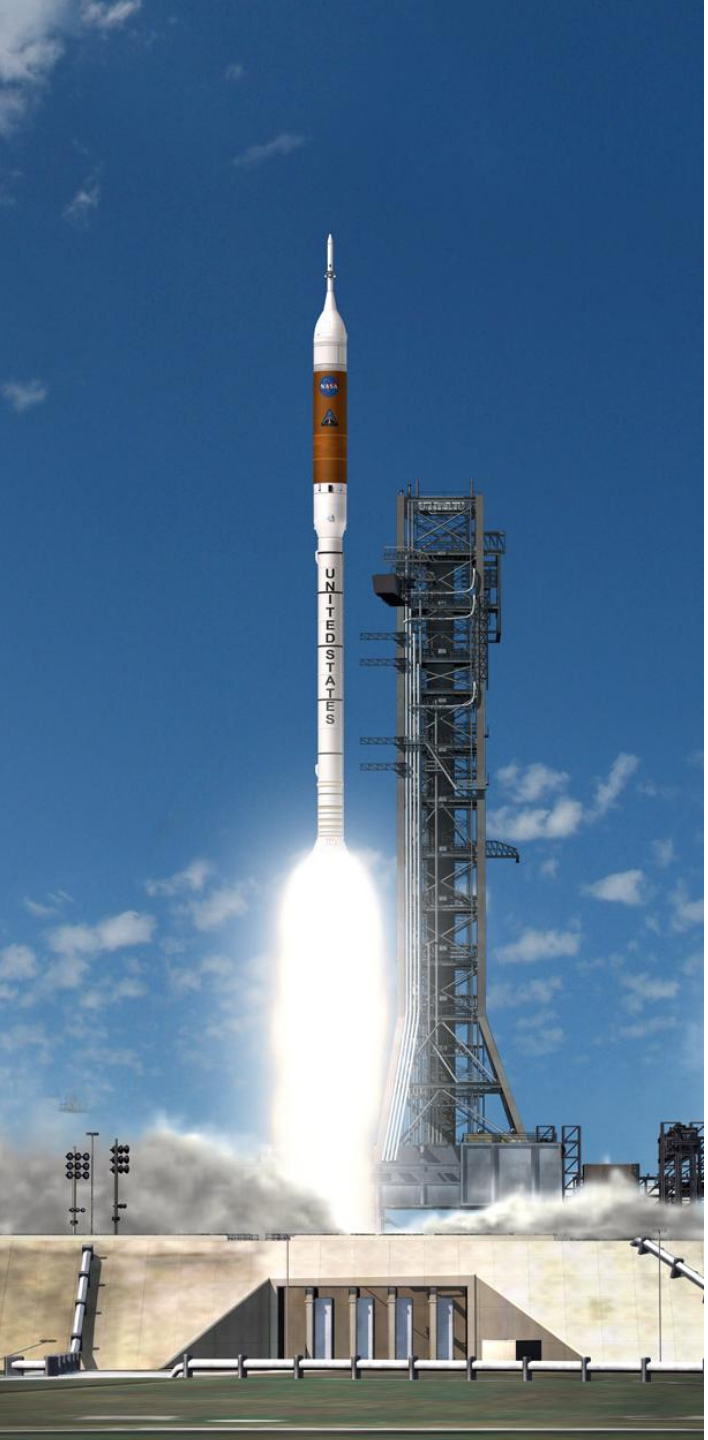
Orion Crew Exploration Vehicle

July 28, 2009

www.nasa.gov

Orion is Moving Forward!

- **Constellation LEO/Lunar mission objectives drove integrated Orion System Design**
- **Completing Preliminary Design Review**
- **Successfully completed rigorous, extensive engineering and development testing**
- **Optimizing the details of our schedule to launch in 2015**
- **Utilizing risk informed design to build a safe vehicle and assure mission success**
- **Started production**



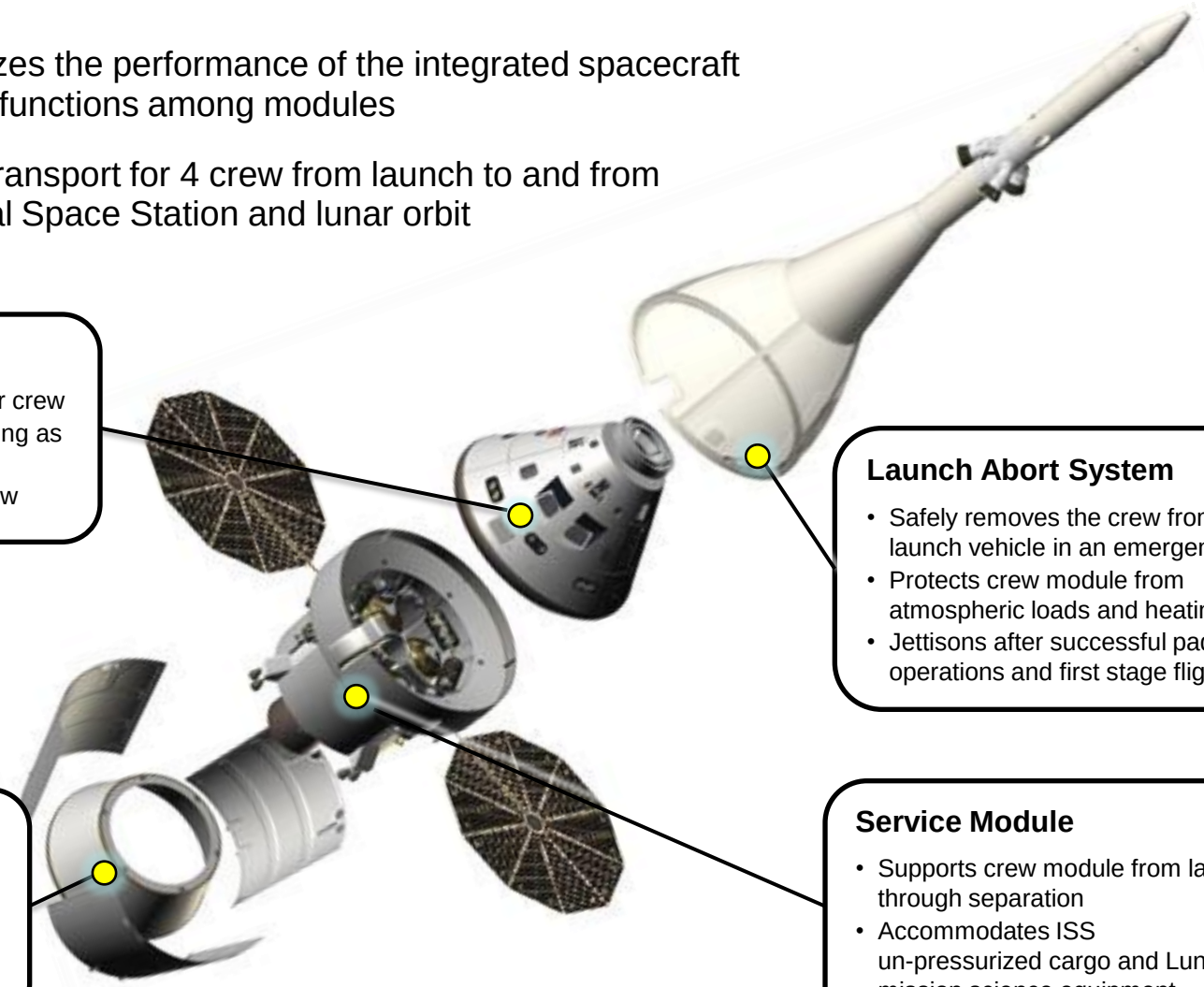
Agenda

- Orion Crew Exploration Vehicle
- Preliminary Design Review
- Orion Progress
- Schedule
- Mass Management
- Human Rating
- Summary

Orion Crew Exploration Vehicle

Orion Crew Exploration Vehicle

- Design maximizes the performance of the integrated spacecraft dividing critical functions among modules
- Provides safe transport for 4 crew from launch to and from the International Space Station and lunar orbit



Crew Module

- Provides safe habitat for crew
- Allows reentry and landing as a stand alone module
- Docks and transfers crew

Launch Abort System

- Safely removes the crew from launch vehicle in an emergency
- Protects crew module from atmospheric loads and heating
- Jettisons after successful pad operations and first stage flight

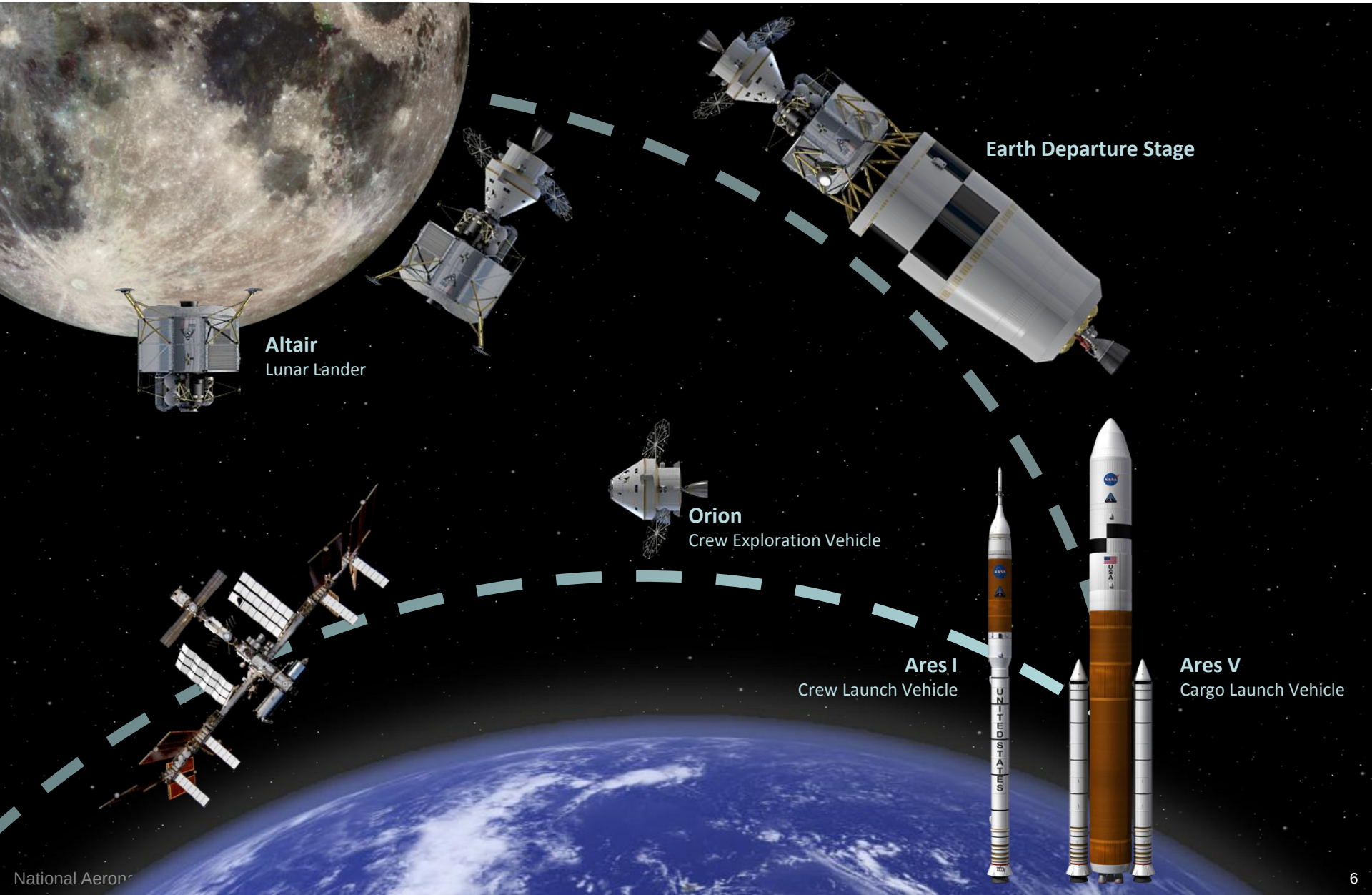
Spacecraft Adapter

- Provides connection to launch vehicle
- Protects Service Module components

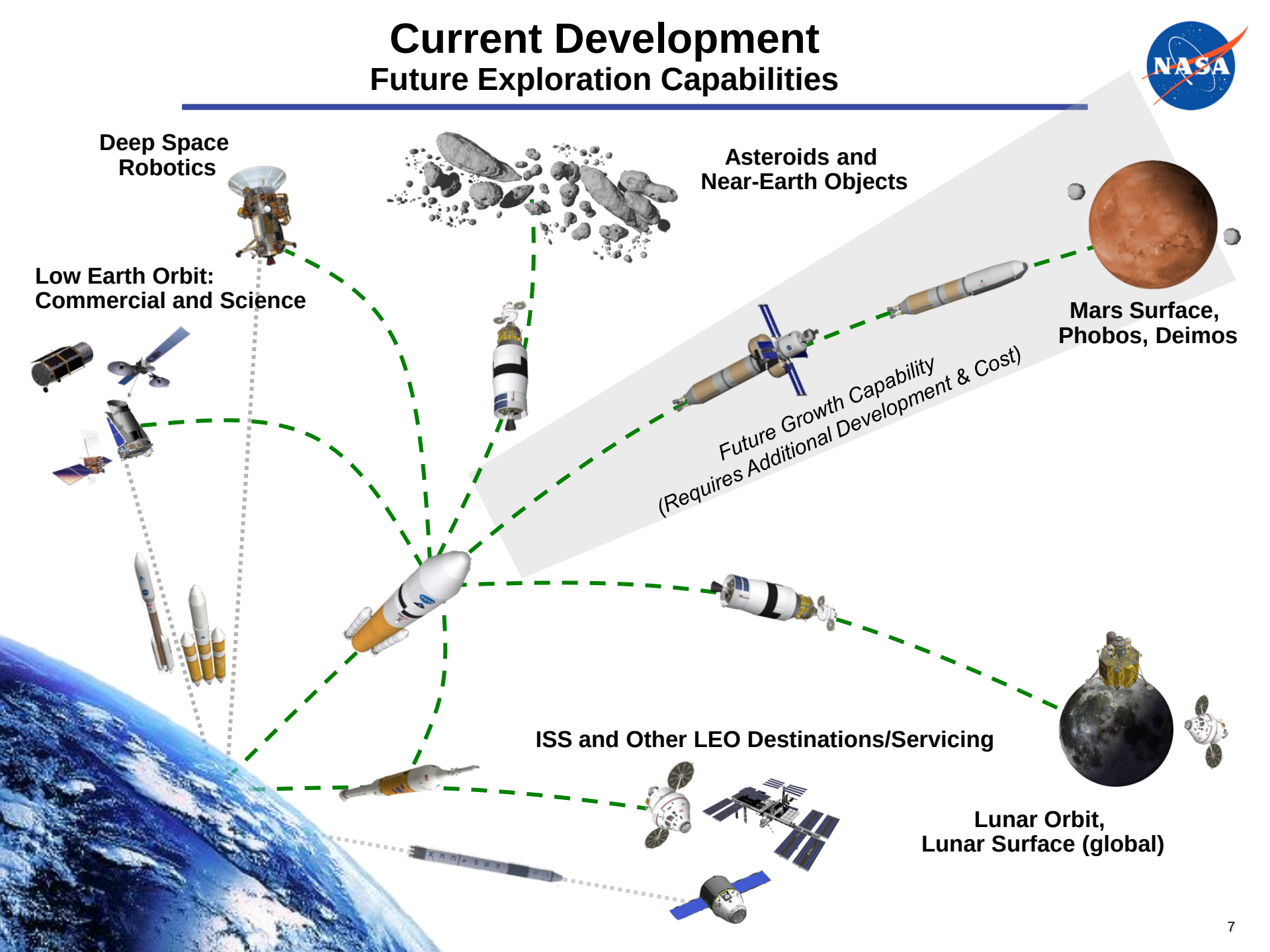
Service Module

- Supports crew module from launch through separation
- Accommodates ISS un-pressurized cargo and Lunar mission science equipment

