS, ATLAS, CPAS, ICCA)**
  - **Advanced Development Projects (TPS ADP, Landing Systems ADP)**
  - **Test Facilities (IET@GRC, CAIL, EEST)**
  - **Abort Flight Test Projects (PA-x, AA-x, facilities)**
  - **Aerodynamics/Aerothermal Testing/Analysis/Database & Model Development (CAP)**
- **Management Processes**
  - **Leadership: NASA Project managers report to respective Orion Managers**
    - Teams utilize resources across multiple centers
  - **Interaction with Prime**
    - Requirements trace/flow from prime (thru NASA) to GFE and ADP projects
    - GFE/ADP design data and PDR/CDR products flows to prime (thru NASA)
    - Both flows utilize Orion Config Management processes & databases
  - **PP&C control: follows similar processes as Prime-led efforts**
    - Integrated Budget & schedule accounting/databases
    - Status Reviews (TCSRs, PMRs, etc.)
    - Budget planning/formulation (PMR08r1, PMR09, etc)
    - Funding issues utilize Orion IRMA and risk review processes

Governance, Technical Authority, and Independent Assessment in Constellation

The NASA Governance Model

(NASA Policy Directive (NPD) 1000.0, NASA Strategic Management and Governance Handbook)

- Separates Programmatic and Institutional Authorities
- Describes Governing Councils
- Articulates Strategic Management Principles
- Establishes Technical Authority

NPD 1000.0

NASA Space Flight Program and Project Management Requirements

NPR 7120.5D (Section 3.4)

Constellation Program Plan

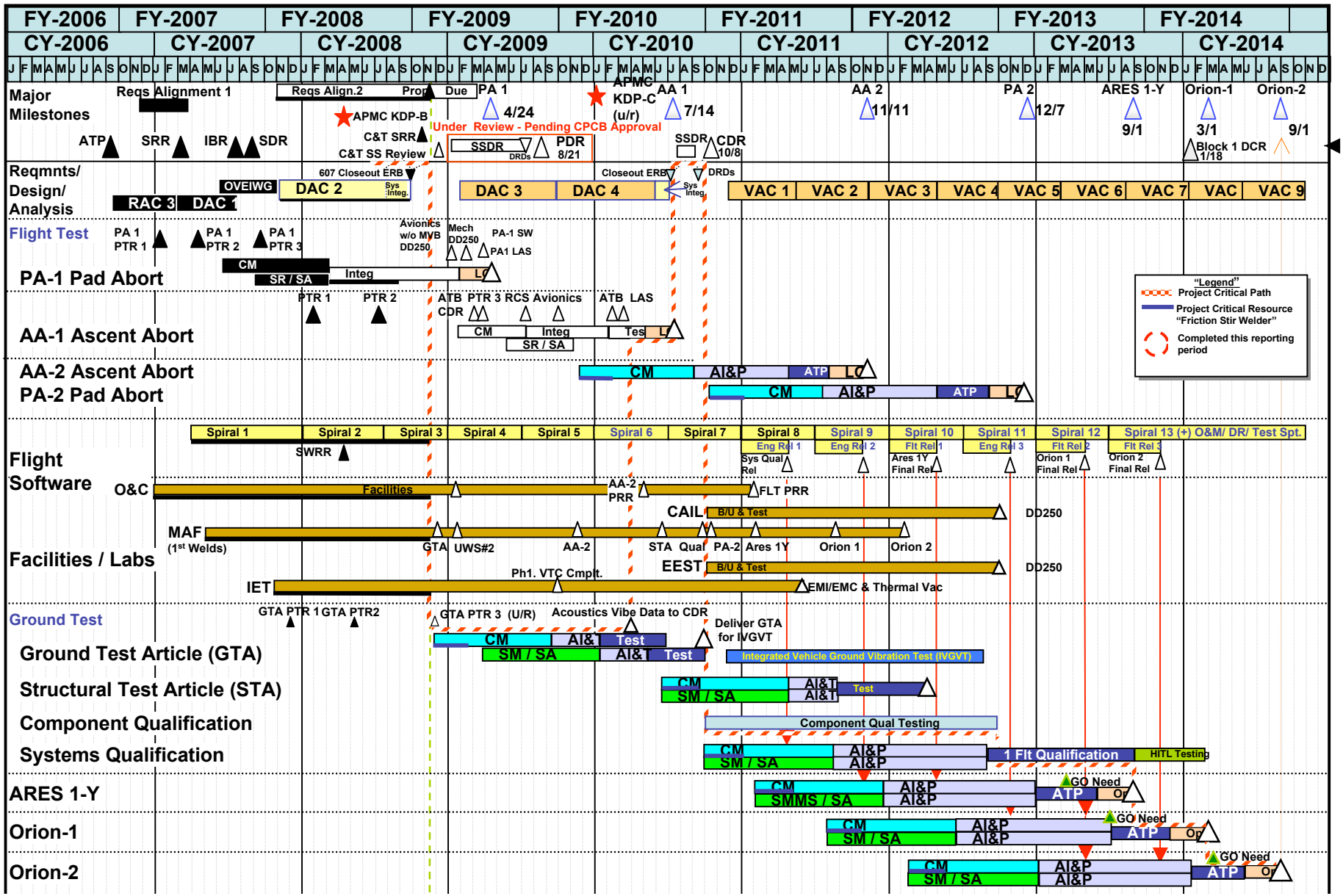
CxP 70003 (Section 4.4)

Technical Authority and Independent Assessment

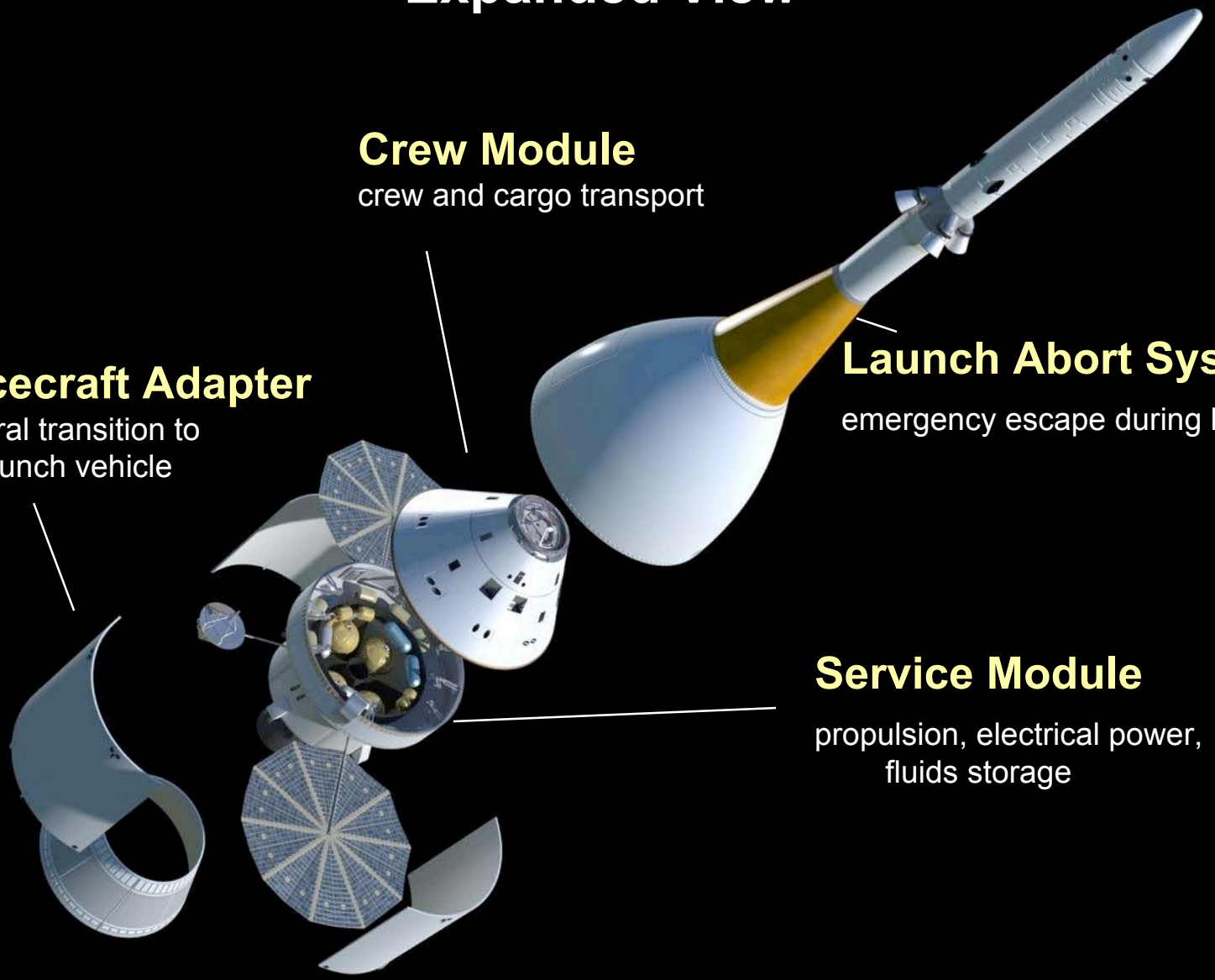
- Technical Authority (TA) is the institutional expertise required in the Engineering, S&MA, and medical fields in order to make sound technical engineering decisions.
- For Constellation (Cx), technical authority consists of the Office of Chief Engineer (OCE), Office of Safety and Mission Assurance (OSMA), and Office of the Chief Health and Medical Officer (OCHMO) and their respective institutional support across the Agency. Implemented at Program and Projects level.
- Independent Assessment performed through HQ chartered Standing Review Boards

Orion Master Summary Schedule

Status as of 11/21/08



Orion Crew Exploration Vehicle
Expanded View



Crew Module
crew and cargo transport

Launch Abort System
emergency escape during launch

Spacecraft Adapter
structural transition to
Ares launch vehicle

Service Module
propulsion, electrical power,
fluids storage

Apollo/Orion Comparison

5 meter diameter capsule – Apollo shape

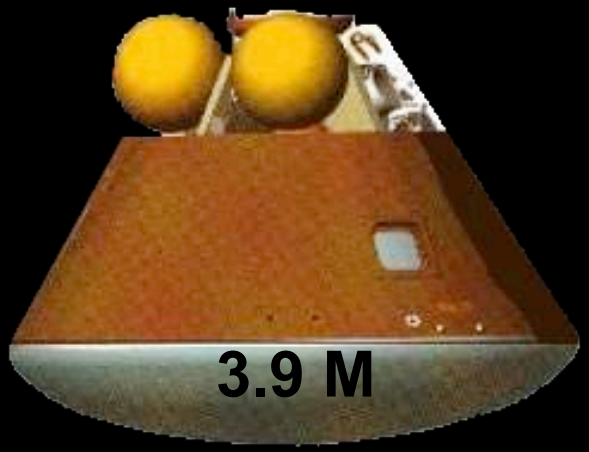
- Significant increase in volume from Apollo (3.9 meter)
- Reduced development time and risk

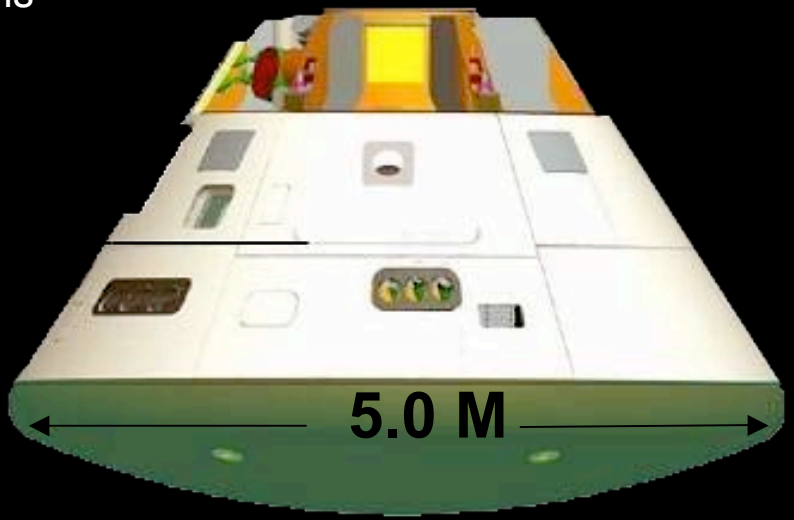
Larger Crew Accommodations

- Lunar missions: 4 crew
- Space Station missions: 6 crew

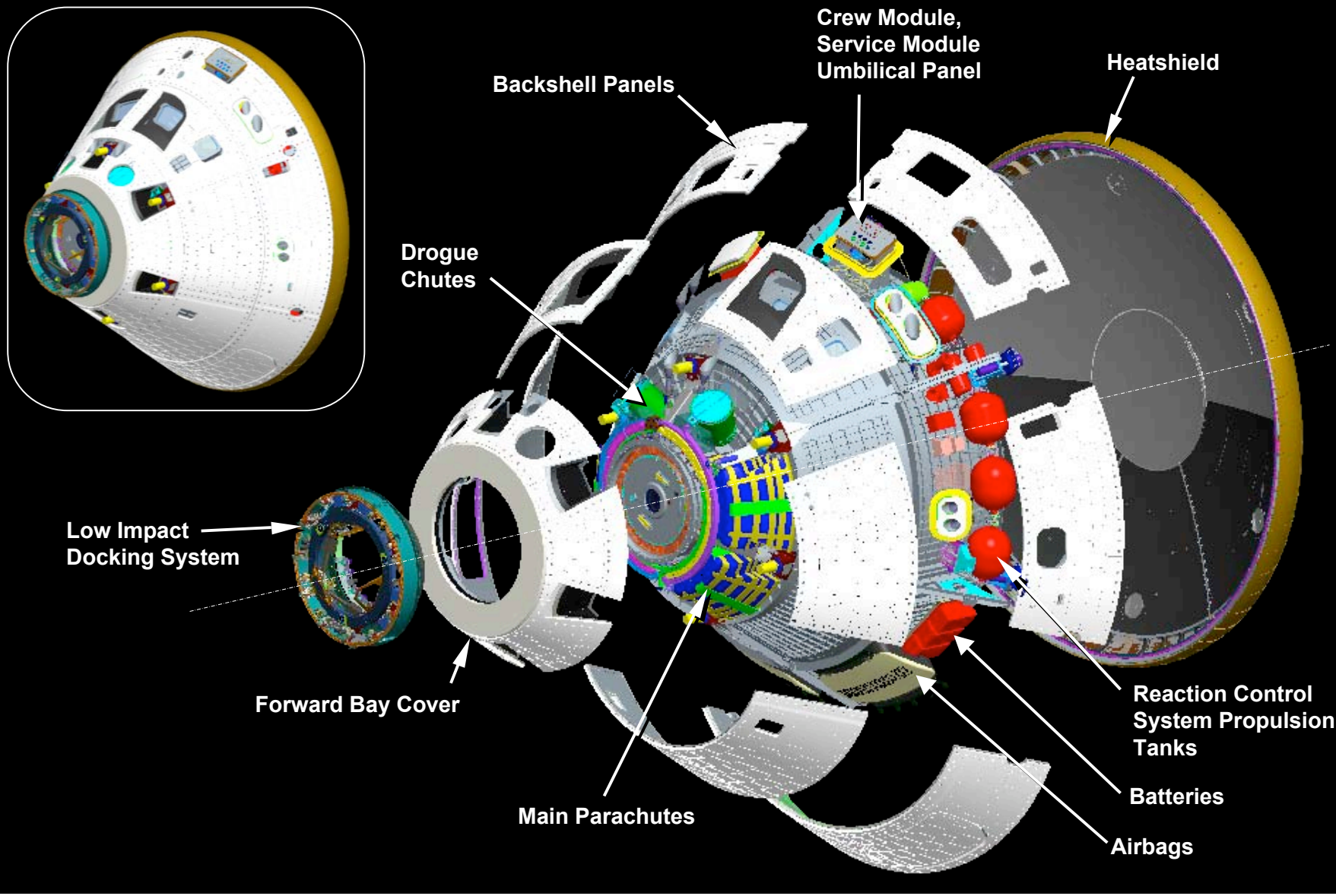
Expanded Mission Capabilities

- Long Duration (6 months)
- State-of-the-Art Materials, Systems

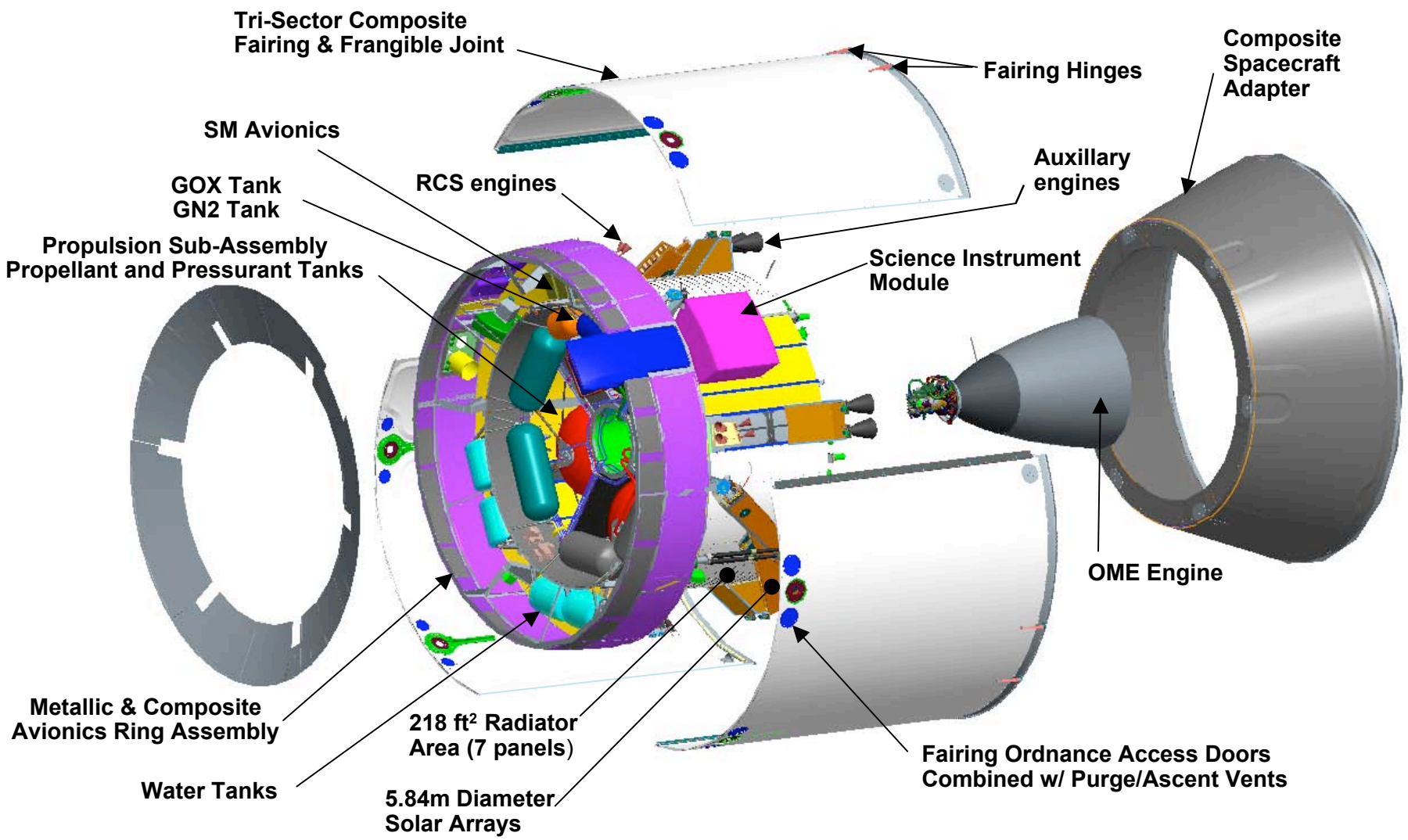




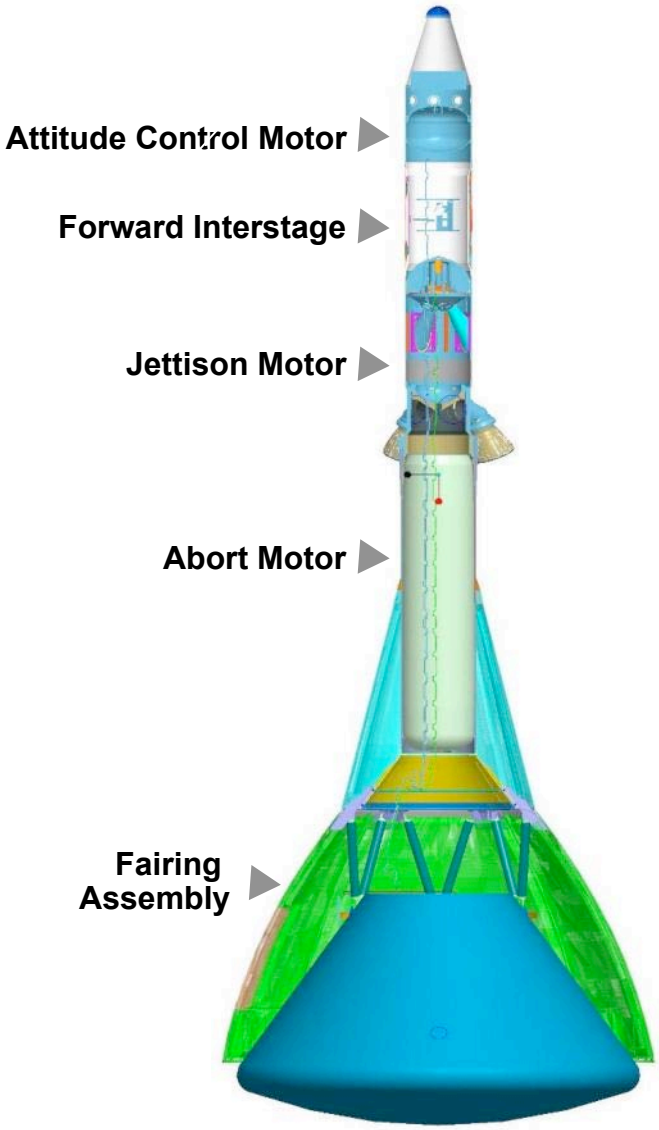
Orion External Configuration



Orion Service Module



Orion Launch Abort System

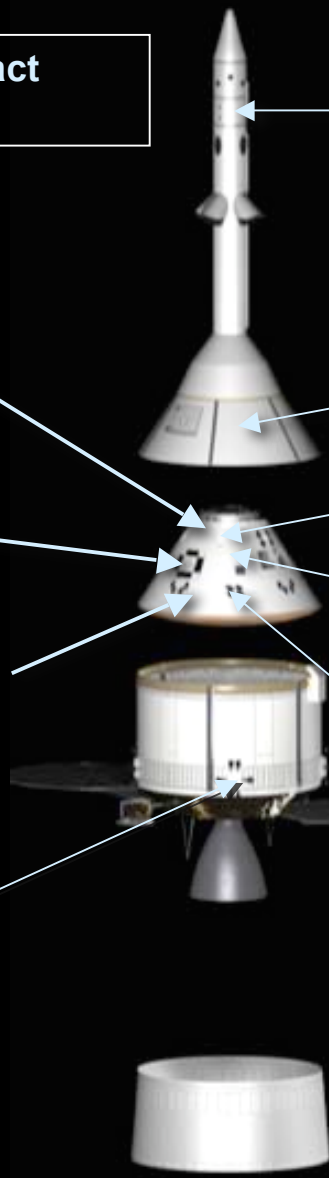


Capability	All Versions
Control Mass	15598 lbm
Abort Range	0 – 300,000 ft
Power Storage	Li-ion 140 V & 28 V Batteries
GN&C	Closed loop control provided by CM
Communications	S- Band for CM mounted on Fillet
Propulsion	Abort Motor No. of Nozzles: 4 reverse flow Nozzle Cant Angle (to CL): 25º Isp (sea level): 245s Thr (Total in Vehicle Axis): 395,000 lbs (Reduced AMTP) Burn Time: 4.4 s Wagon wheel grain design Attitude Control Motor No. of Nozzles: 8 Nozzle Cant Angle (to CL): 90º Isp (vac): 227s Thr (per Nozzle): 4101 lbs max Burn Time: 30s Jettison Motor No. of Nozzles: 4 Nozzle Cant Angle (to CL): 35º Isp (vac.): 221s Thrust axial vac: 32.9k lbs Burn Time: 1.55s