Constellation Systems: LEO/Lunar Missions

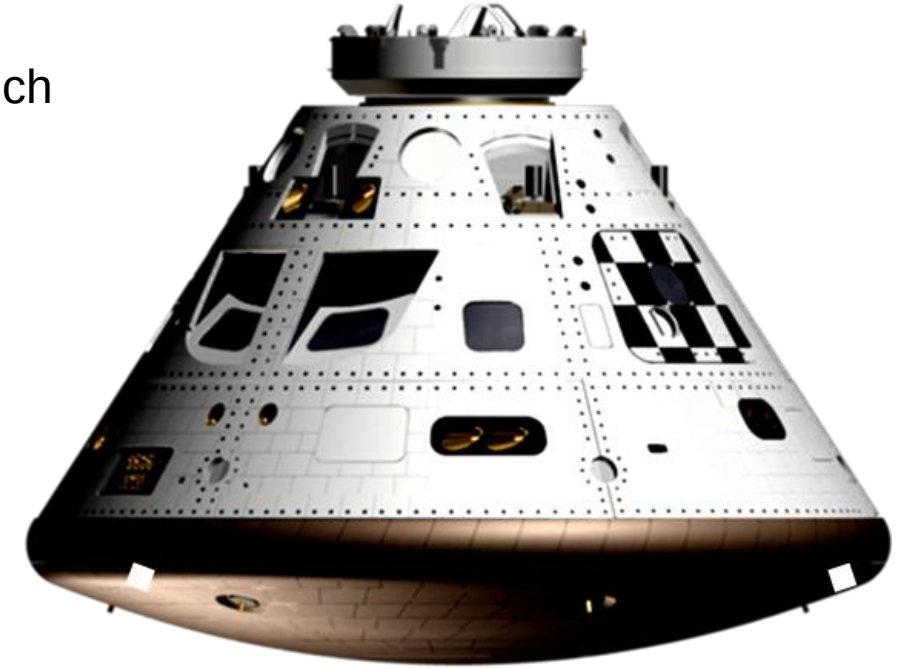


Current Development
Future Exploration Capabilities

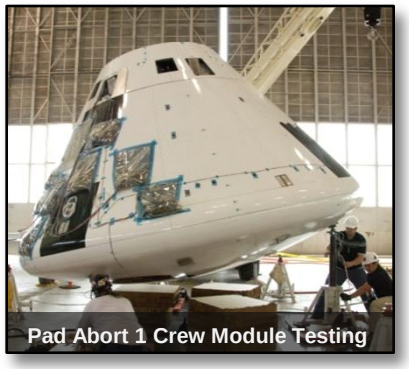


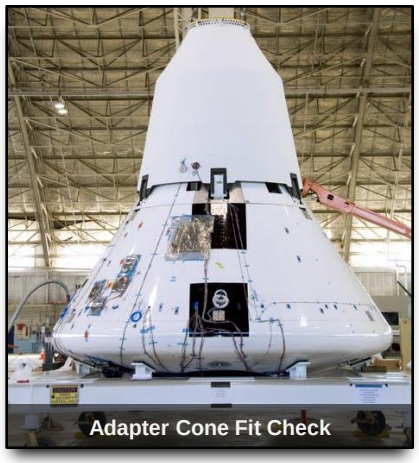
Orion Crew Module

- Provides a safe habitat from launch through landing and recovery
- Re-enters and lands as a stand alone module
- Docks and transfers crew with constellation elements
- Seats 4 crew to the International Space Station and Moon



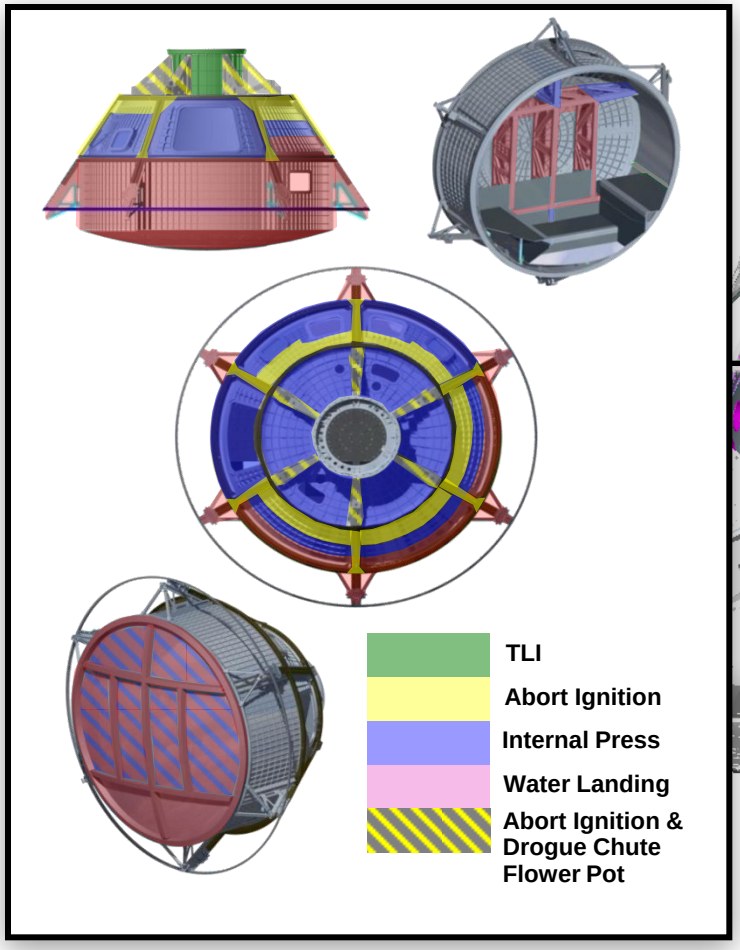

Pad Abort 1 Crew Module Tow

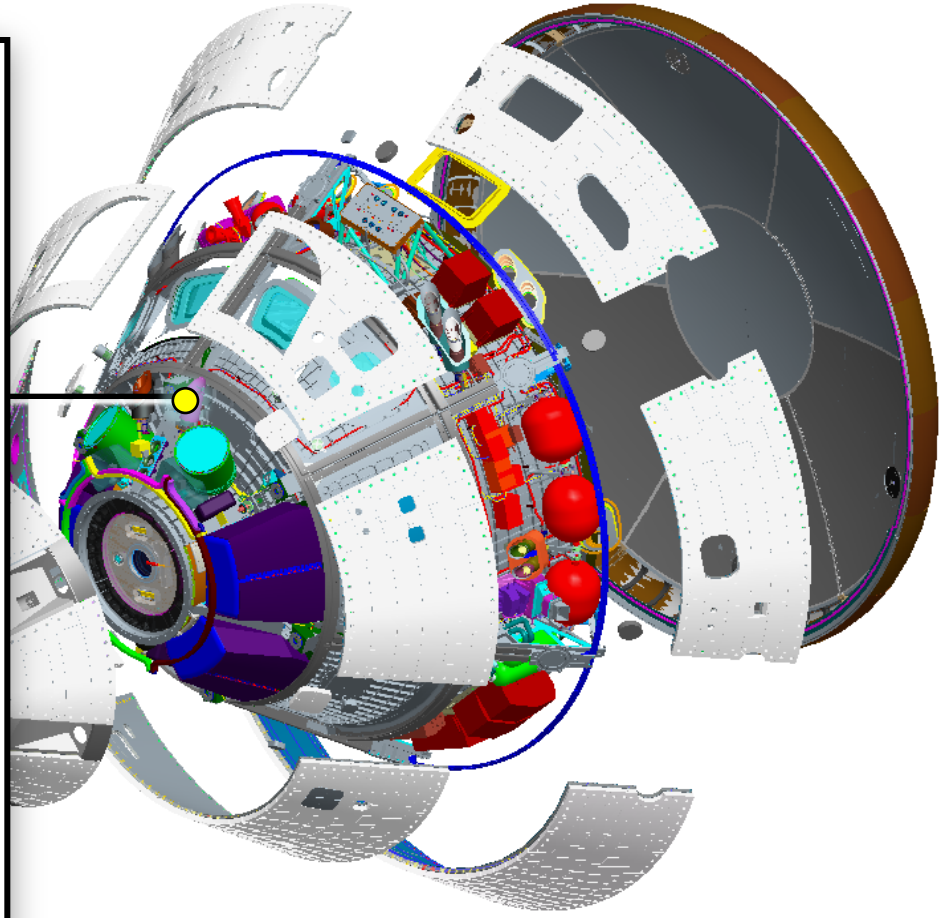

Pad Abort 1 Crew Module Testing


Adapter Cone Fit Check

Crew Module Primary Structure

- Carries launch, abort, pressure and landing loads
- Supports secondary structure and subsystem components





Loads & Structures Integration

Mass Properties
Master Equip List

System Design
System Configuration
CAD Models

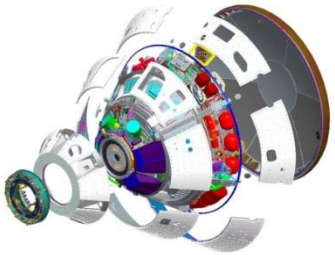
Finite Element Models
Loads
Stress

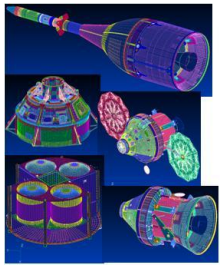
Mission Design
Trajectories

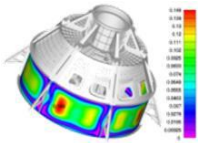
Propulsion
Engine/Motor Forces

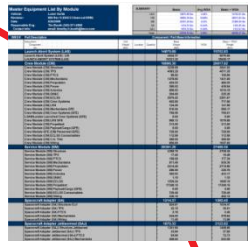
Loads Analysis
Liftoff/Ascent
Aborts
On-orbit
Chute deploy
Landing

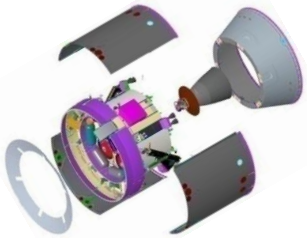
Aero Sciences
Aero Loads
Aero Coefficients
Plume Pressures
Ignition Overpressure