Major Configuration Changes Since Contract Award

604 -- Contract award 9/2006

606E -- Phase B Mid-Term 9/2008



Canards

SLA Ablator Backshell

Revised Boost Protective Cover Outer Mold Line

Side Hatch Relocated

4 Main Parachutes

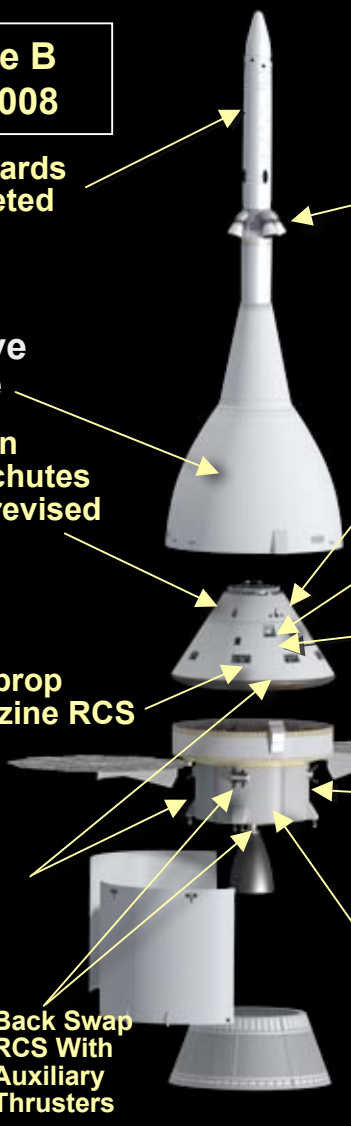
Confluence Retrorocket

Freon Post-landing Cooling

G0x/Methane RCS

Quad RCS

Avionics:
Reduced FT added BEC
Added significant C3I functionality
TTGBE and star topology
Phased array C&T antenna system
Dissimilar voice
Double display formats



Canards Deleted

Reduced Abort Motor Thrust Profile

AETB Tiles Backshell

3 Main Parachutes And revised FBC

Ammonia Post-landing Cooling

Side Hatch Relocated

Monoprop Hydrazine RCS

Solar array Packaging & Multi axis gimbal

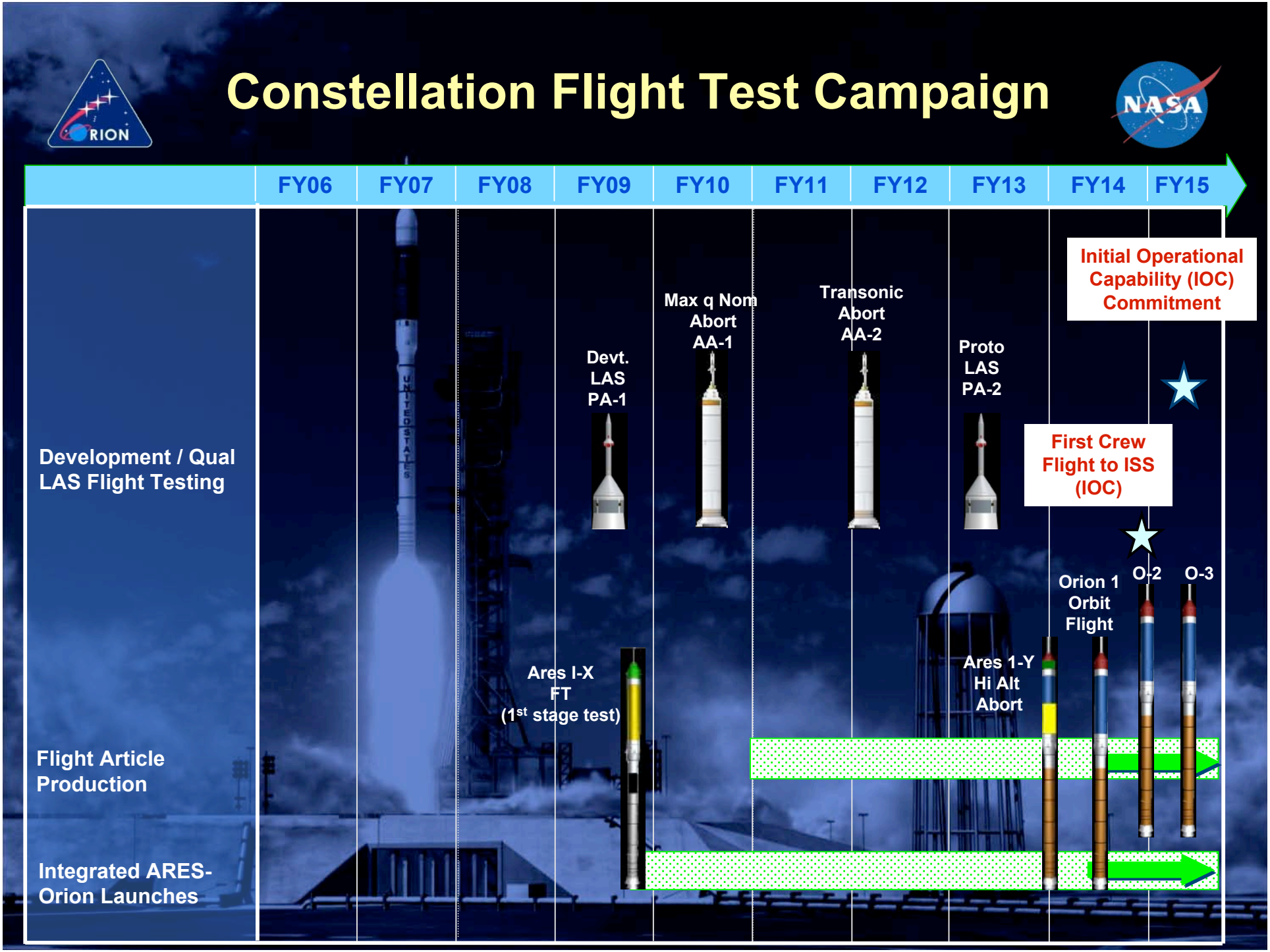
Encapsulated Service Module with Jettisonable Fairing

Back Swap RCS With Auxiliary Thrusters

Unpressurized Cargo Capability for ISS

Prim/Sec Structure changes due to maturing loads
Added validated Safety, Testing, Requirements & Design Standards

Constellation Flight Test Campaign



Orion **Accomplishments**

May 2009

Orion Challenges and Opportunities

- Technical
- Non-Technical
- Personnel

Technical Challenges

- **Extending capability of current design heritage**
  - **LAS Attitude Control Motor**
    - Test anomalies: i.e. ACM HT-7 followed by successful HT-6 and HT-8 after investigation and design modifications
  - **Parachutes – limiting capability during landing**
  - **Command/Crew Module – even though using heritage shape, increase in capability still driving extensive testing and validation**

- **Mass (in 2007, reduced ~ 7000 lbs and 300 lbs of risk**
  - **Always a challenge no matter how much capability you have**
  - **Mass affected by meeting other requirements; acoustics (LAS O-Jive Fairing), loads, LOC/LOM improvements**

- **Program requirement maturation in parallel to Orion concept and architecture development – SE&I challenges**
  - **Communication system**
  - **Landing (primary water with contingency land landing)**

Technical Opportunities

- **Risk Informed Design**
  incorporating PRA into architecture studies and preliminary design integration
- **Imbed Technical Authority**
  Engineering, SRQA and H&M, and use them
- **Implementation of the technical oversight team across agency**
- **Strong requirement push/pull**
  - Contractor ⟷ NASA CEV
  - NASA CEV ⟷ CxP and other elements
- **Use NESC for specific support tasks and analysis**

Non-Technical Challenges

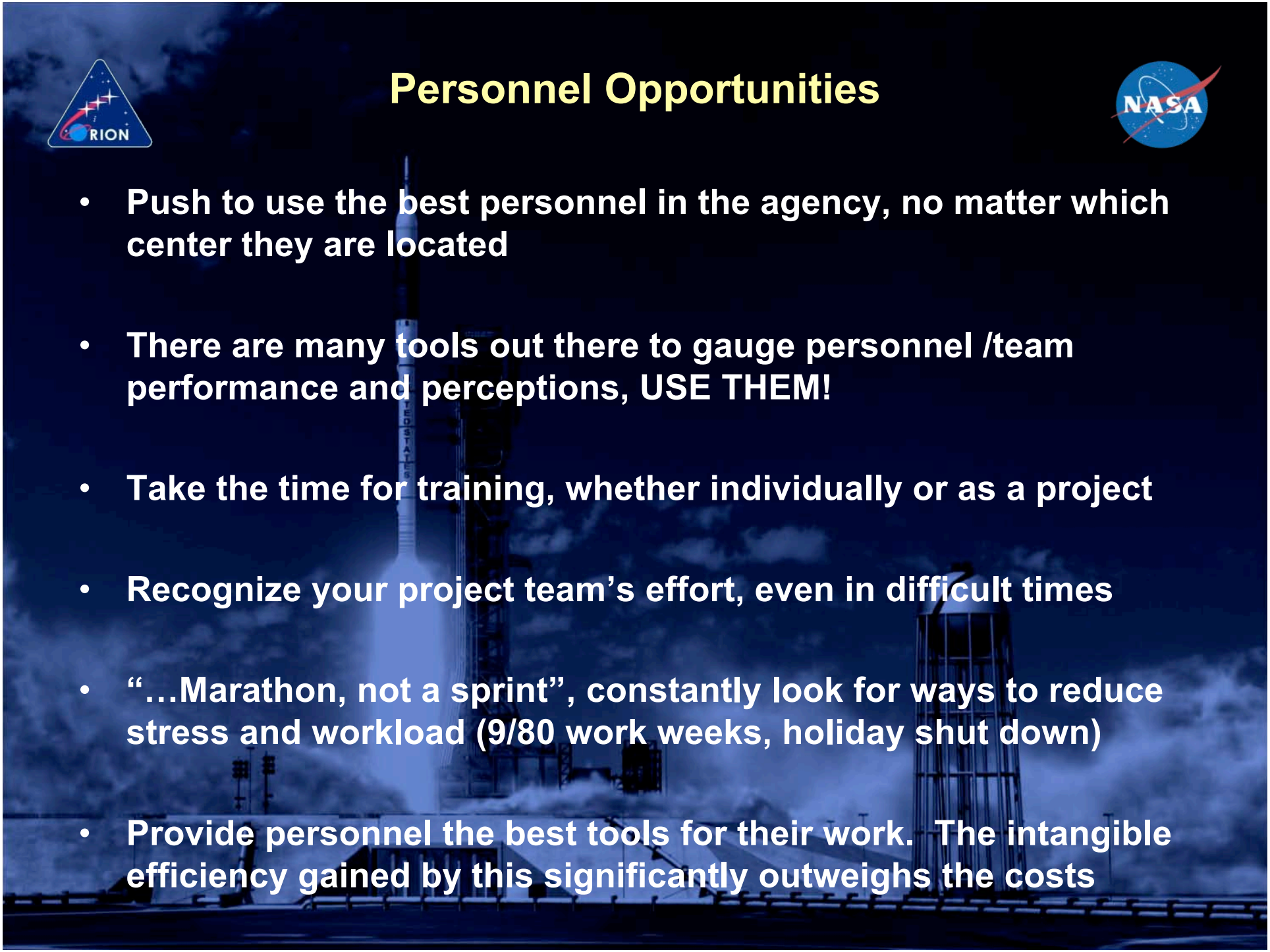
- Level of independent oversight activities due to size of project
  - External – IG and GAO (continuous), OMB (periodic, as needed)
  - Internal – SRB (Cx and Orion), ASAP, NAC, PA&E, OCE
- Keeping the contract aligned with the changing requirements and budget
- Projects need to consider the "illogical" political ramifications of actions internal and external to the project
- "Death by Meetings"
  - What is the right balance in phase B of a major DDTE effort? Due to so many levels of boards/panels, authority gets confused
- Tracking and maintaining risks (technical, cost and schedule)

Non-Technical Opportunities

- **Plan on change**
  Project needs budget, schedule and technical flexibility to handle change
- **Engage procurement personnel the same way you would technical folks**
  Fold them into the team
- **Don't get fixed on organization and board structure**
  These are tools and need to be changed to maximize performance.
- **Use independent review outputs**
  Investigate and learn from independent reviews (also review other relevant reviews)
- **Use previous lessons learned**
  Most of the time, something you are seeing for the first time has probably happened before

Personnel Challenges

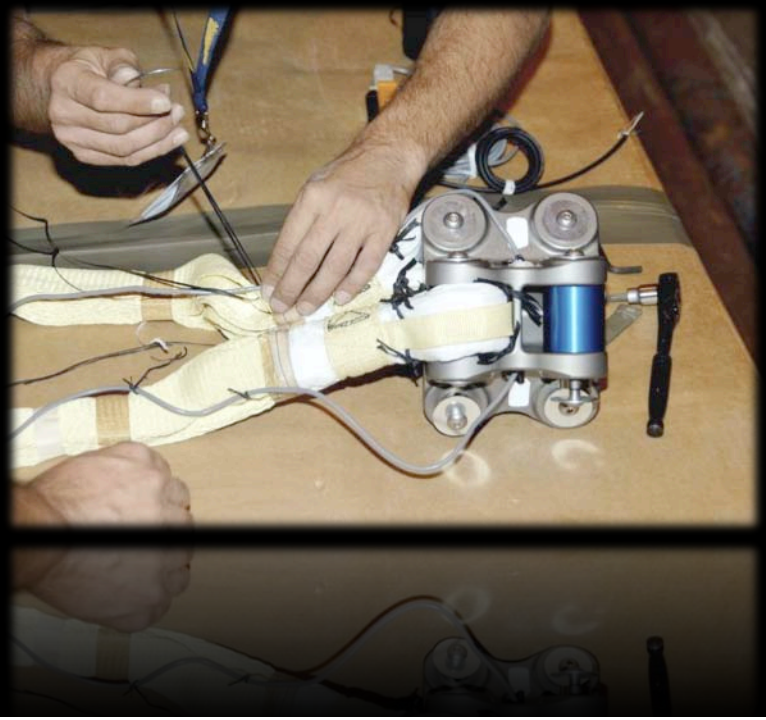
- **Working with a dispersed team**
  Even though we have a lot of remote support capability, it still is not as effective as it could be. Also, appreciation isn't as strong at dispersed centers
- **Communication, no matter how good, is not satisfactory to all**
  Some want more, some want less. Also, communication is probably one of our biggest hurdles to being more effective and efficient. If there are 10 people, there are 10 different interpretations
- **Work load!**
  With the IT infrastructure we use, information travels faster and constantly. Always in a race to keep in front of the "bad news" before it reaches higher management. With blackberries, everyone works at some level 16 hours a day, only time we don't, it seems, is when we sleep (which is another thing we sacrifice in a project)
- **Relationships**
  Constant reassuring and "massaging" of relationships between NASA and with the contractor



Personnel Opportunities

- Push to use the best personnel in the agency, no matter which center they are located
- There are many tools out there to gauge personnel /team performance and perceptions, USE THEM!
- Take the time for training, whether individually or as a project
- Recognize your project team's effort, even in difficult times
- "…Marathon, not a sprint", constantly look for ways to reduce stress and workload (9/80 work weeks, holiday shut down)
- Provide personnel the best tools for their work. The intangible efficiency gained by this significantly outweighs the costs

Parachute Integration



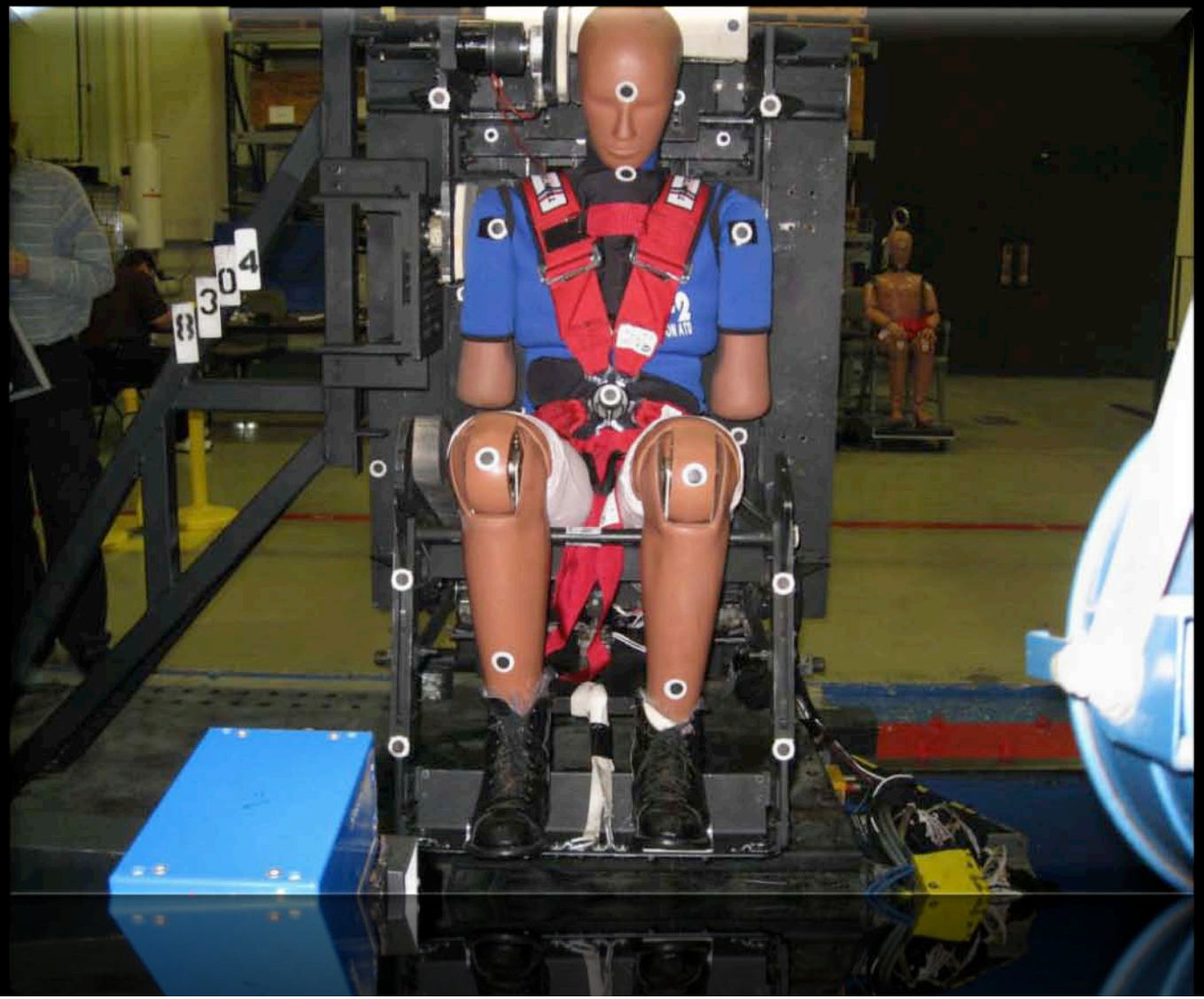
Parachute Test Vehicle

Parachute Tests

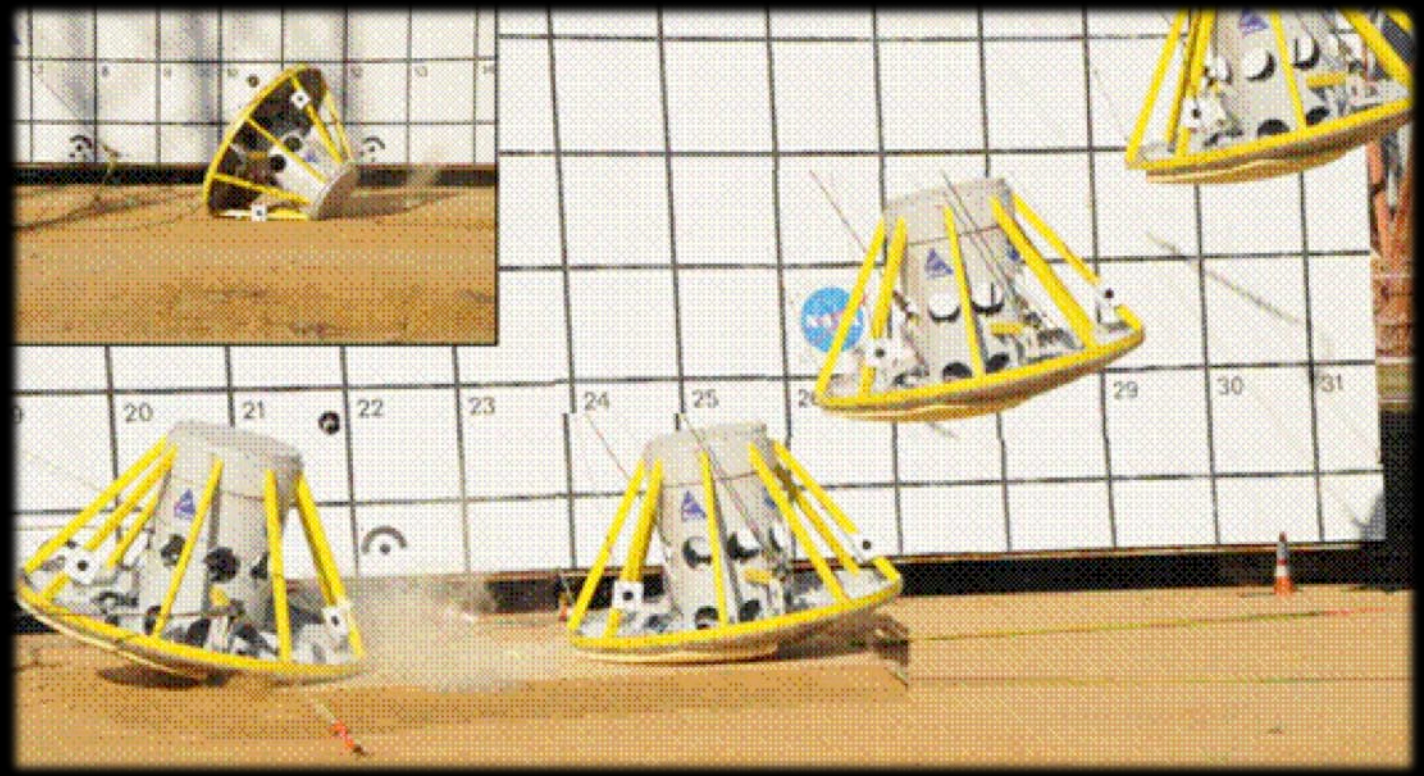
Crew Impact Attenuation System **Test Fixture**