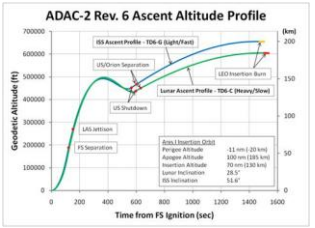


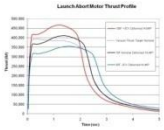


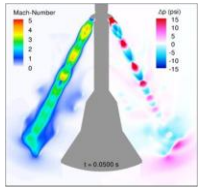


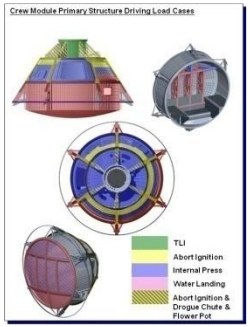


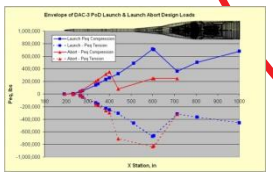


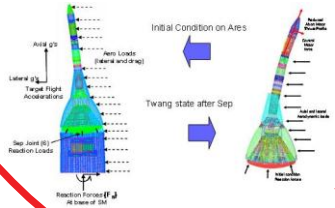


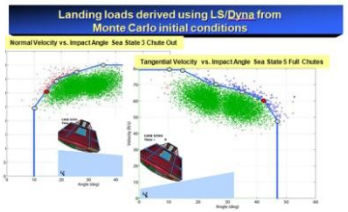


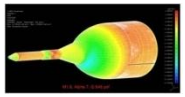


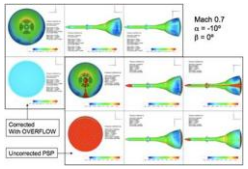


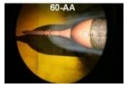


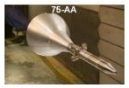




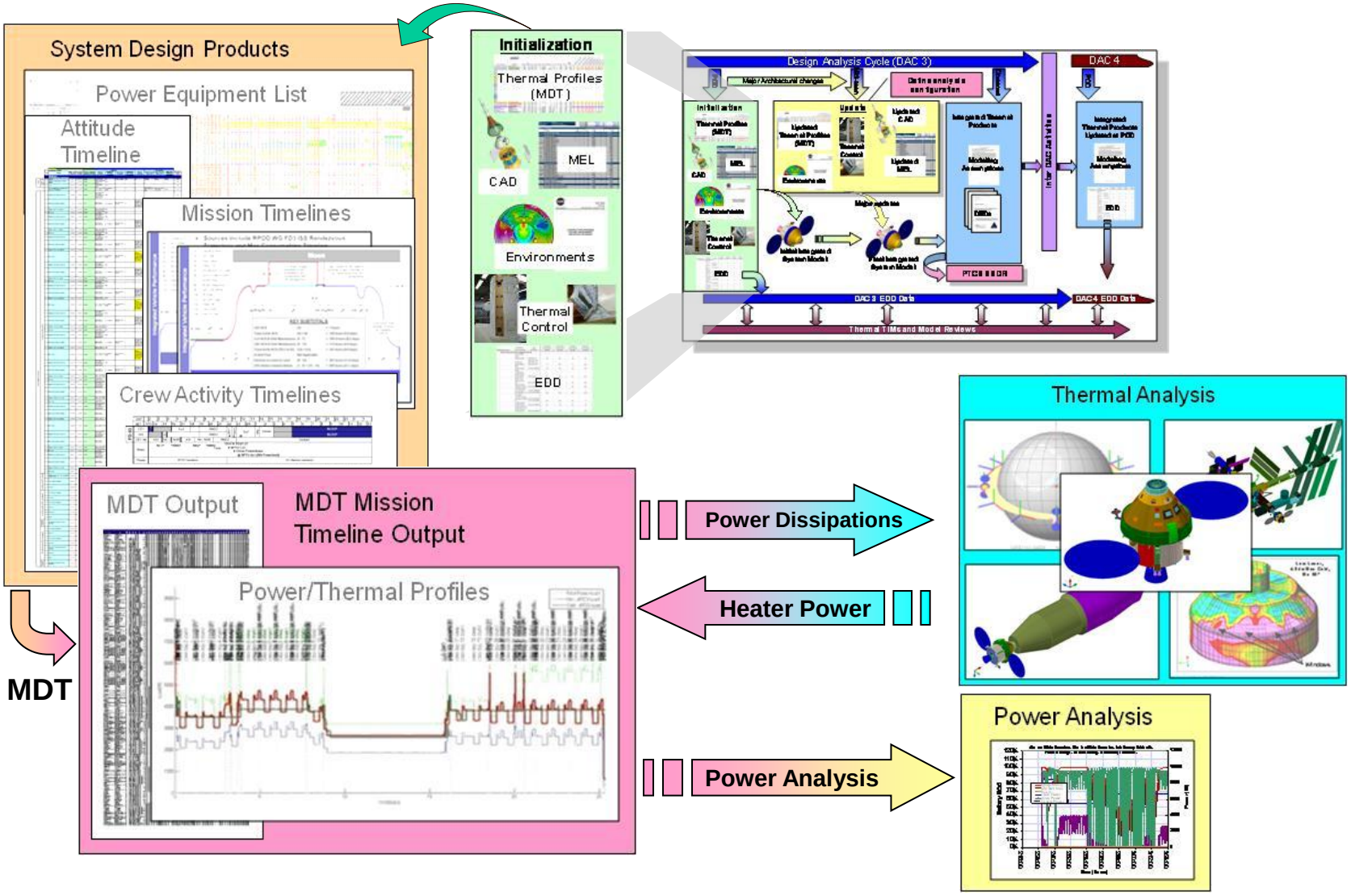






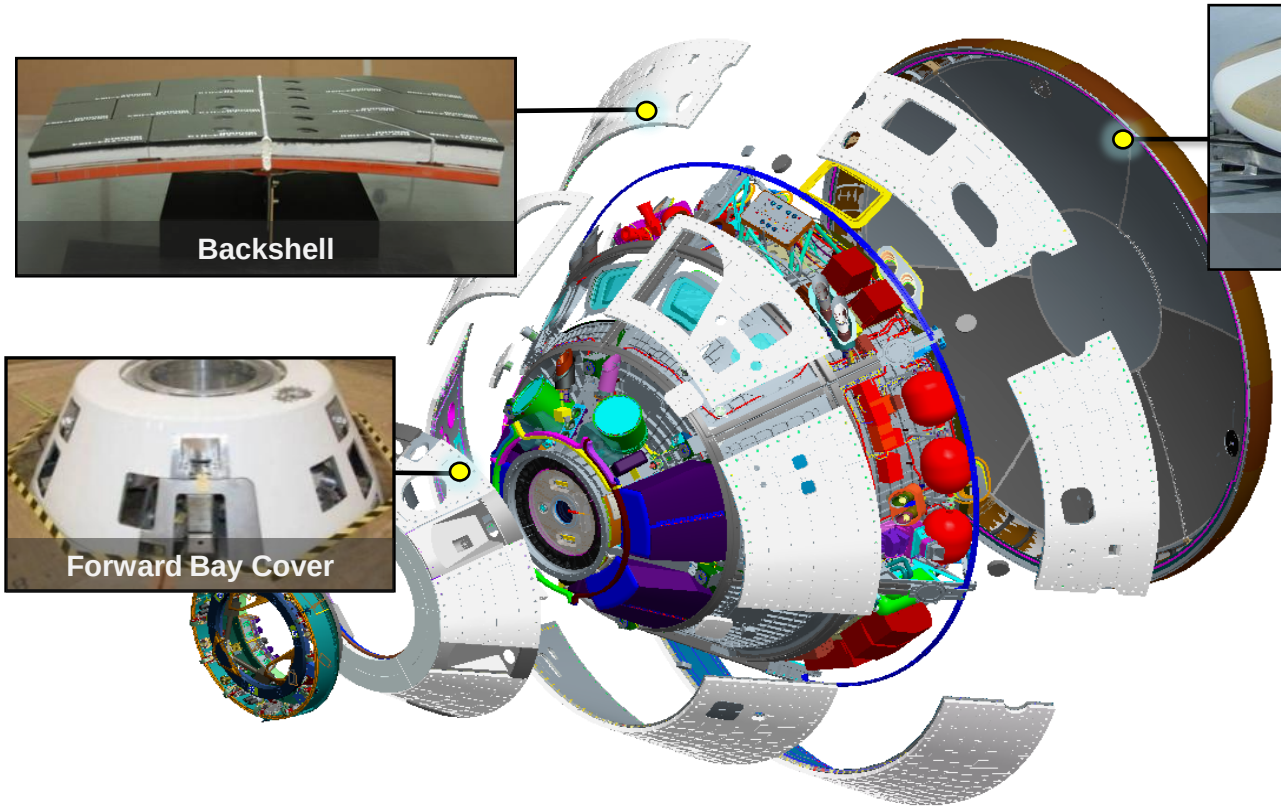


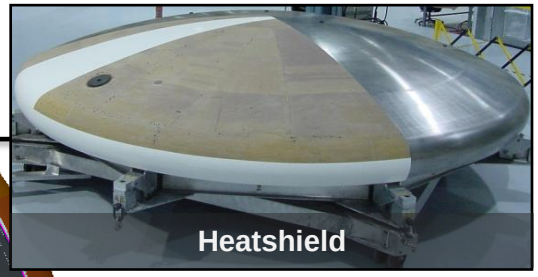
Integrated Power and Thermal Analysis Closes

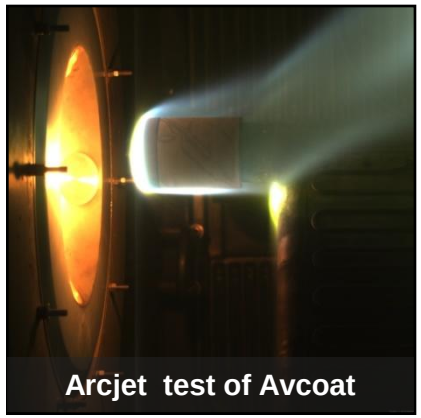


Thermal Protection System

- Defines outer mold line aero shape
- Dissipates and isolates crew module from reentry heat

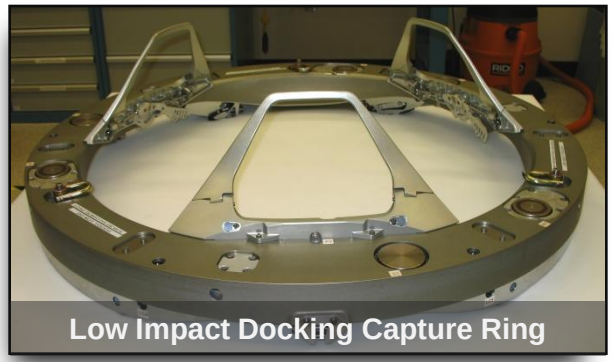


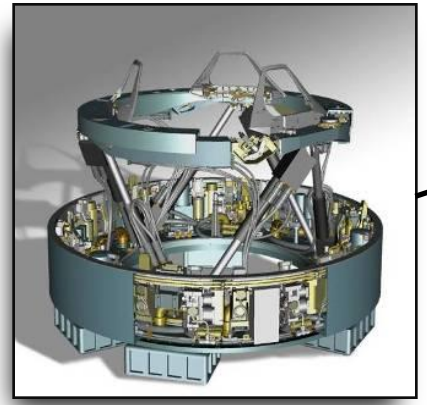


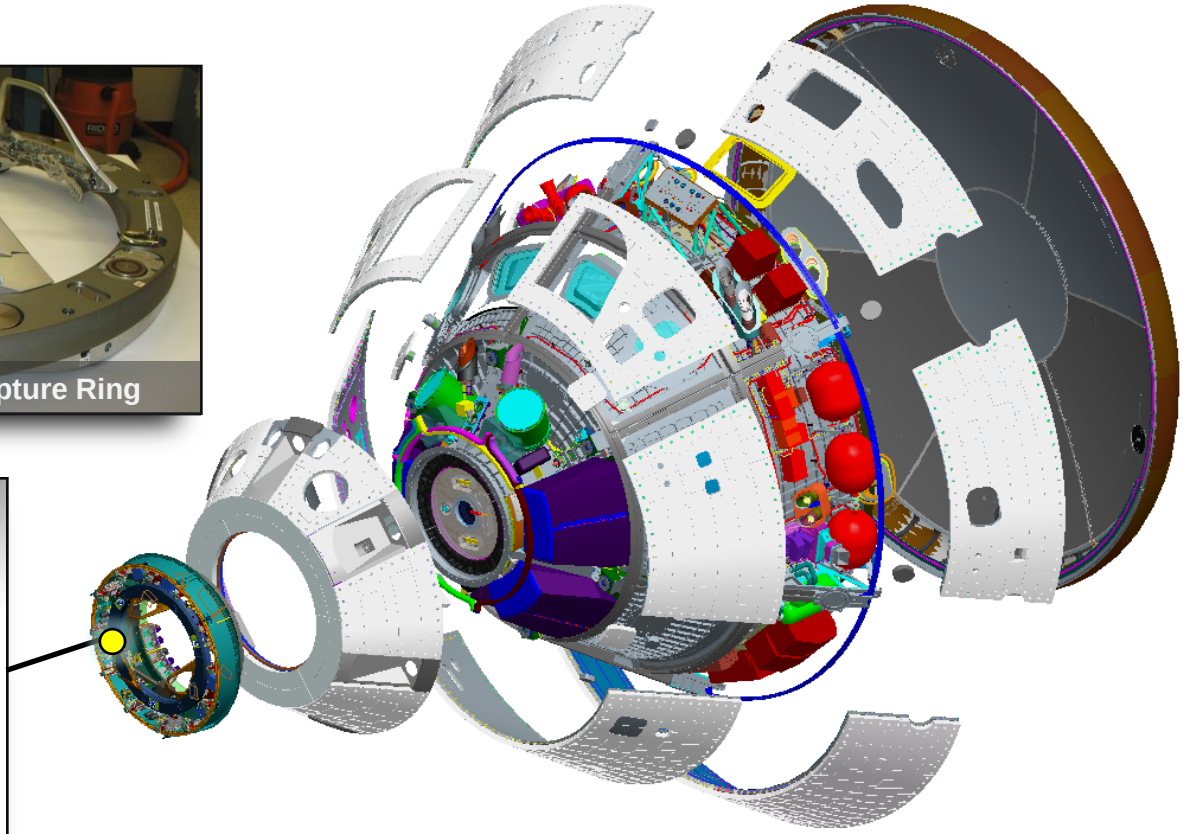


Low Impact Docking System

- Low impact to minimize loads
- Common interface with International Space Station and Constellation


Low Impact Docking Capture Ring



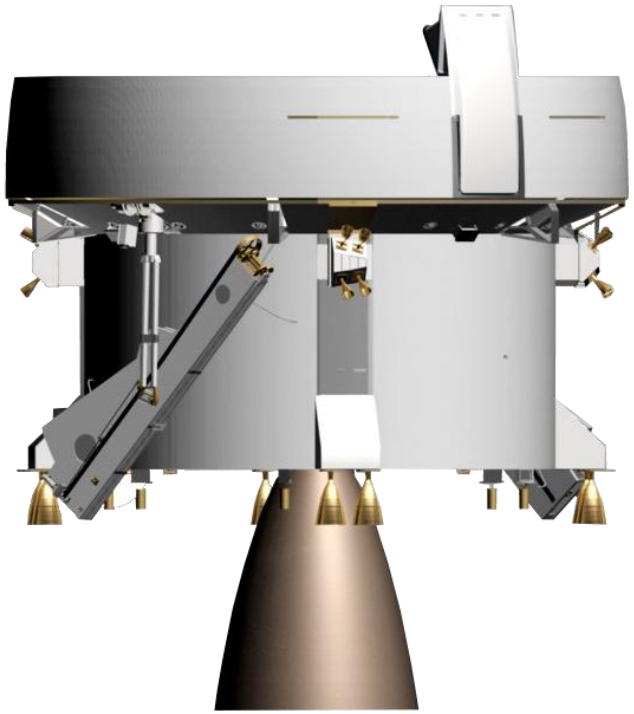


Crew Module Console

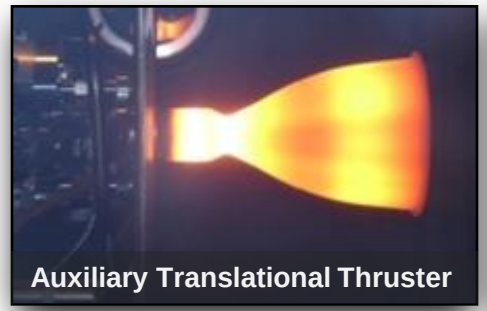
Provides:

- Situational awareness, control and communications
- Spacecraft state, caution/warning, system health, and electronic procedures data
- Input interface through control panel switches, display bezel keys, rotational and translational hand controllers, key pad and cursor control devices
- Communications with ground control and other constellation elements
- Exterior views through hatch, side and forward windows
- Backup display modes
- Manual backup control of power, ECLSS and communications functions

Orion Service Module



- Supports crew module from launch through separation
- Maneuvers vehicle to the ISS or Lunar orbit and back
- High altitude ascent abort propulsion after Launch Abort System jettison
- Provides orbital maintenance and attitude control
- Supplies power, storage, and consumables
- Primary thermal control while mated with crew module
- Accommodates ISS un-pressurized cargo and Lunar mission science equipment


Auxiliary Translational Thruster

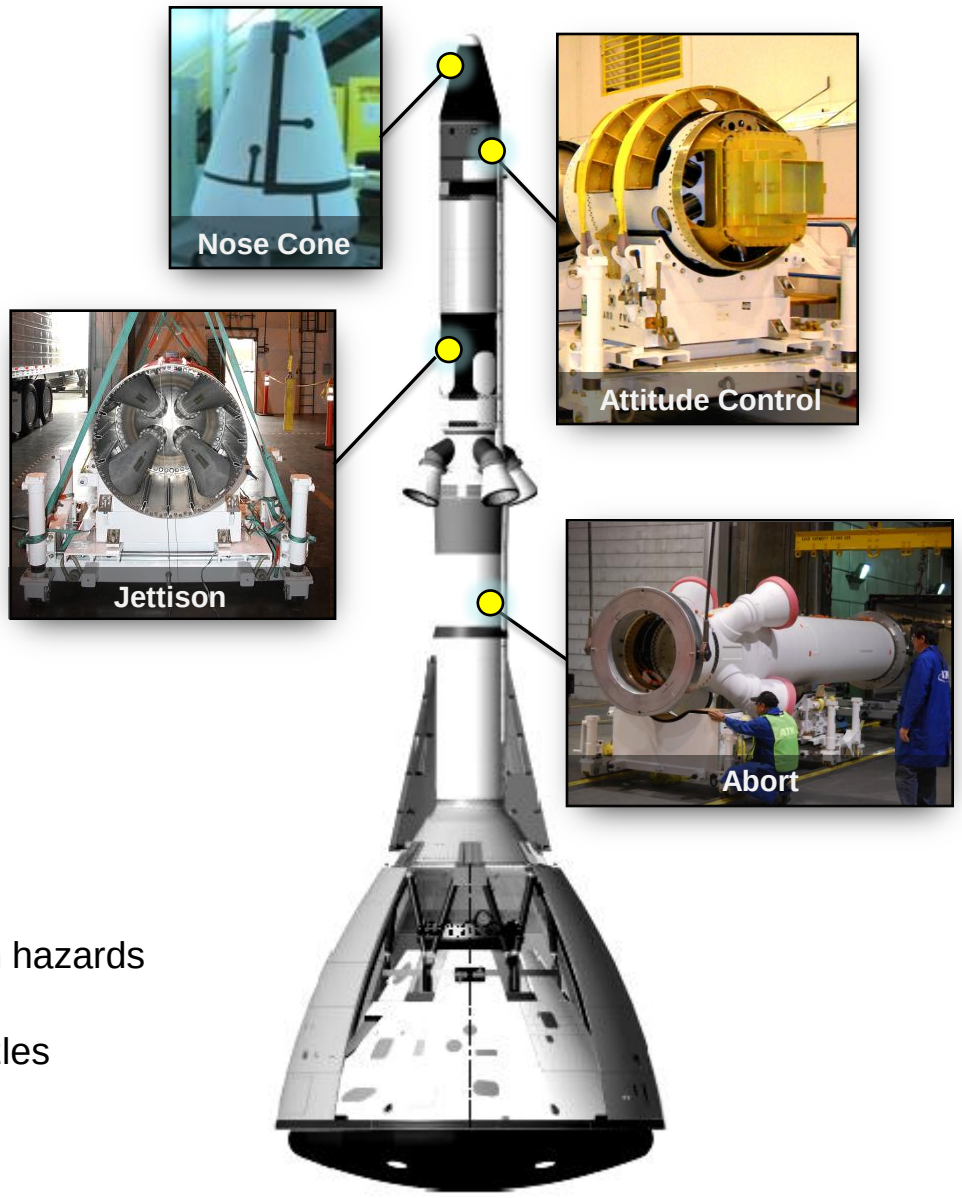

Solar Array Testing


Attitude Control RCS Thruster


Propellant Tank

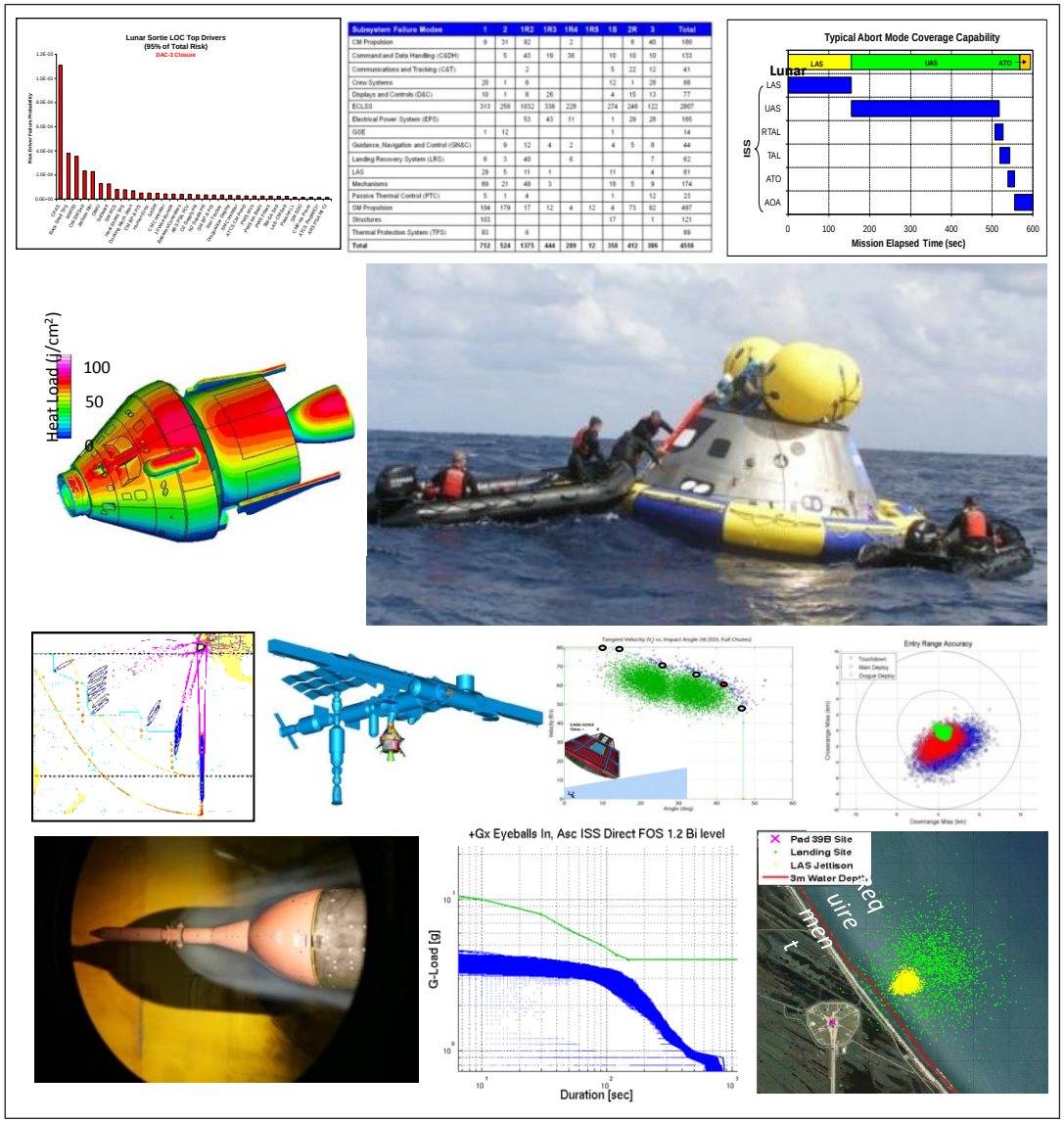
Orion Launch Abort System

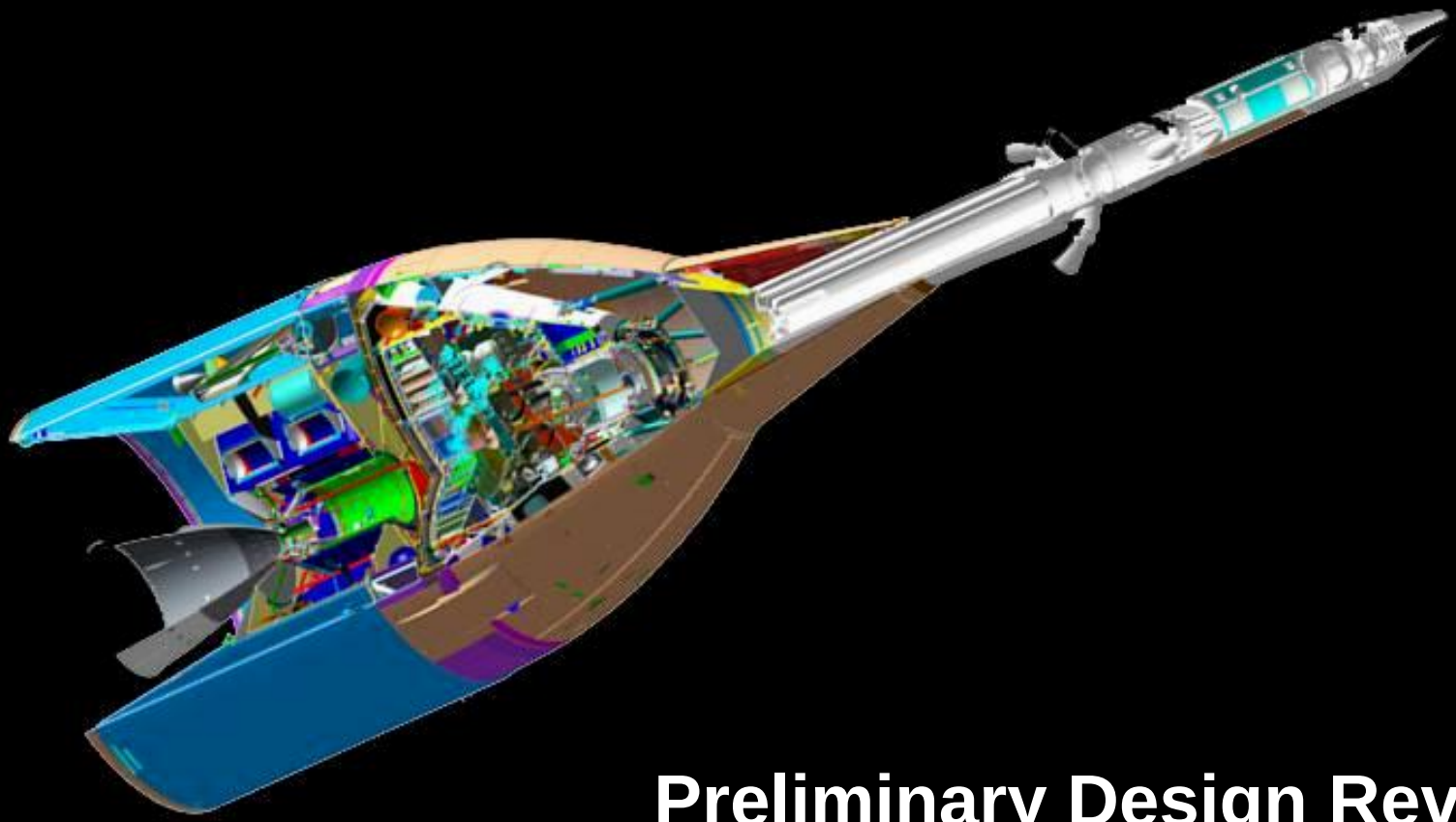
- **Launch Abort System**
  - Safely removes the crew from launch vehicle on the pad through first stage flight
  - Jettisons after successful operations
- **Nose cone**
  - Aero fairing for control motor
- **Attitude control motor**
  - Provides active control during flight
  - Performs reorientation prior to jettison
  - Solid rocket motor with 8 nozzles
- **Jettison motor**
  - Separates the Launch Abort System from the crew module
  - 1 solid rocket motor, 4 nozzles
- **Abort motor**
  - Pulls the crew module and crew away from hazards during a pad or mode 1 ascent abort
  - Solid rocket motor with 4 reverse flow nozzles



Flight and Ground Crew Safety
Foundation for all Orion Engineering Decisions

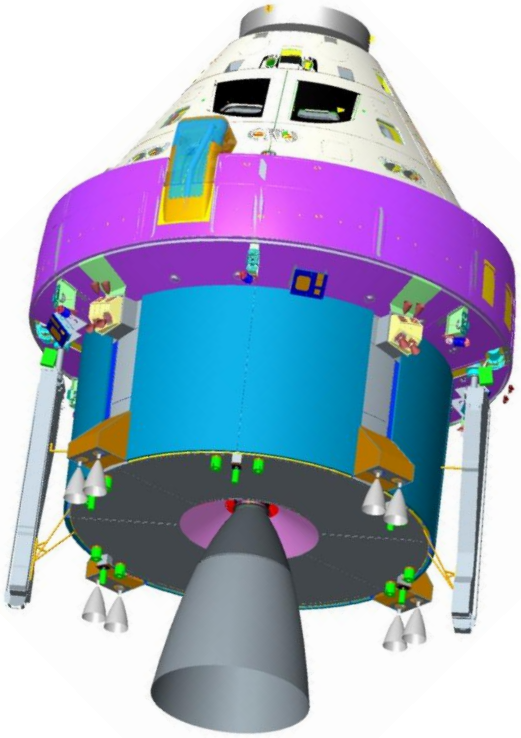
- Abort system Aero/GNC
- Abort Aerothermal heating
- Abort coverage/gap analysis
- Trajectory planning/debris disposal
- Landing accuracy analysis
- Crew loads (ascent, entry, water/land landing)
- Crew rescue/recovery planning
- Failure modes effects/analysis
- Hazard analysis & control
- PRA LOC/LOM analysis
- MMOD analysis/protection





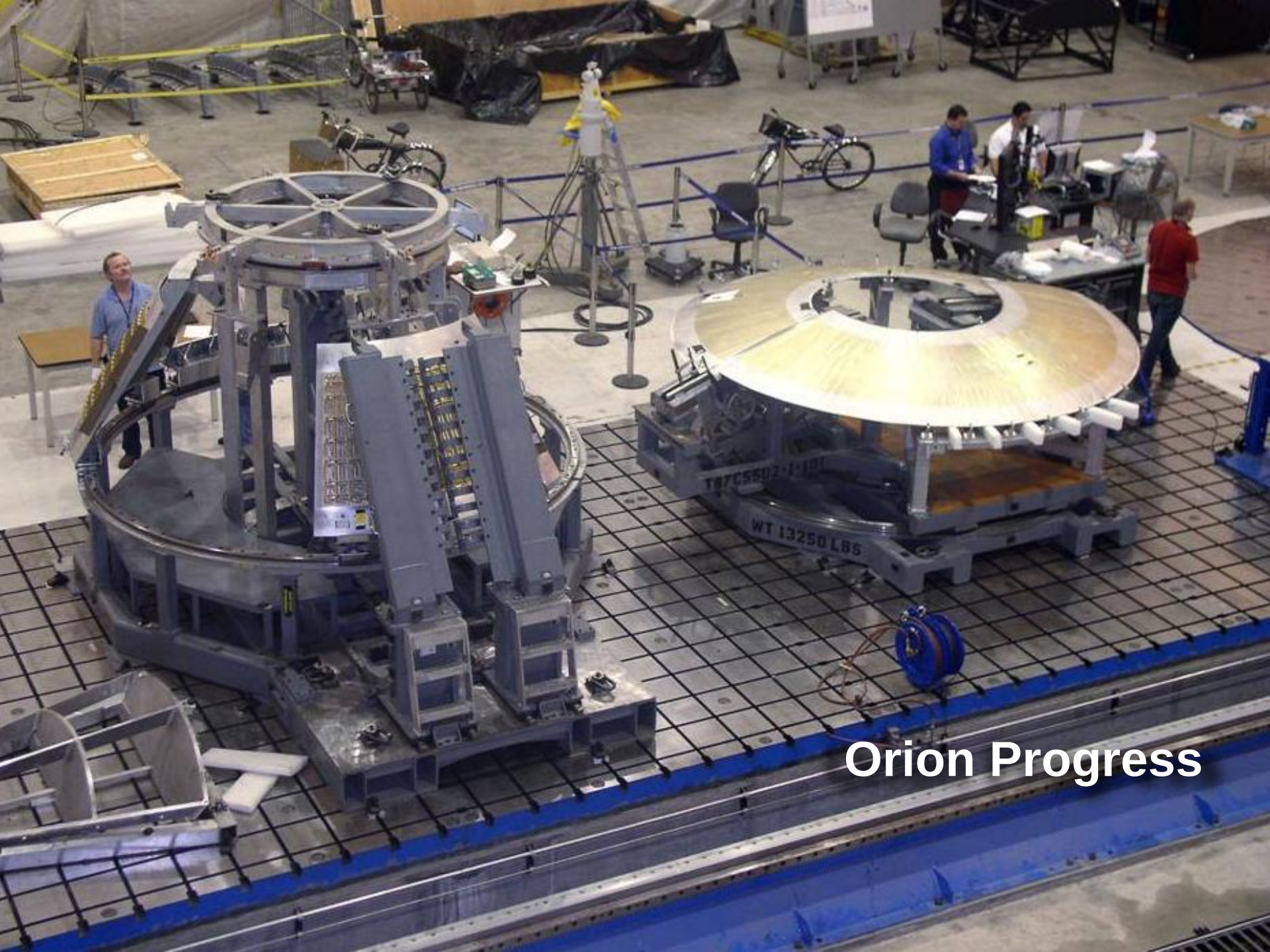
Preliminary Design Review

Orion's Preliminary Design Review
Demonstrates High Level Maturity of Design



- **200+ analysis reports and design descriptions delivered for review**
- **500+ drawings released for broad review**
- **Preliminary Design Review verifies technical plans, subsystem designs, Constellation's concept of operations and processes meet system requirements with acceptable risk within cost and schedule**

184 Technical Reviews	**Completed**
104 Peer Reviews	**Completed**
10 Combined Tech/Peer Reviews	**Completed**
18 Subsystem Design Reviews	**Completed**
System and Module Review	**Completed**
Screening & Disposition Teams	July 22 - August 3
PDR Pre-Board	August 17-20
PDR Board	August 21

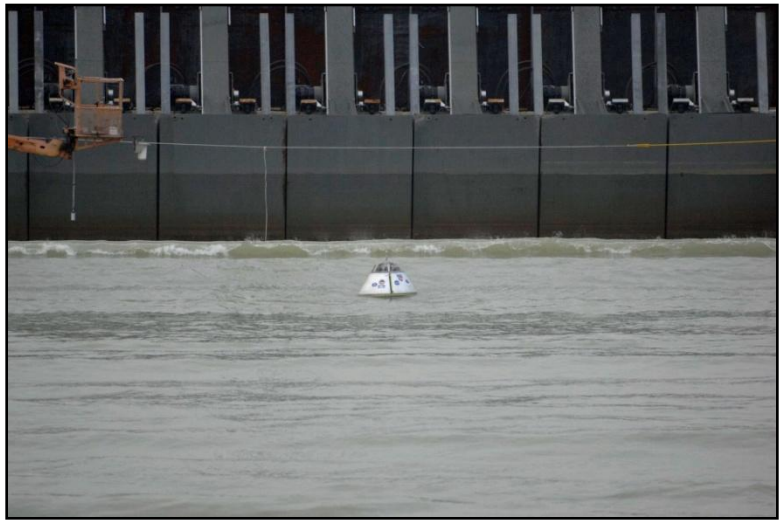

Orion Progress

Human Factors Crew Evaluations

- **Since April 2009**
  - 47 days of testing
  - 20 vehicle assessments and tests
  - 19 familiarization sessions for Constellation and Orion teams
  - 13 human engineering evaluations