Orion Seat Evaluations

Crew Systems Lateral Restraint Sled Testing

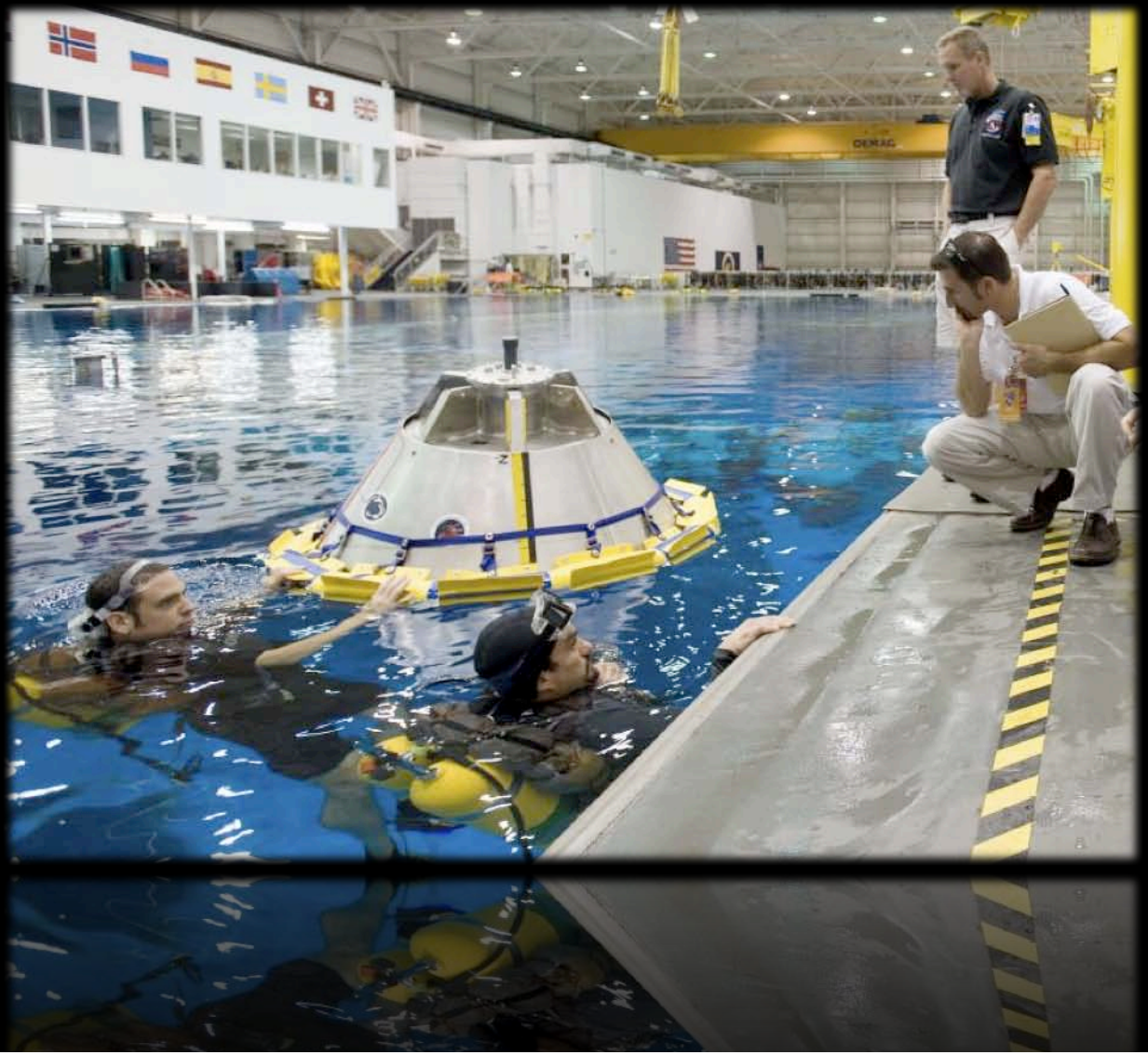


Avcoat Friction **Drop Tests**

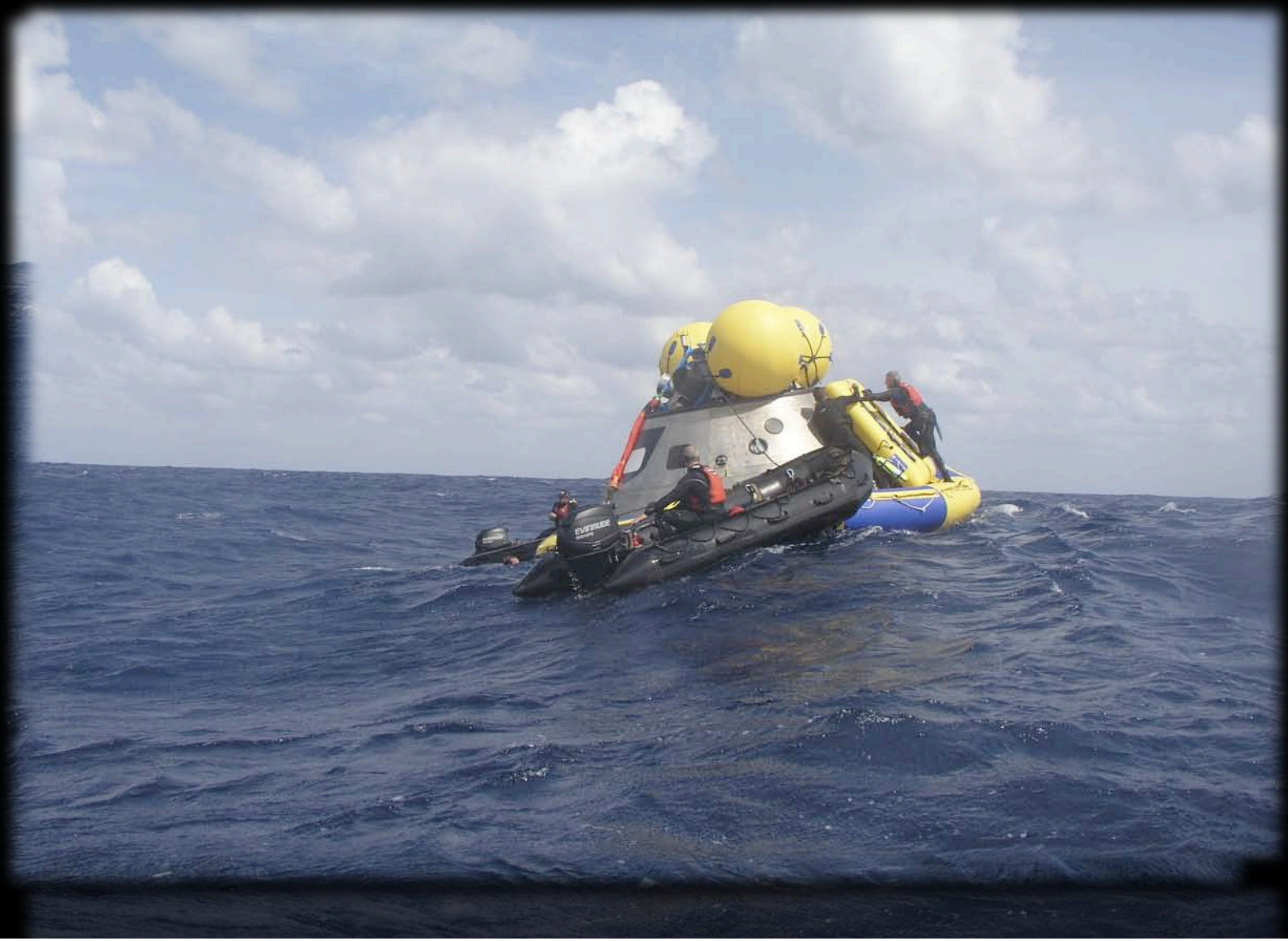


Downselect of Avcoat &
Thermal Protection System Transition

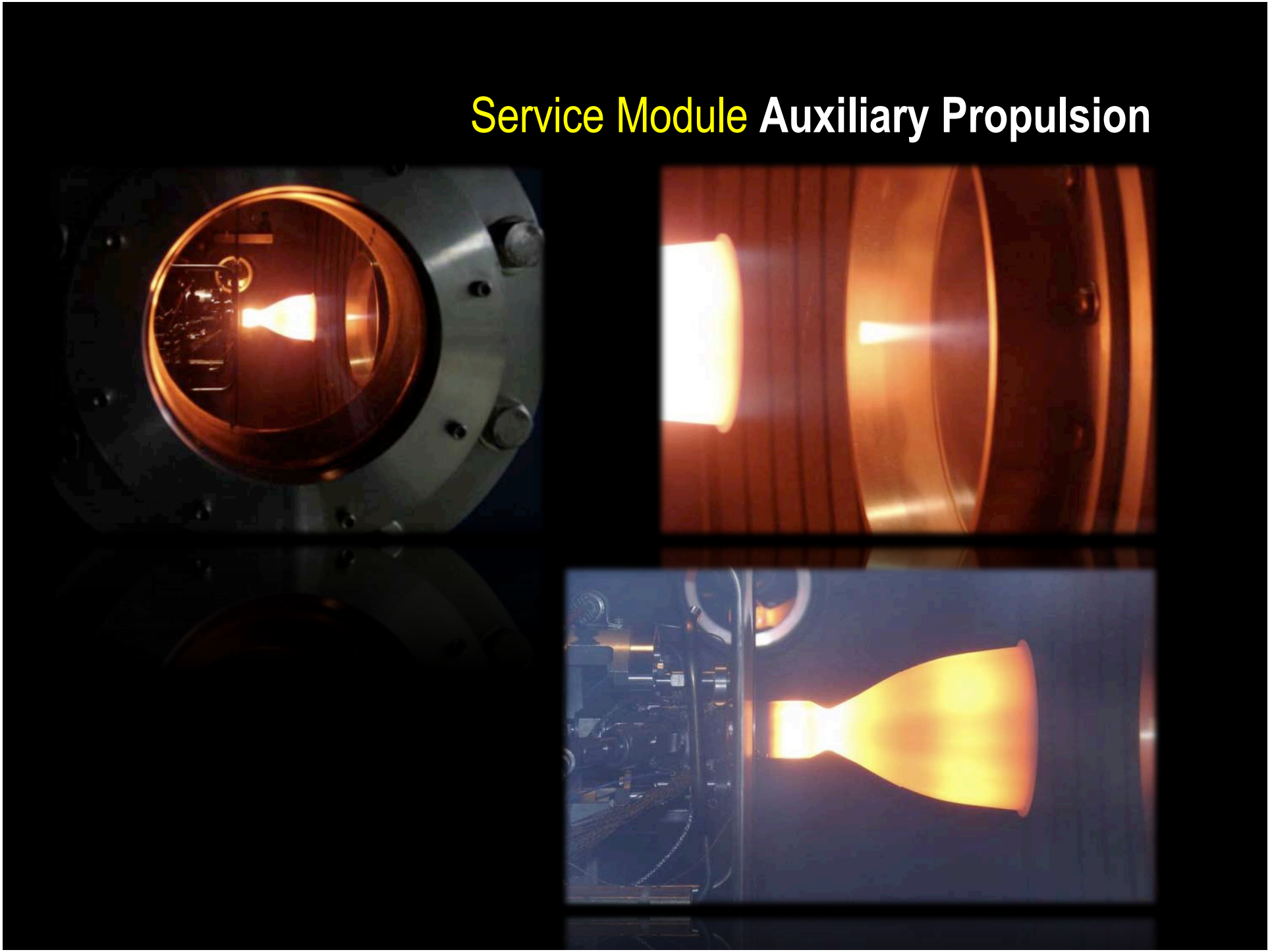
¼ Scale Crew Module Testing **Neutral Buoyancy Lab**