Post-Landing Orion Recovery Tests

Naval Surface Warfare Center
Carderock Division – Bethesda, Maryland



Water Egress Survival Trainer
Aberdeen Proving Ground – Aberdeen, Maryland

Atlantic Ocean
Kennedy Space Center - Florida

Landing System Development Tests

Crew Impact Attenuation System Test Article
Langley Research Center – Hampton, Virginia

- **8 retro rocket heatshield penetrator tests**
- **5 sets soil type properties characterization test sequences**
- **Fabricated numerous test article units**
- **129 Drop Tests**
  - Airbag system demonstration
  - Crew seat attenuation
  - Crushable structures demonstrations
  - Heatshield friction testing

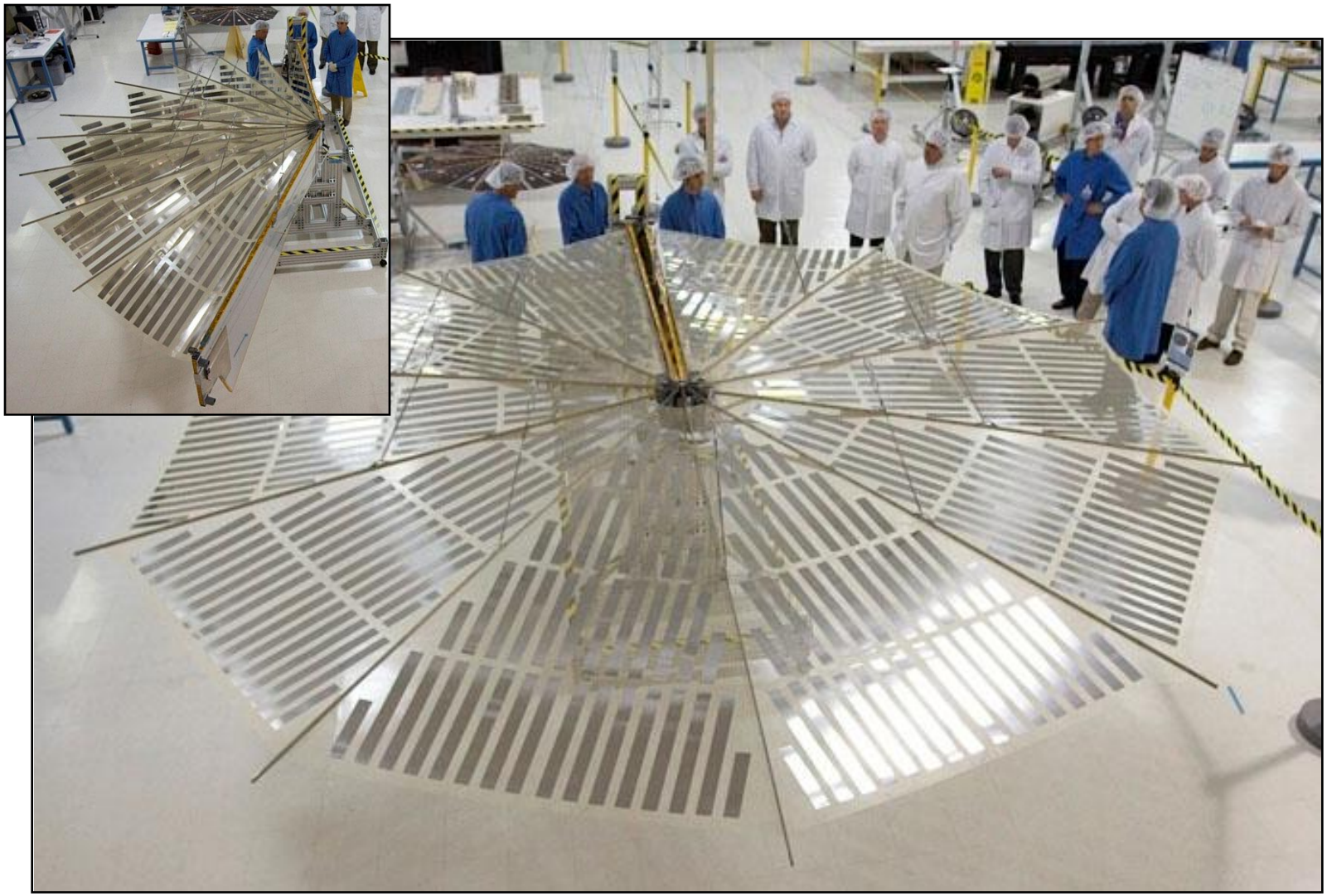
Crew Module Boilerplate Drop Test
Langley Research Center – Hampton, Virginia

Parachute Drop Tests

- **Component tests completed**
  - 3 Single Drogue only test
  - 3 Single Main chute tests (MDT)
  - 4 Pilot drop test
  - 2 single main test, 1 cluster of mains
- **Assembly Tests**
  - 3 Cluster Drop Tests (CDT)

U.S. Army Proving Grounds
Yuma, Arizona

Solar Array Deployment Testing



Testing and Deployment of 5.5m (18ft)-Diameter UltraFlex Solar Arrays
Goleta, California

Launch Abort System – Successful Motor Tests

Attitude Control Motor

Jettison Motor

Abort Motor

Integration and Testing
Crew Module Flight Test Article

Dryden Flight Research Center - California

Progress Toward Pad Abort 1 Flight Test

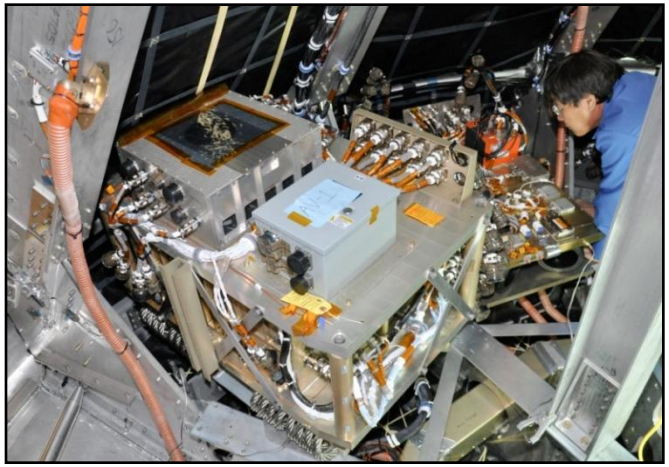
Launch Abort System Motors Delivery

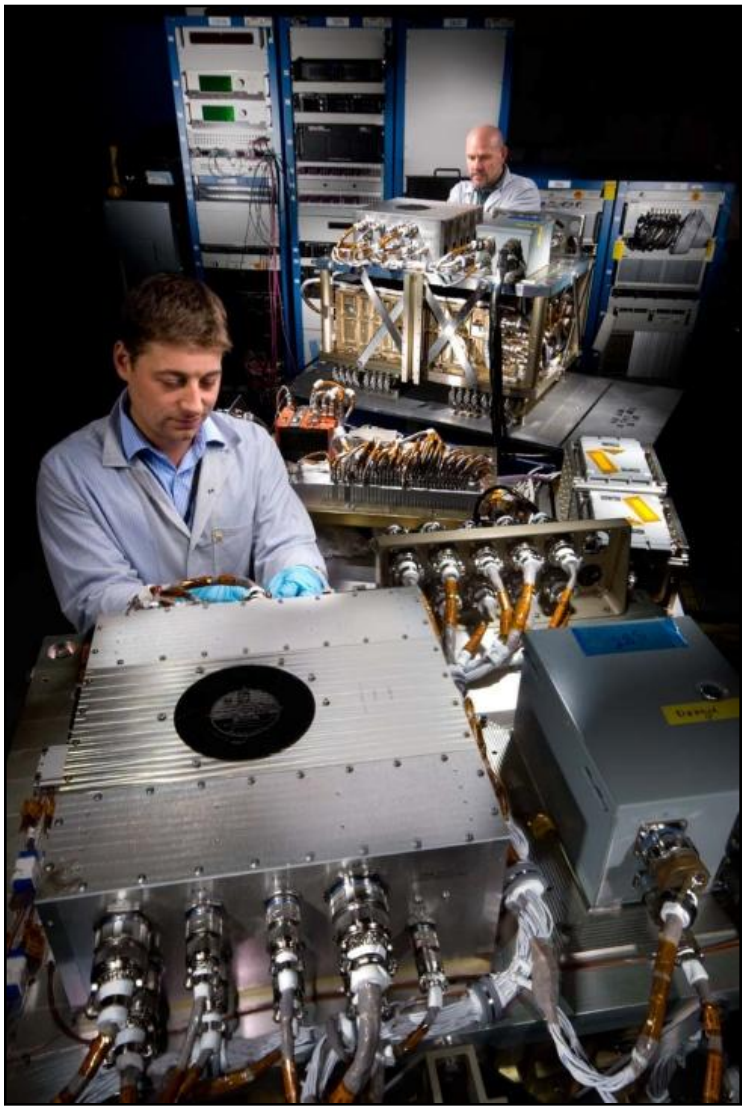
Crew Module and Adapter Cone Acoustic Test

Adapter Cone Fit Check

Center of Gravity Test

Installation of Integrated Avionics Pallet





Dryden Flight Research Center - California

Orion Launch Complex Facility

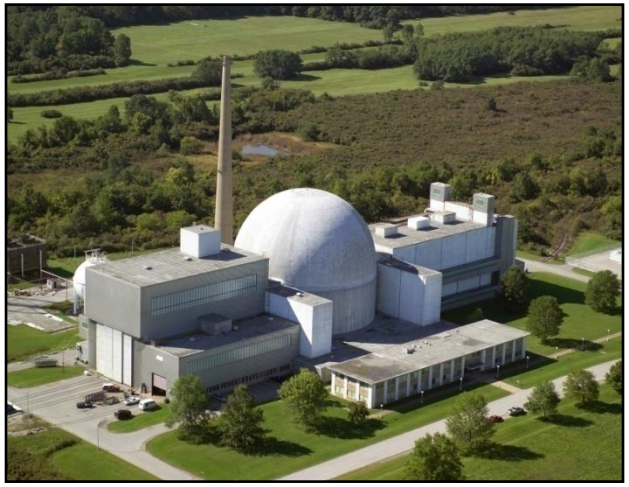
White Sands Missile Range, New Mexico

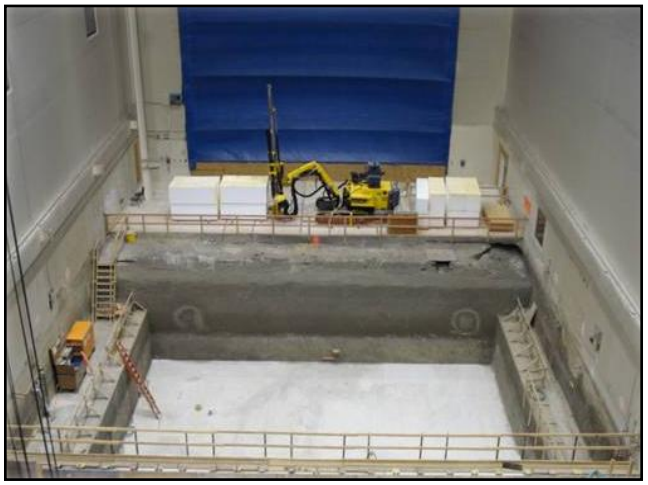
Ascent Abort Gantry

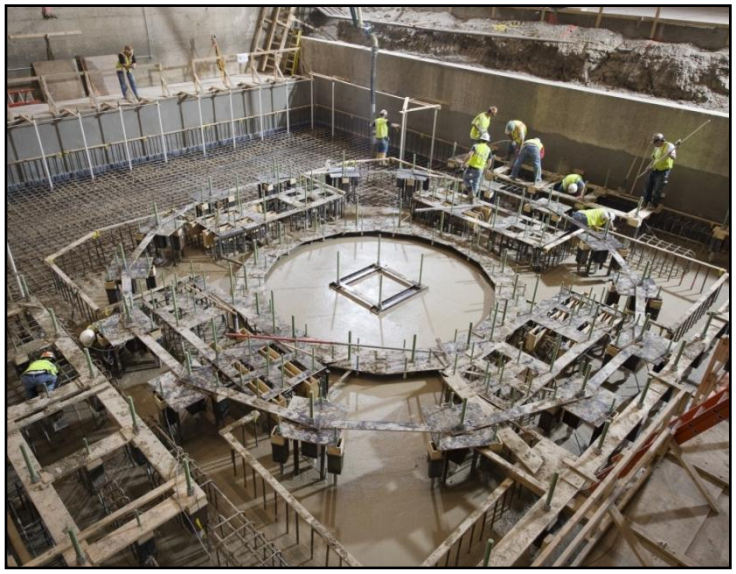
Flight Integration and Test Facility

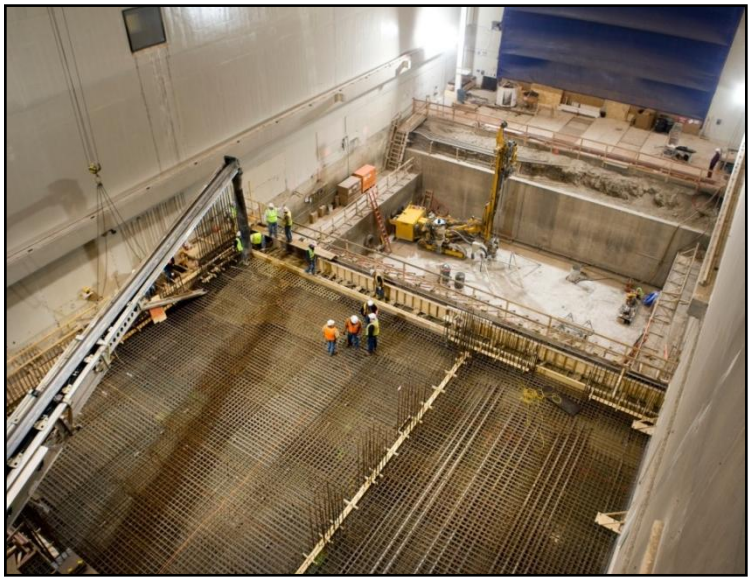
Mobile Operations Flight Test Control Room

Spacecraft Environmental Test Facility
A National Asset







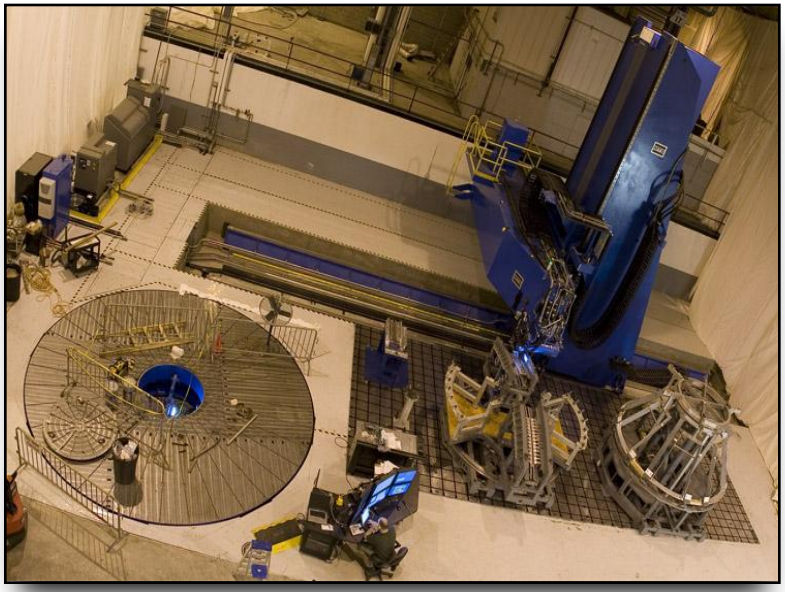


Renovations at the Spacecraft Environmental Test Facility
Plumbrook Station – Sandusky, Ohio