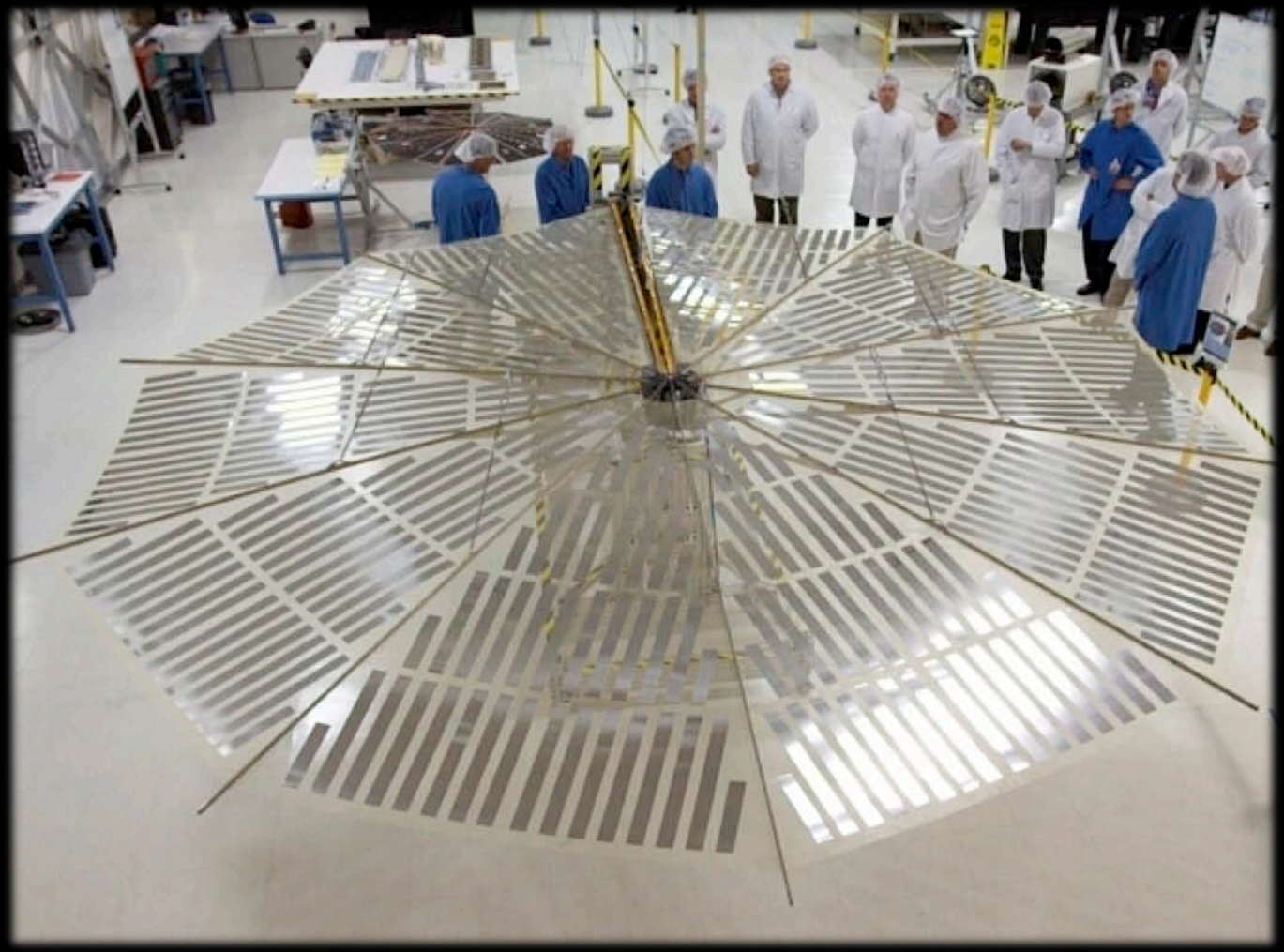
Orion PORT Sea State Testing



Service Module Auxiliary Propulsion



Solar Array Deployment Testing



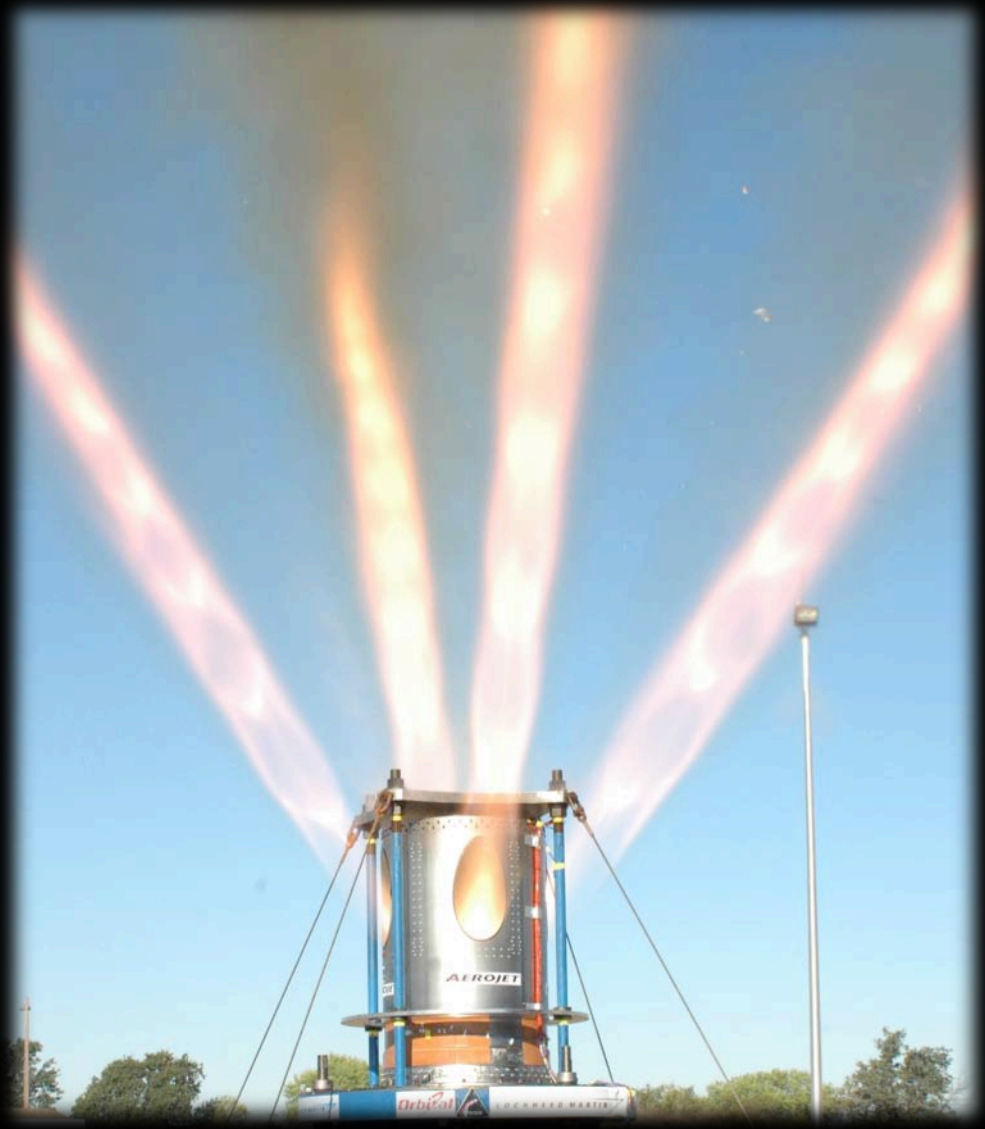
Abort Motor **Static Test-1**

video

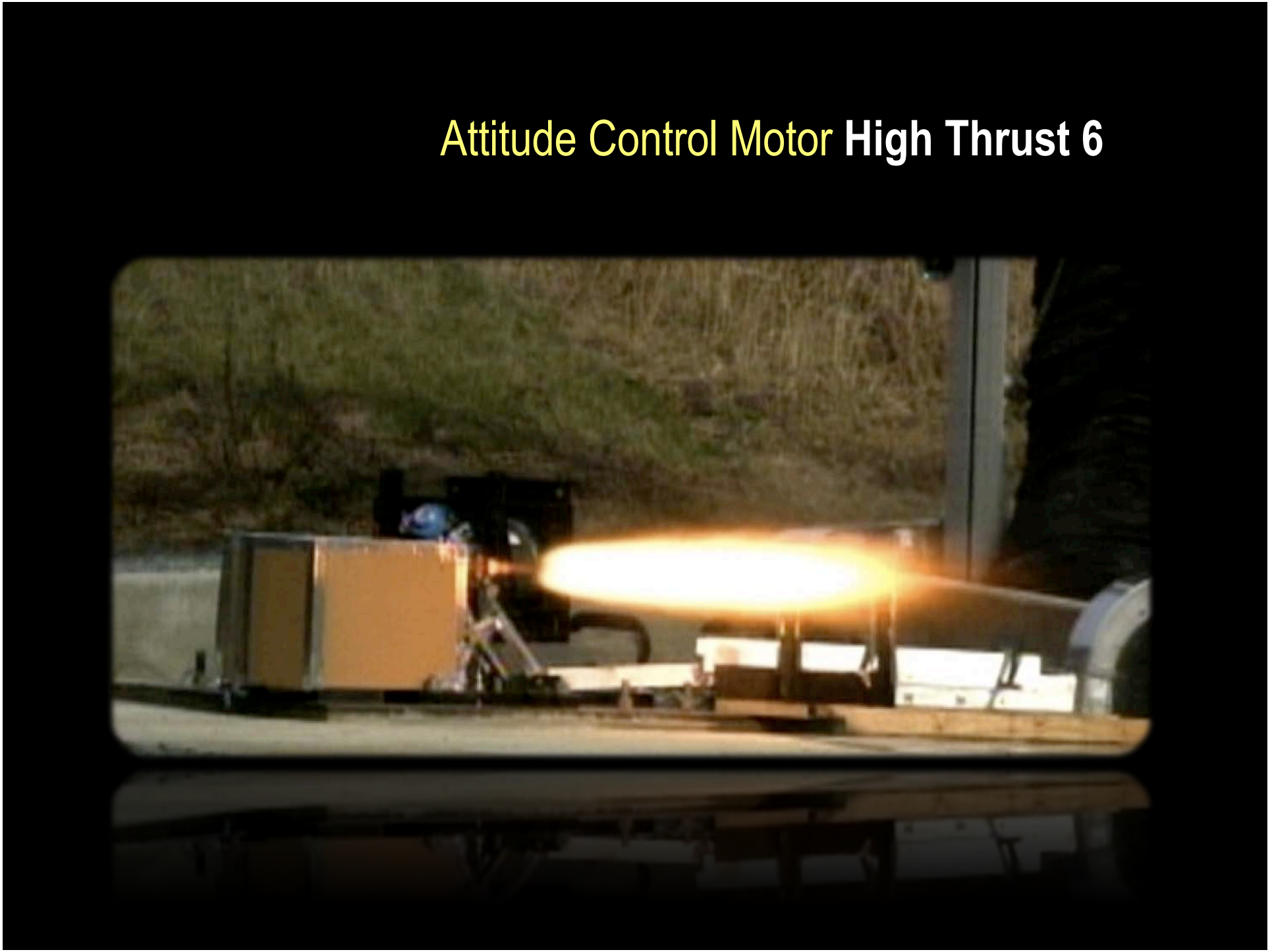
Launch Abort System **Jettison Motor**

SDU Case

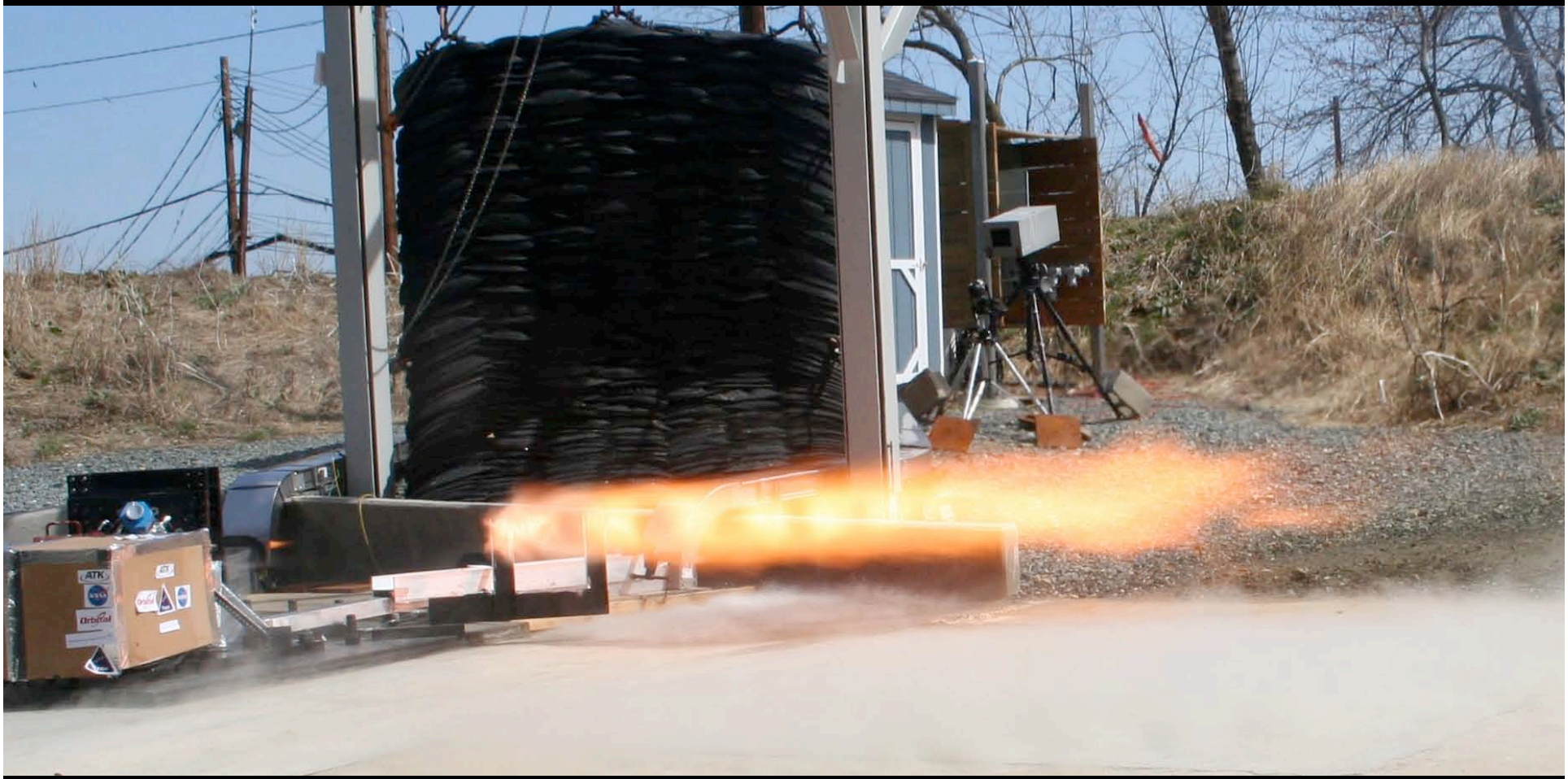
SDU Core



Attitude Control Motor **High Thrust 6**