Activation of Orion Production Facilities

- **Operations & Checkout Facility (O&C)**
  - 100% of construction complete below cost, ahead of schedule
  - Installation of assembly, integration & production tooling in work
  - Steady progress on tooling, training, systems and processes
- **Michoud Assembly Facility (MAF)**
  - 85% of construction complete on cost and on schedule
  - Currently supporting Orion production
- **Canister Rotation Facility**
  - Minor modifications in work to support Orion Launch Abort System (LAS) assembly, integration and production

Test Systems Activation
Operations & Checkout Facility



GTA Tooling Complete, Operational
Michoud Assembly Facility, Louisiana

Completed Operations & Checkout Facility
Kennedy Space Center, Florida

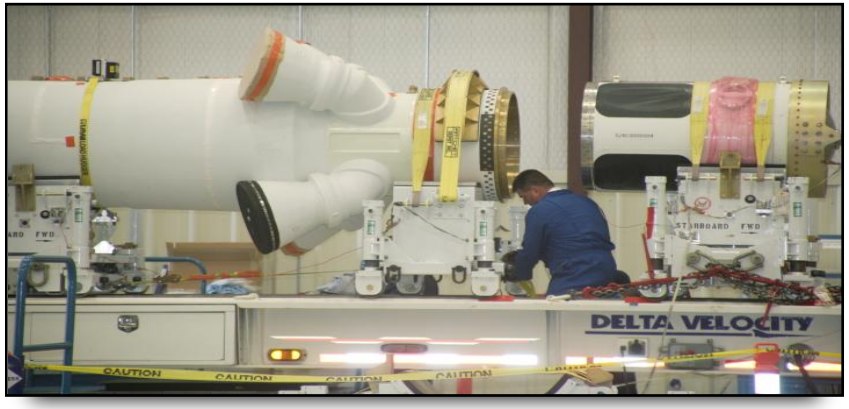
Production Facilities Now Online

- **Orion Crew Module Ground Test Article in Fabrication**
  - Manufacturing of the Orion Ground test Article (GTA) in progress
- **Launch Abort System for Pad Abort 1 in Final Assembly**
- **Orion Service Module**
  - Facility, tooling, supply chain, etc. and support ready for Orion production

Window Bulkhead for Ground Test Article
Michoud Assembly Facility – New Orleans, Louisiana

Ground Test Article Weld
Michoud Assembly Facility

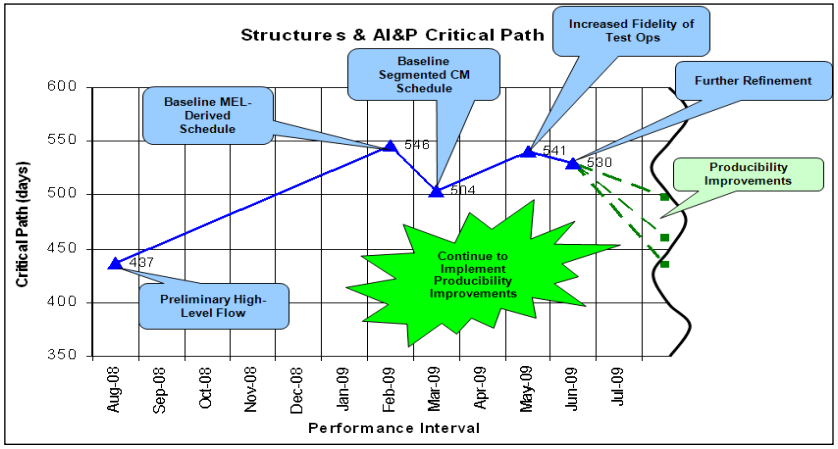
Barrel Panel Forming
Michoud Assembly Facility



Launch Abort System Motor integration
White Sands Missile Range, New Mexico

Early Program Production Improvements

Enables Significant Risk Reductions in Production and Resulting Life Cycle Costs



Significant Structured Improvement Activities

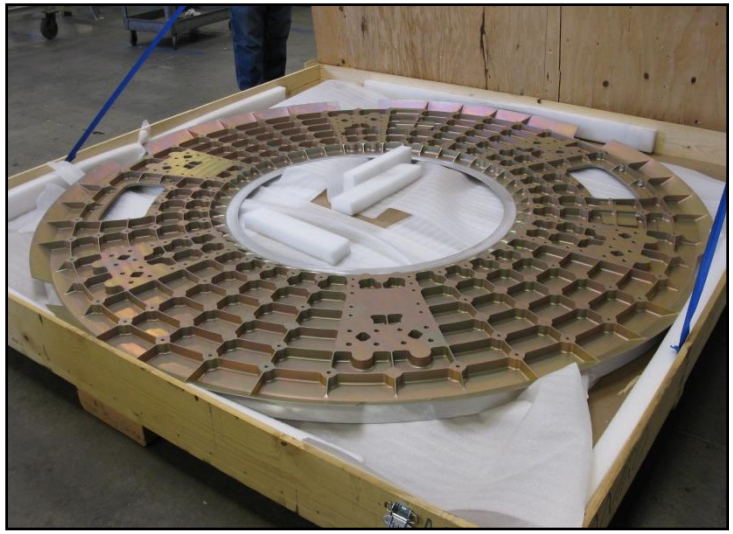
Event	Date	Title	Benefit
1	19-Dec-05	KSC O&C AI&P PDK	Reduce Build Sta from 21 to 9
2	9-Mar-06	LAS AI&P PDK	Reduce Final Assy by 50%
3	9-Mar-06	Structures AI&P PDK	Reduce Tooling Sta
4	23-Apr-06	S/C Ground Test PDK	Improved Integ Test Plans
5	30-Nov-06	Structures Manfg Ops	Reduce Risk with flow Definition
6	19-Jan-07	Hazardous Ops PDK	Operations Improvements
7	26-Jan-07	Flight Test Obj PDK	Improved Test Objectives
8	26-Jan-07	Acceptance Test PDK	Defined Test Risk Reduction
9	21-Mar-07	TPS Heat Shield PDK	Common Tools/Reduce Costs
10	3-May-07	LAS PDK	Integrate CEV Offline
11	9-Aug-07	O&C Schedule VSM	Improve Sched Margin 28d
12	23-Aug-07	Production Training	Integrate LM & USA Workforce
13	1-May-08	Factory of the Future VSM	Production (AI&P) Concept of Operations development
14	15-May-08	Orion O&C Tooling VSM	Improved design/approval process
15	19-Jun-08	Orion Activation Schedule JDI	Sched. Margin Risk Reduction
16	18-Jul-08	Crew Module Training Mockup	Produceabiity Risk Reduction
17	1-Aug-08	O&C Fac. Activation Baseline (Prod Ops Pt 1)	Schedule Risk Reduction
18	28-Aug-08	Inspection Assignment Strategy (USA)	Product Quality Improvement
19	18-Sep-08	Technical Supervision (USA)	Product Quality Improvement
20	21-Oct-08	AI&P Production Simulation	Risk Reduction, Build Sta improvement
21	6-Nov-08	Joint Orion/Ground Ops PDK	Schedule Risk Reduction
22	13-Nov-08	AI&P Information Technology	Produceability Risk Reduction
23	11-Mar-09	SM Propulsion PKO	Risk Reduction, Failure Modes Analysis
24	21-May-09	O&C Floor Space Utilization PDK	Produceability/Capacity Planning
25	22-May-09	Path to Orion Composite Fabrication - Part 2 (MAF)	Risk Reduction – Future machining and handoffs
26	22-Jun-09	Lean Product Development (MAF)	Risk Reduction – Produceability improvements

Improvements Incorporated into Orion Vehicle

Item	Producability Initiative	Benefit	Cost	Schedule	Risk	Margin
1	O&C Air Bearings vs Wheeled Pallet	Eliminated Specialized Wheeled Fixtures Reduces O&M Costs	Yes			Yes
2	O&C 100K Clean HVAC CONOPS	Reduced Operations Costs by Local Protocols at 100K,10K,1K Levels	Yes	Yes		
3	Common Tooling at KSC,MAF, PlumBrook	Reduces Design, Fab, and O&M	Yes			
4	O&C Proof Test Cell Pressure added margin1	Increase Facility margin for Rqmts Growth				Yes
5	O&C Airlock ve Refurbishment Cell	Added Flexibility of West End of Building			Yes	Yes
6	O&C Rate Capacity of 5 Vehicles per Year	Increased Margin within baseline	Yes	Yes	Yes	Yes
7	O&C Non ESD Flooring	Apply locally at each Station	Yes			
8	O&C Use of Dedicated Production Mockups	Early Process & Operations Learning	Yes	Yes	Yes	
9	Backshell Carrier Plate design for I/Fs	Improves Tolerances for Fitup/Install	Yes	Yes	Yes	
10	O&C Min Suspended Load Operations (SLO)	No Cat 1 & min Cat 2 Lifts reduces Risk		Yes	Yes	
11	O&C Single Low Bay Crane Capability	Provide Single Crane Capability	Yes			Yes
12	O&C Eliminate Haz Ops (hydrazine and amm	Segregate Haz Ops to MPPF	Yes	Yes	Yes	
13	CM Pressure Vessel Weld length reduction	Reduce part count and inches of welds	Yes	Yes	Yes	
14	CM Unpressurized Part Reduction	Reduce Fabrication cost at assembly	Yes	Yes	Yes	
15	CM Weld Tooling Reduction	Reduce Tooling Cost	Yes	Yes	Yes	
16	O&C Common Utility Drops in Floor	Provides Flexibility for Layout Changes	Yes			Yes
17	O&C Relocatable Tooling Designs	Eliminates Fixed Monuments enabling Flex	Yes	Yes		Yes
18	Descrete Event Simulations	Early Identification of Prod Ops for Waste	Yes	Yes	Yes	Yes
19	Commonality between CM, SM and Integrated Stack tooling designs	Reduces Tooling cost	Yes	Yes		
20	Hybrid Technician Organization	Combined org and job designs to deconflict dual USA/LM organization requirements on Orion touch labor	Yes		Yes	
21	Technician Lean Foundation Training	Establish foundation to trigger oncoming program paradigm shift to Orion focus	Yes		Yes	
22	Design of Experiment - Alum Tubing	1) Established competency for evaluating interactions in new processes. 2)Determined feasability of applying available processes to new matrials/methods			Yes	
23	Floor Inspection Assignment Strategy	Reduce inspection real time response time	Yes	Yes	Yes	
24	Technician Resource Pool Sizing Algorithm	Applied Lean Replinishment Pull formula to minimize excess technician pool required trained	Yes	Yes	Yes	
25	Segmented CM	Reduced schedule, Improved access and degree of reuse	Yes	Yes	Yes	Yes

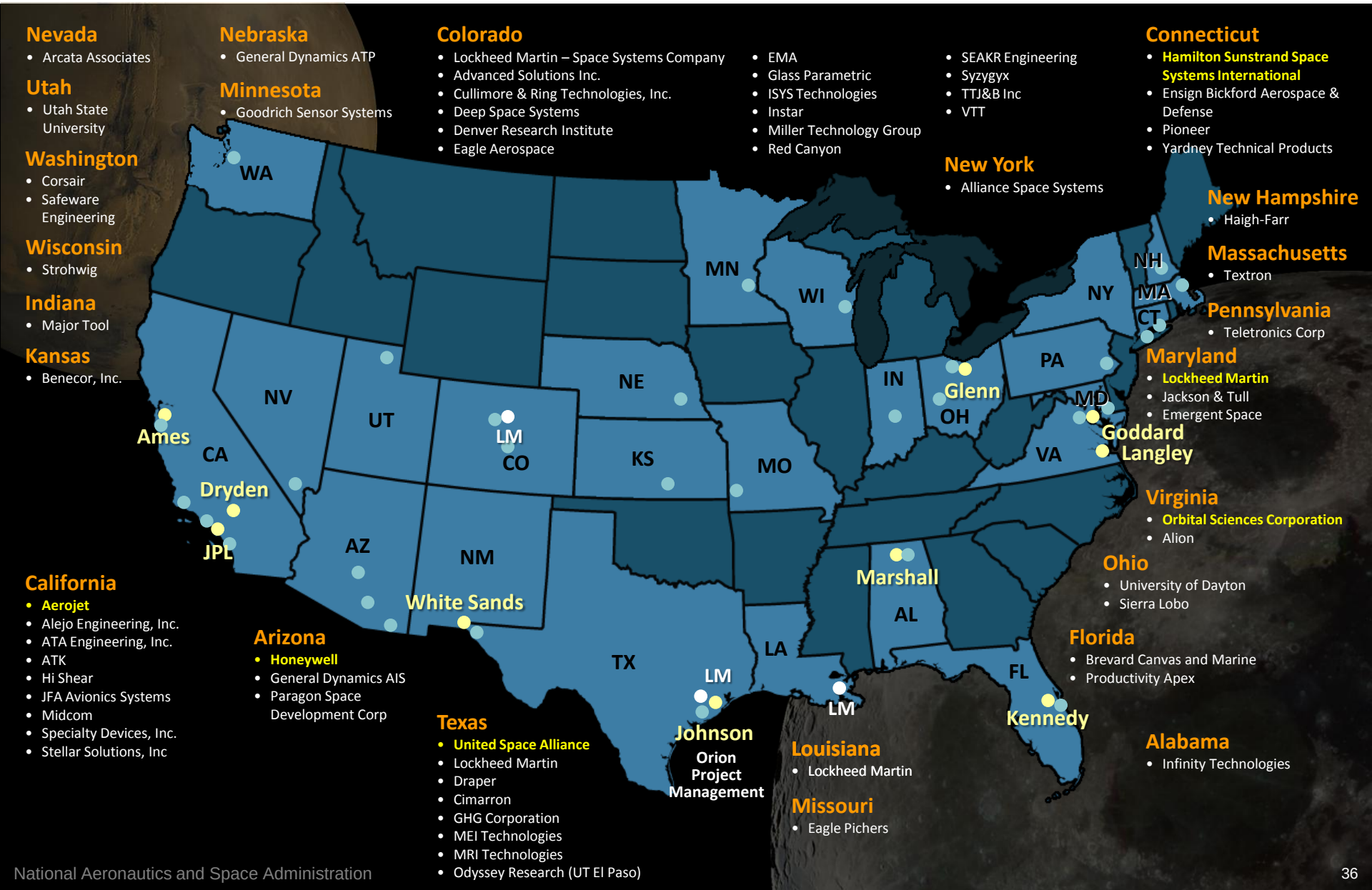
Orion Production Has Started !

Ground Test Article Friction Stir Welding
Michoud Assembly Facility – New Orleans, Louisiana



Ground Test Article Panel Fabrication
AMRO Fabricating Corporation - El Monte, California

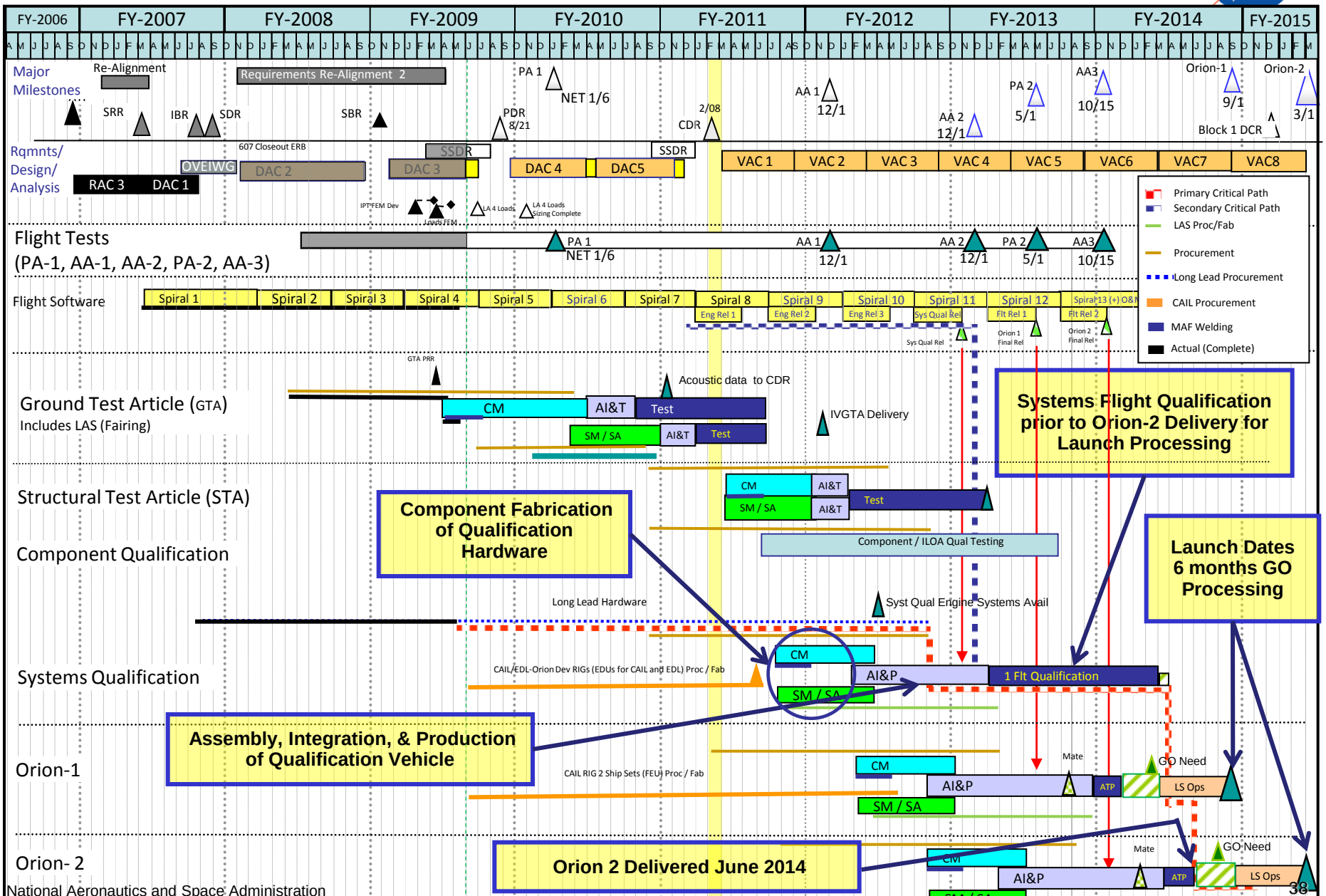
3100 Orion Team Members Nationwide




ORION AVE
LC-32 EAST
Orion Launch
Complex
Abort Flight
Test Program
NASA

Schedule

Orion Baseline Schedule



System Qualification Test

CM AI&P (O&C)

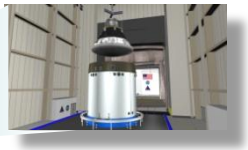
ESM AI&P

ALAS AI&P

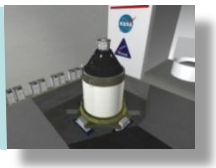
All system Functional, Performance, Mission Sequence and Pre-Ship Testing Complete prior to shipment to PBS

Ship to SPF

Assy CEV 1m



CM, SM/SA Vibration 1m



SM/SA w/Fairing + CM (Basedrive Sine Vib Test w/ Ti Heat Shield)*

*Alternate Random Vibe (TBD)

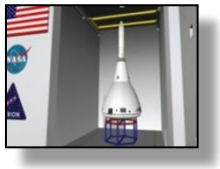
CEV Acoustics 2m

CEV Config. w/GSE stub LAM, SM Qual Level, 2 test – 1st w/ 4 tanks full, 2nd w/ 2 tanks filled

In Acoustics chamber @ Ambient Pressure

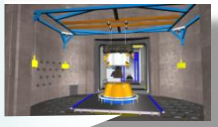
Fairing Sep. 1st motion

SM Fairing Pyro Shock



CM, LAS Fairing, LAS Nominal launch & Abort Level

LAV Acoustics



In Disassembly Area S/A. HGA Deployment

In Chamber: SM/SA Shock

Combined 1m

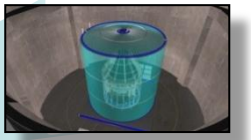
Combined 1m

SM/SA Pyro Shock

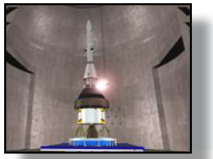
LAS/CM In Acoustics Chamber

LAS Pyro Shock

TB/TV 5.5m



• 1 Cycle TB
• 7 Cycles TV



EMC/EMI in TV Chamber

CM/SM EMI/EMC 1.5m

CM/SM + Pyro Shock

ATLAS Sep
LIDS Sep
Drogue Bridgewire
Fwd Bay Cover Sep
Righting System Bridgewire
CM/SM Shock

Heat Shield R&R (TBR)

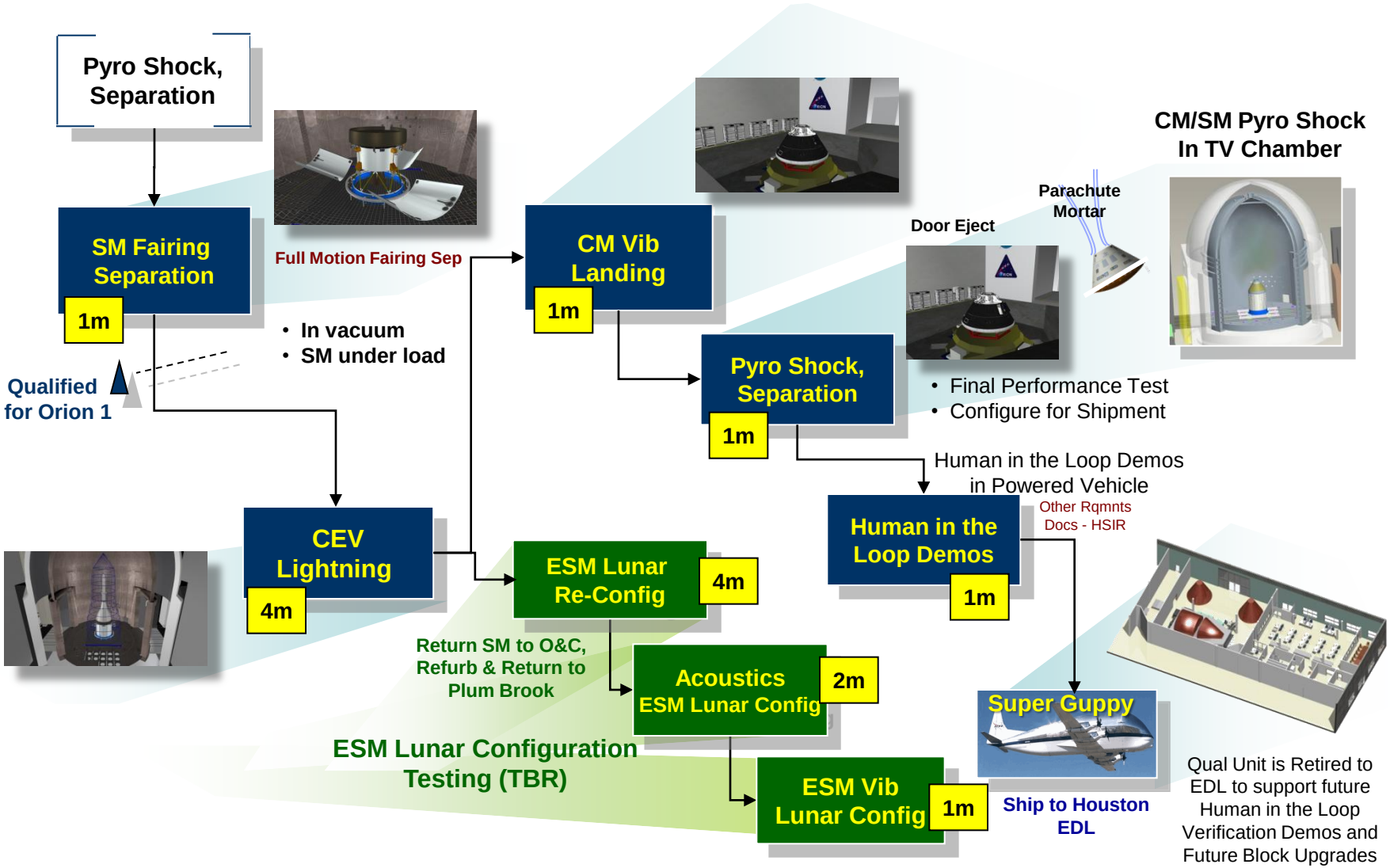
SM Fairing Separation 1m

CM Abort Test 2m

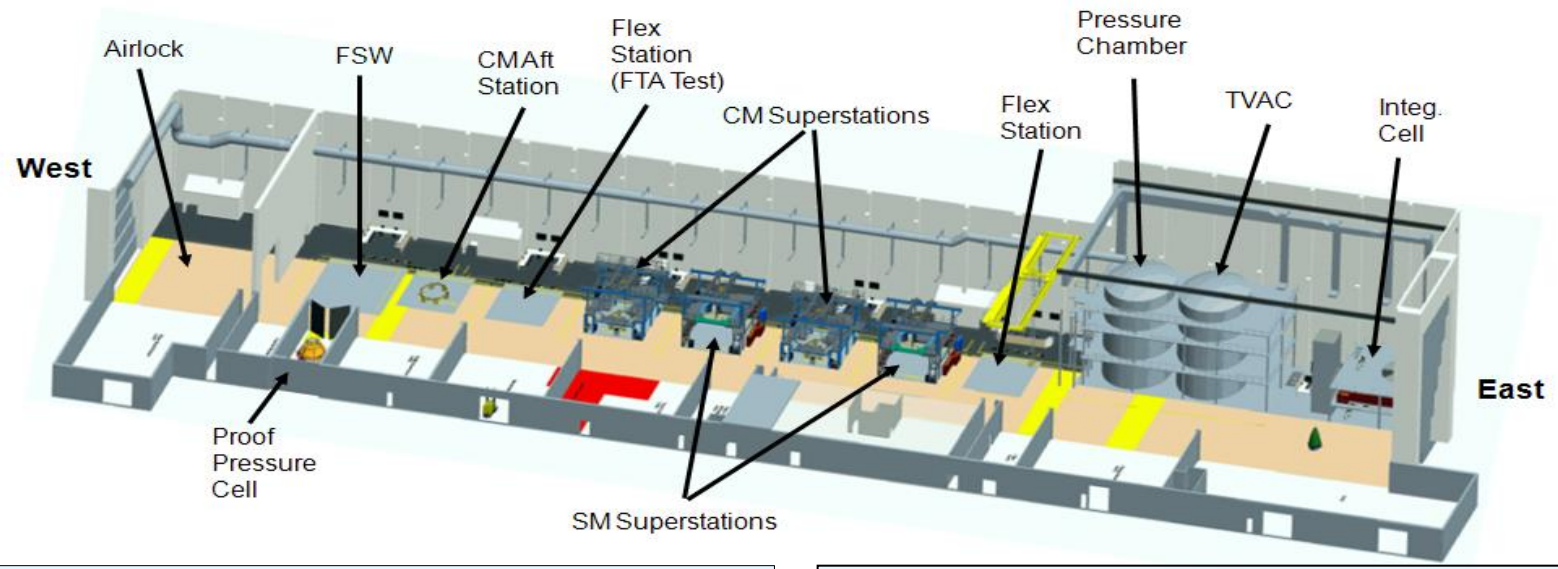
Qual Vehicle - Flight Like Production Article
- Inert ALAS
- Current exceptions are:
  - One CM RCS Thruster Ship-set

1 Nominal Mission Complete

System Qualification Test (cont.)



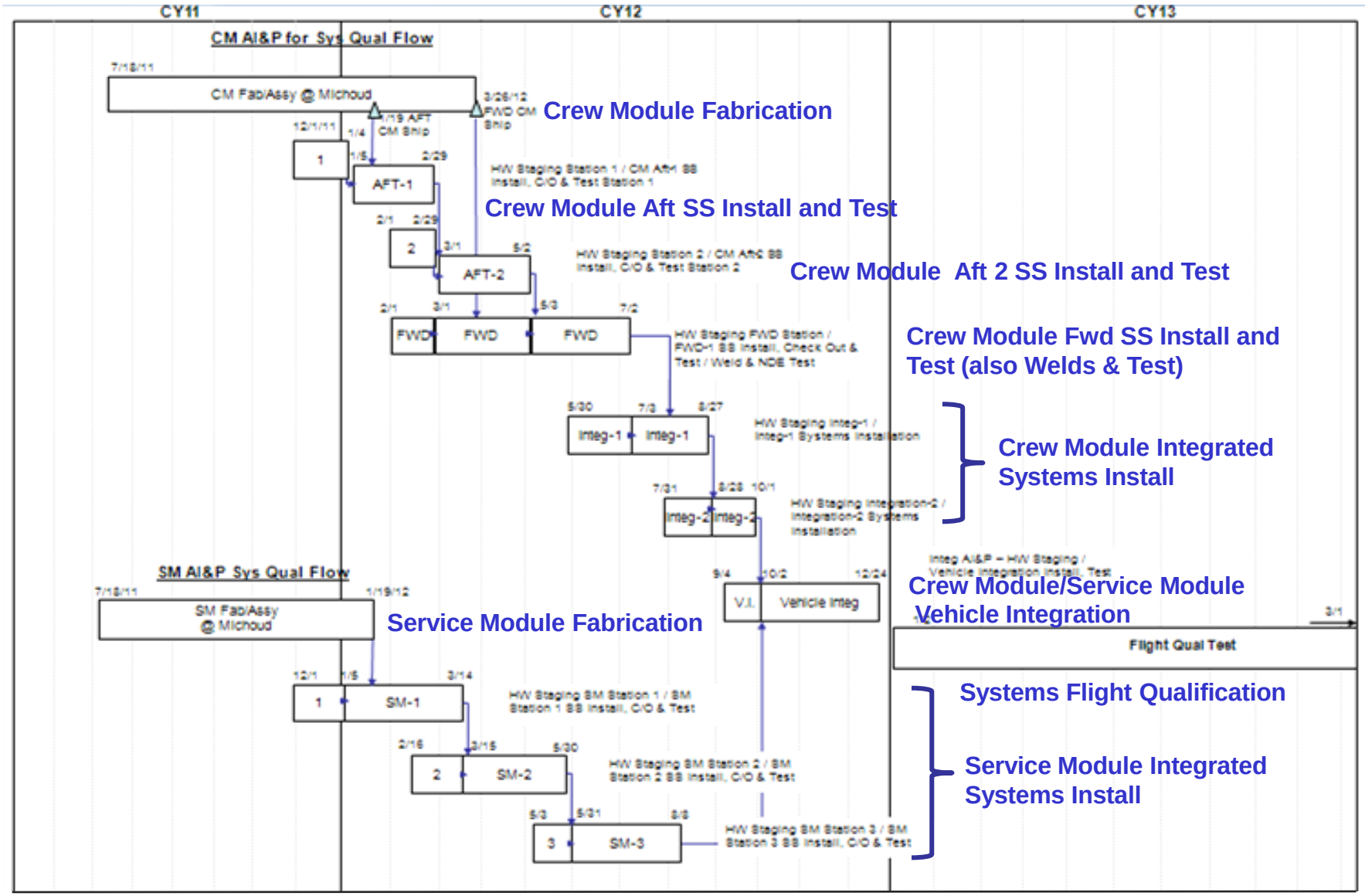
Assembly, Integration and Production
Operations & Checkout Facility