Attitude Control Motor **High Thrust 8**



Operations & Checkout Facility **High Bay Looking West**

Before

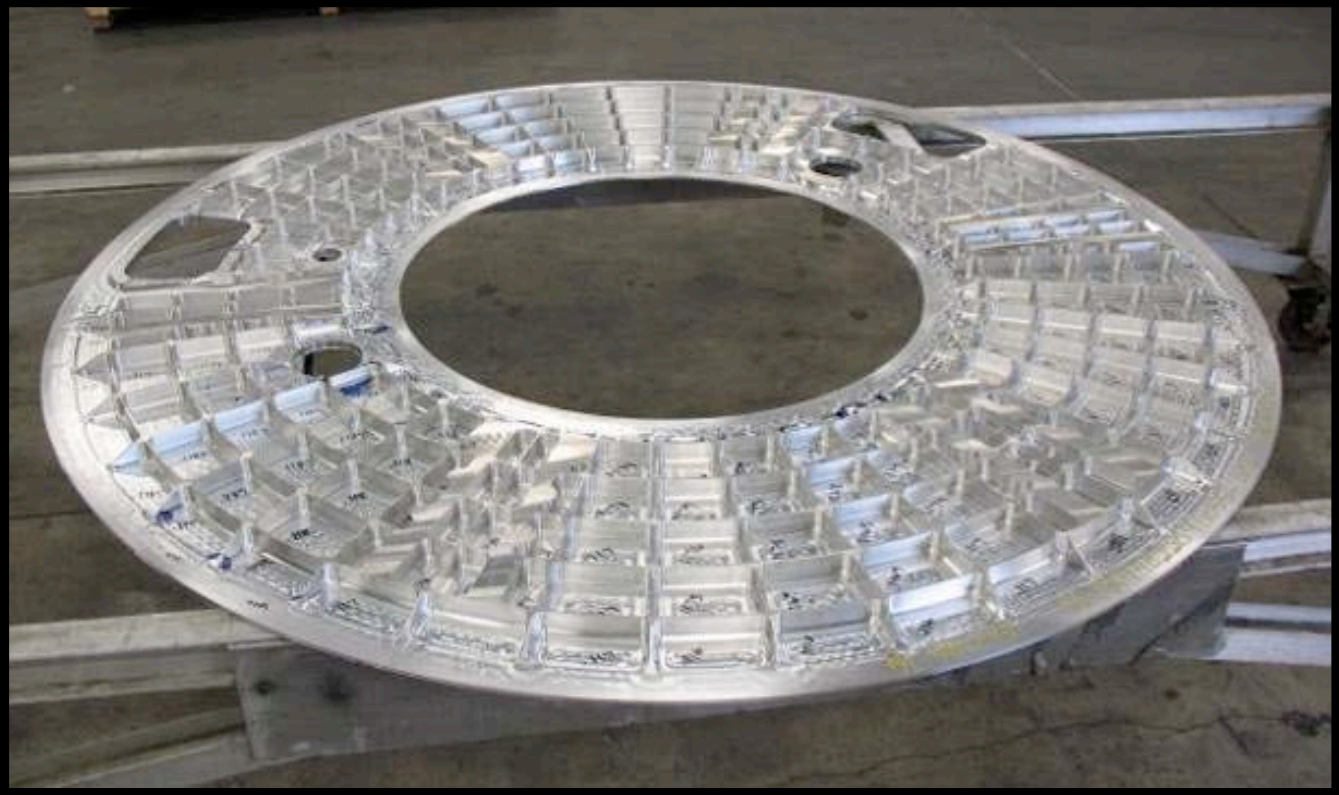
After

Operations & Checkout Facility **Basement**

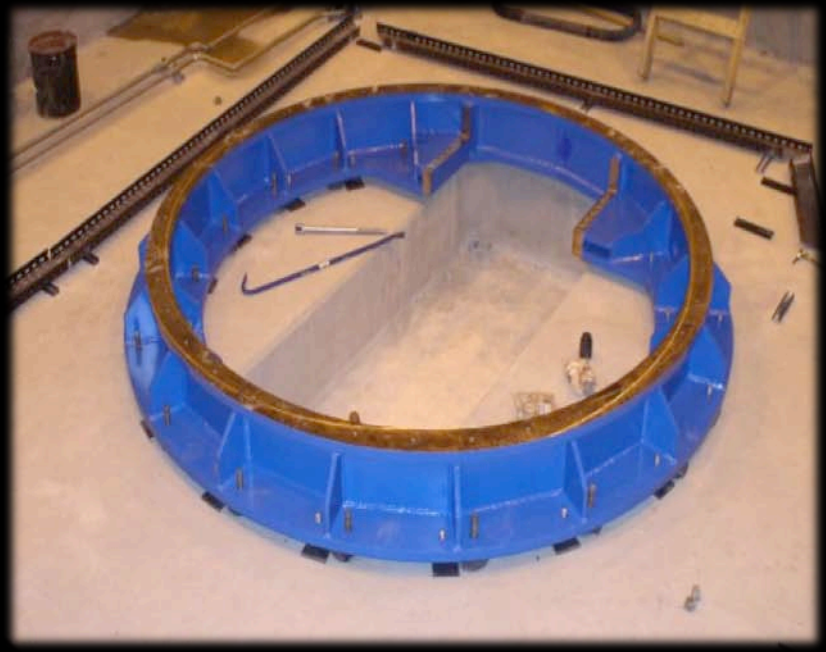
Before

After

Michoud Assembly Facility **Orion Structural Manufacturing**

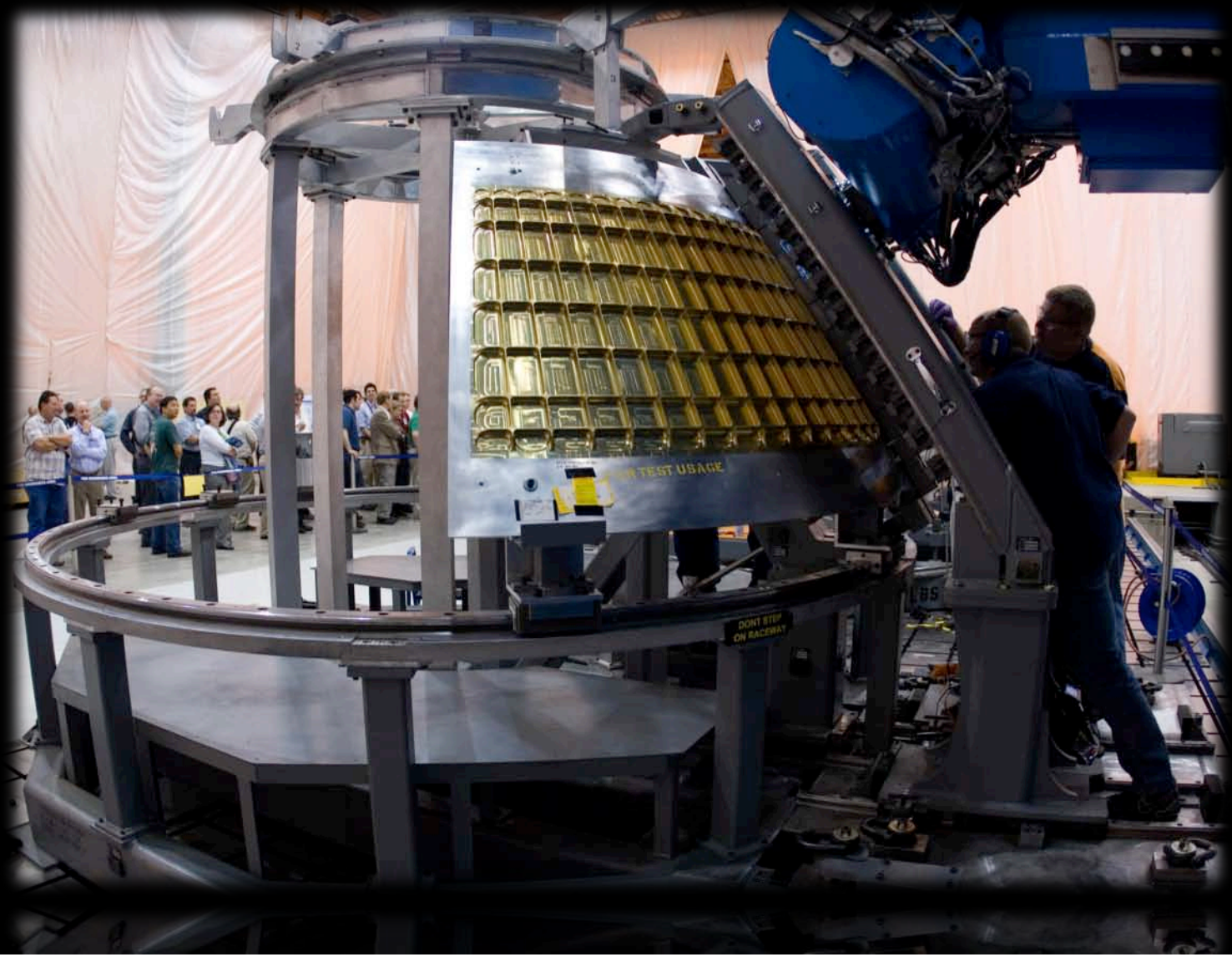


Michoud Assembly Facility **Universal Weld System 2 turntable base and Y-Column X-Rails**

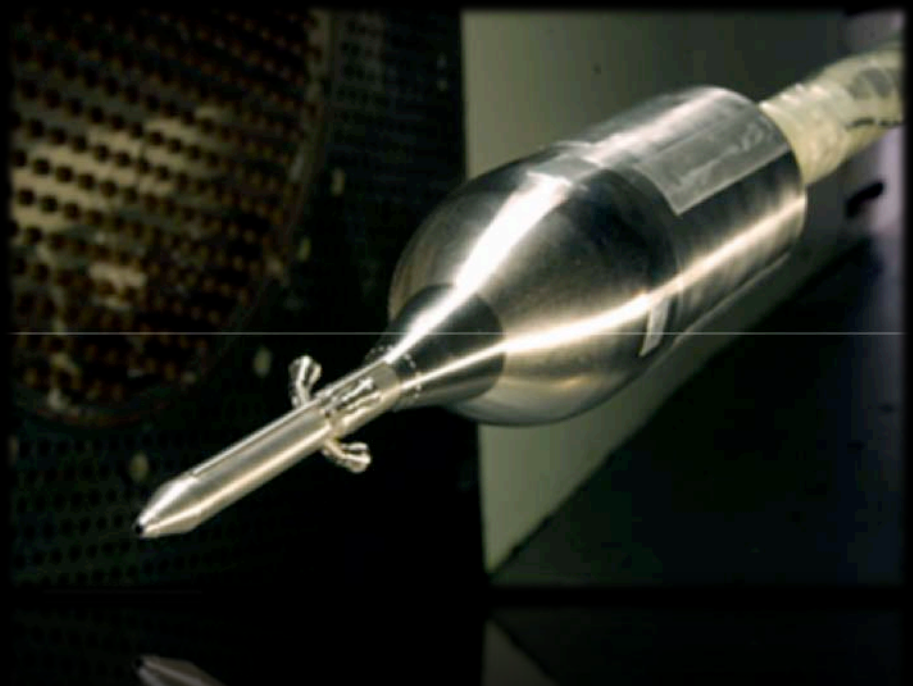


First friction stir weld

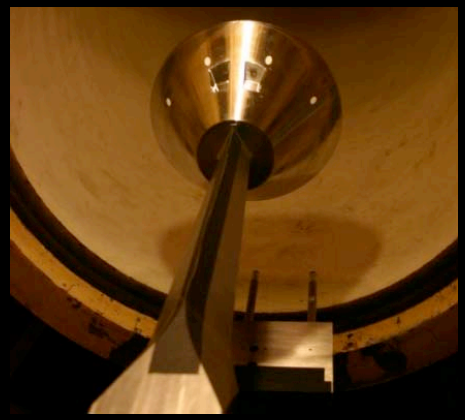
Orion crew module Ground Test Article Lite

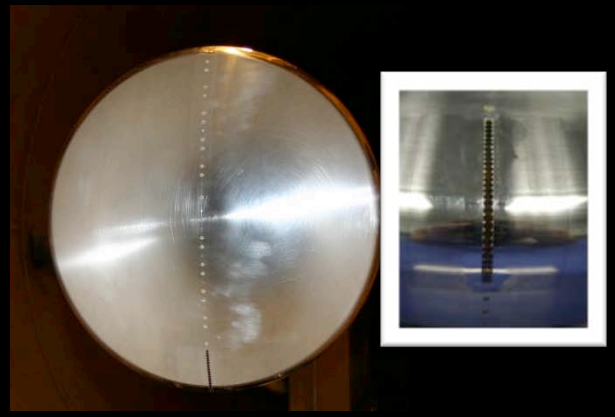


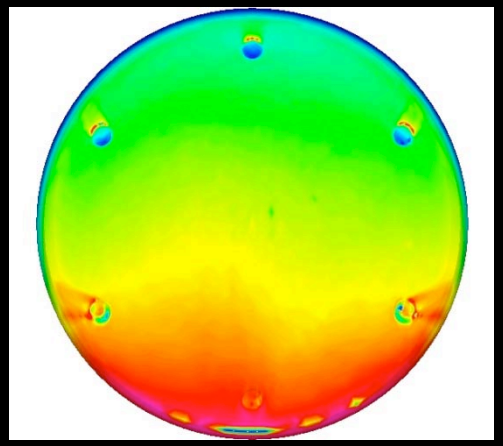
Wind Tunnel **Testing**

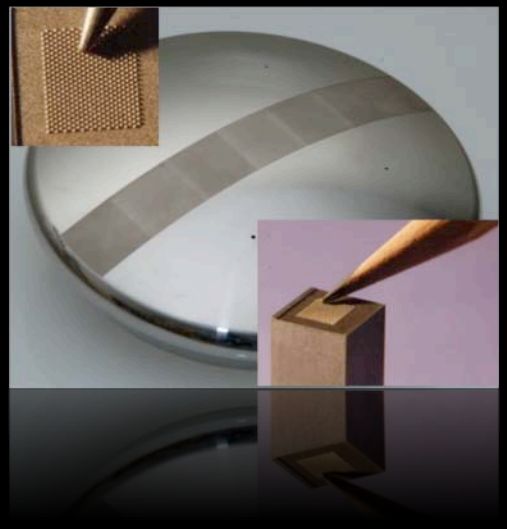


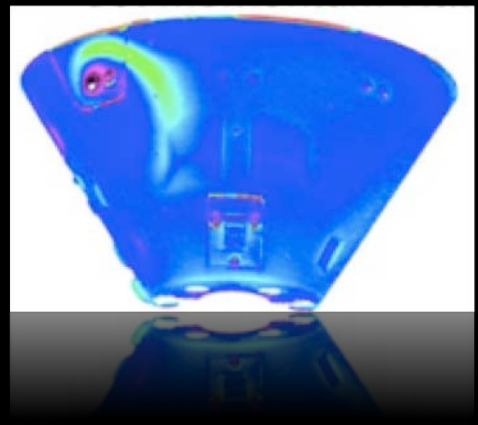
CAP Aerothermodynamic Testing







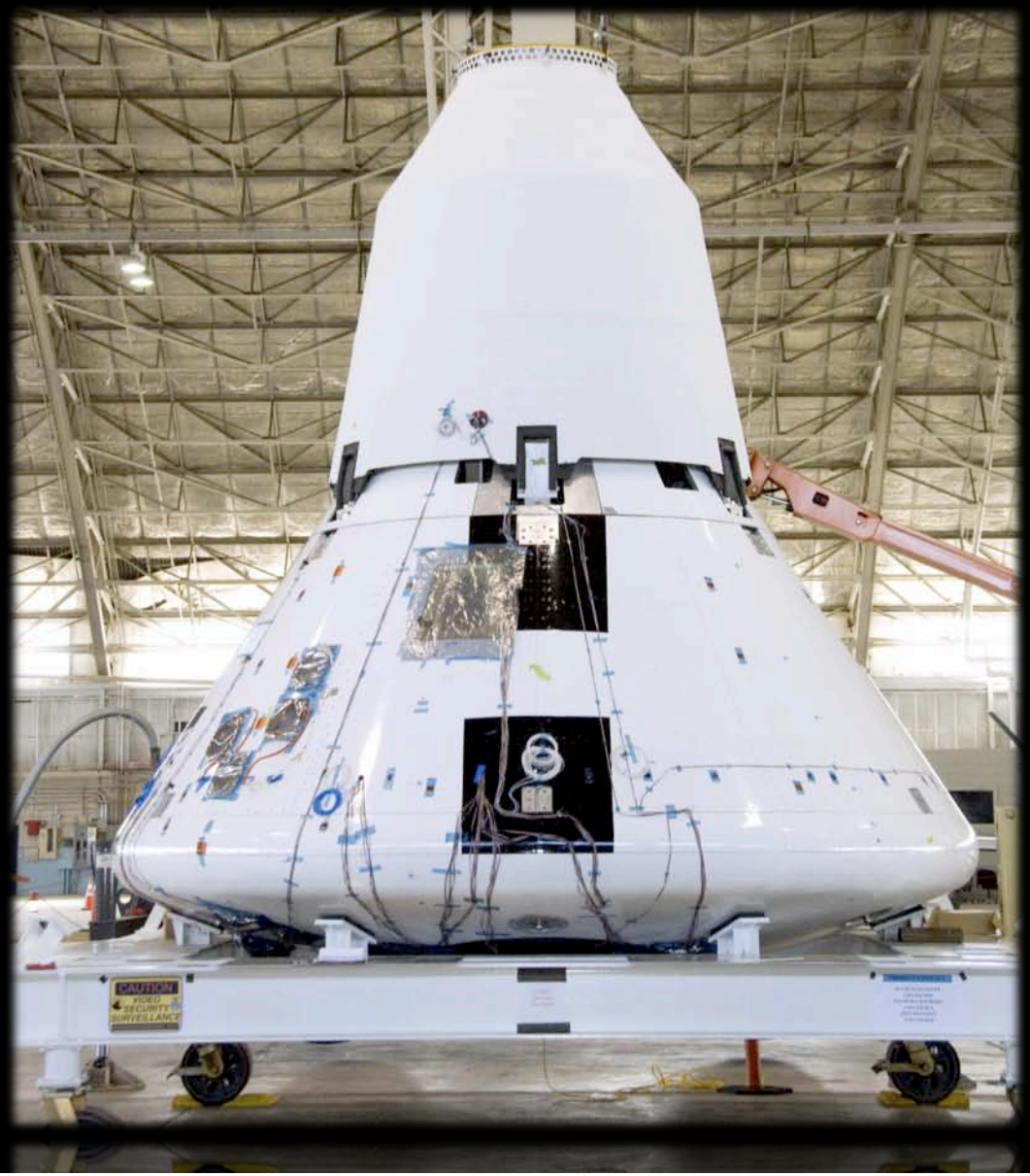




Pad Abort 1 Crew Module **Weight and balance testing**

Pad Abort 1 Launch Abort System **Jettison Motor Delivery**

Pad Abort 1 Adapter Cone to Crew Module Fit Check



CEV Parachute Assembly System Hardware
Installed on top of the Pad Abort 1 vehicle

Ascent Abort 1 **Gantry Construction**