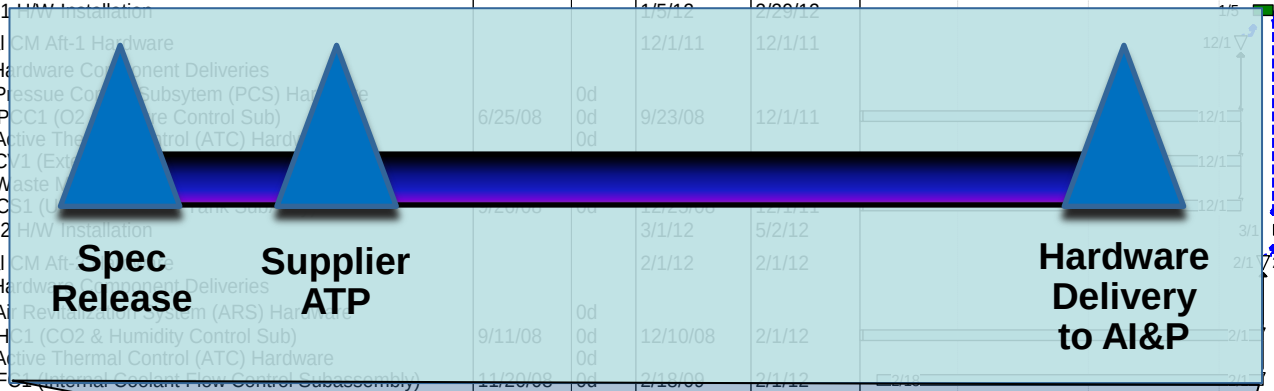
Service Module Superstation	Upper SM is populated with components prior to SM integration with the Crew Module (CM)
Pressure Chamber	Proof test of closeout weld that connects the upper and lower portions of the CM
TVAC	Conduct of acceptance thermal vacuum testing of integrated spacecraft
Integration Cell	CM is stacked with SM and Spacecraft Adapter; final acceptance testing.
Proof Pressure Cell	Structurally reinforced cell for welded propulsion and ECLSS tubing proof tested
Airlock	Entry of large scale components without compromise of cleanliness

Friction Stir Welder	Used to mate upper and lower crew module segments
Crew Module Aft Station	Aft portion of the Crew Module is populated with components
Flex Station	Added production capacity during flight test vehicle builds and provides future growth
Crew Module Superstation	Upper CM populated with components (prior to CM mate),final CM installations and testing occur after CM mate prior to CM integration with the Service Module (SM)

System Qualification
Assembly, Integration and Production Schedule Flow



Crew Module Component Delivery Schedules
System Flight Qualification



	Spec Rel Need Dat	Float	Start (ATP)	Finish
Milestones			9/8/06	3/1/15
Qual CM Aft-1 H/W Installation			1/5/12	2/29/12
Need Qual CM Aft-1 Hardware			12/1/11	12/1/11
ECLS Hardware Component Deliveries				
CM Pressure Control Subsytem (PCS) Hardware		0d		
OPC1 (O2 Pressure Control Sub)	6/25/08	0d	9/23/08	12/1/11
CM Active Thermal Control (ATC) Hardware		0d		
FCV1 (External Coolant Flow Control Subassembly)		0d		
CM Waste Management Hardware				
UCS1 (Urine Collection Sub)	5/29/08	0d	12/23/08	12/1/11
Qual CM Aft-2 H/W Installation			3/1/12	5/2/12
Need Qual CM Aft-2 Hardware			2/1/12	2/1/12
ECLS Hardware Component Deliveries				
CM Air Revitalization System (ARS) Hardware		0d		
CHC1 (CO2 & Humidity Control Sub)	9/11/08	0d	12/10/08	2/1/12
CM Active Thermal Control (ATC) Hardware		0d		
CFV1 (External Coolant Flow Control Subassembly)	11/26/08	0d	2/13/09	2/1/12
Qual CM Fwd-1 H/W Installation			3/1/12	5/2/12
Need Qual CM Fwd-1 Hardware			2/1/12	2/1/12
ECLS Hardware Component Deliveries				
CM Air Revitalization System (ARS) Hardware		0d		
SNF1 (Snorkel Fan Sub)	3/9/08	0d	6/7/08	2/1/12
CM Fire Detection and Suppression Hardware		0d		
CGAO1 (Contingency Gas Analyzer)	12/4/08	0d	3/4/09	2/1/12
Qual Weld/Test/NDE/Paint			5/3/12	7/2/12
Qual CM Intgr-1 H/W Installation			7/3/12	8/27/12
Need Qual CM Intgr-1 Hardware			5/30/12	5/30/12
ECLS Hardware Component Deliveries				
CM Air Revitalization System				
AVTC1 (Ventilation & Tem				
CVTC1 (Cabin Ventilation				
CM Active Thermal Control (A				
LWC1 (LCG Water Cooling				
LRS Hardware Component Deliv				
Drogue Parachute Mortar Ass				
Auxiliary Parachute Gun Asse				
Qual CM Intgr-2 H/W Installation				
Need Qual CM Intgr-2 Hardware				
Qual Vehicle Integ. Installations / Tes				
Need Qual Vehicle Integ. Hardware			9/4/12	9/4/12
Delivery to Qual Test			12/31/12	12/31/12
Flight Qualification Test			1/7/13	2/28/14

FY09 | FY10 | FY11 | FY12 | FY13 | FY14 | FY15

PDR 8/21 | CDR 2/8 | Orion-1 9/1 | Orion-2 3/1

- **Evaluate all system qual hardware in component procurement matrix**
- **Calculate margins to AI&P need dates**

Options to Increase Schedule Confidence

- Assembly, Integration & Production Delivery Dates
- Dollars to accelerate
- Mass efficiency

Optimizing the Details
2015 Launch Schedule

- **Current budget was infused with additional program dollars from stimulus and reserves**
  - Increased confidence through additional early engineering development unit testing and other risk mitigations
  - Increased margin by starting higher risk critical path activities early
- **Detailed task planning enabled prioritization and streamlining of critical path**
  - Detailed procurement schedules of all components with manufacture and assembly/tests dates have been generated
- **Analysis of schedule has identified and validated critical paths and risk mitigation opportunities**


Mass Management

Orion Spacecraft Mass Status

Current ISS (6-Crew) Mass Status	Mass Summary
Total Spacecraft GLOW Current Best Estimate Weight	54329 lbm
Mass Growth Allowance at PDR	4325 lbm
Mass Management Reserves held at PDR	2090 lbm
Total Mass Estimate at PDR	60744 lbm
Total Spacecraft GLOW Control Mass - ISS	61015 lbm
Total Orion (under) Control Mass	**-271 lbm**
Total Orion GLOW Margin at PDR (wrt Dry Mass)	**15.6%**
Total Orion Injected Margin at PDR (wrt Dry Mass)	**18.4%**

Current Lunar Mass Status	Mass Summary
Total Spacecraft GLOW Current Best Estimate Weight	62243 lbm
Mass Growth Allowance at PDR	4227 lbm
Mass Management Reserves held at PDR	2090 lbm
Total Mass Estimate at PDR	68560 lbm
Total Spacecraft GLOW Control Mass - Lunar	66706 lbm
Total Orion (over) Control Mass	**+1854 lbm**
Total Orion GLOW Margin at PDR (wrt Dry Mass)	**12.2%**
Total Orion Injected Margin at PDR (wrt Dry Mass)	**10.7%**

Mass Reduction Opportunities

- Unrealized ISS reductions
- Block upgrades implementation
- CM/SM reallocations
- Orion propellant load changes
- Addl Lunar mission refinements

Human Rating

Human-Rating Requirements Failure Tolerance

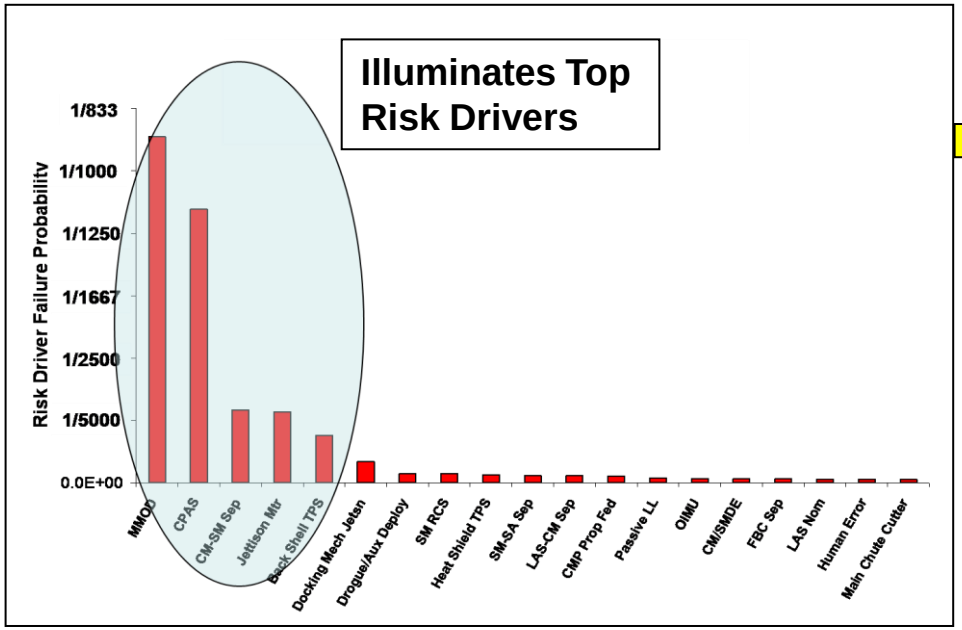
- **NPR 8705.2 Rev B was released in May 2008 and established the current accepted Agency approach to failure tolerance for safety engineering**
  - *The space system shall provide failure tolerance to catastrophic events (minimum of one failure tolerant), with the specific level of failure tolerance (one, two or more) and implementation (similar or dissimilar redundancy) derived from an integrated design and safety analysis (per the requirement in paragraph 2.3.7.1) (Requirement)*
- **NASA developed process and criteria for deriving appropriate failure tolerance to support design process**
  - Uses Probabilistic Risk Assessment, Failure Modes and Effects Analysis, system reliability analyses, related engineering analyses and evaluation
  - Safety analysis is done iteratively with design and the risk assessments are updated as information and analyses mature.

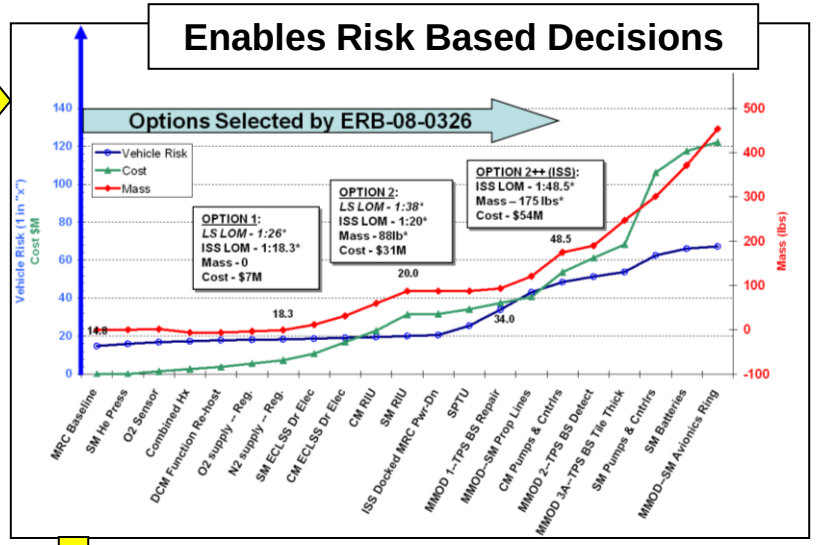
Risk Informed Design

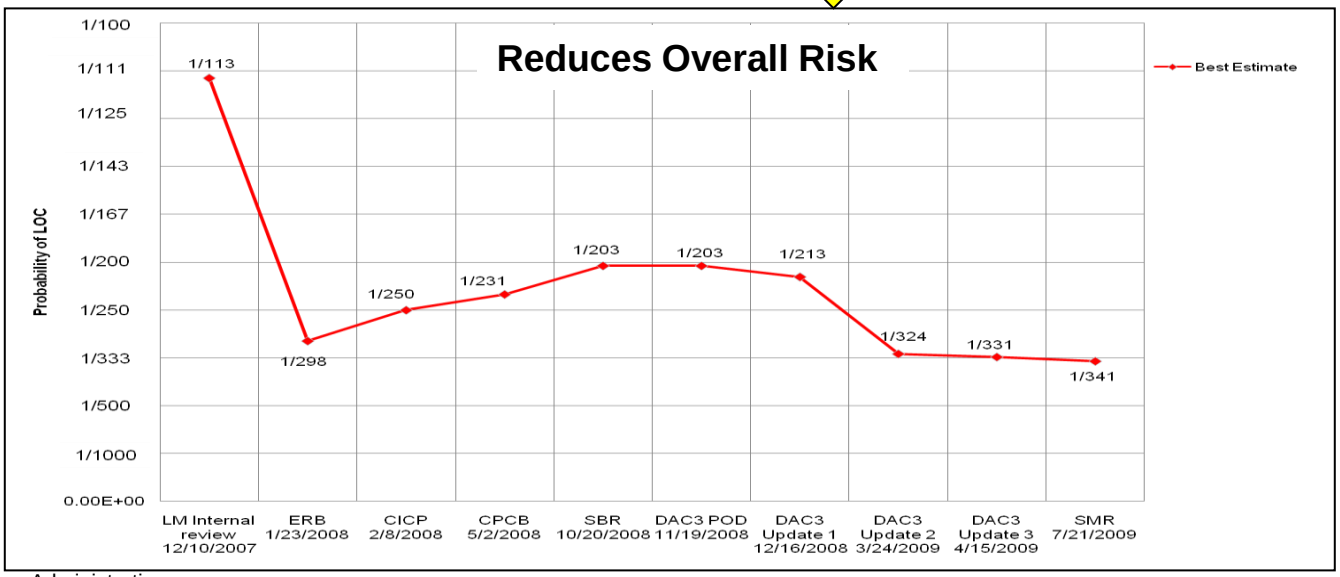
Reduces Risk, Improves Safety and Increases Mission Success

- **Rigorous safety analysis required to support risk informed design decision process throughout the lifecycle**
- **Formal review ongoing with independent Constellation Safety Panel**
  - 78 flight hazards identified (57 reviewed to date)
  - ~25 ground hazards identified
- **Design issues identified through safety process and worked through Orion design team**
  - 4500+ preliminary FMEAs developed and reviewed for PDR
  - 4000+ candidate CILs reviewed at tech reviews, Subsystem Design Reviews, and Orion Critical Item Review as part of PDR process
- **Over 60 design changes identified through this process were incorporated to reduce safety risk to crew and increase mission success**

Risk Informed Design







Summary

The Orion Team Has Met the Challenge

- **Orion's low earth orbit and Lunar capable human System is fully integrated**
  - Conducting rigorous systems engineering to meet all requirements
  - Achieving a robust and safe vehicle with Risk Informed Design
  - Lowering life cycle costs with producability design
- **Orion has a stable design that meets the mission of International Space Station, Lunar and beyond**
- **Production has begun!**