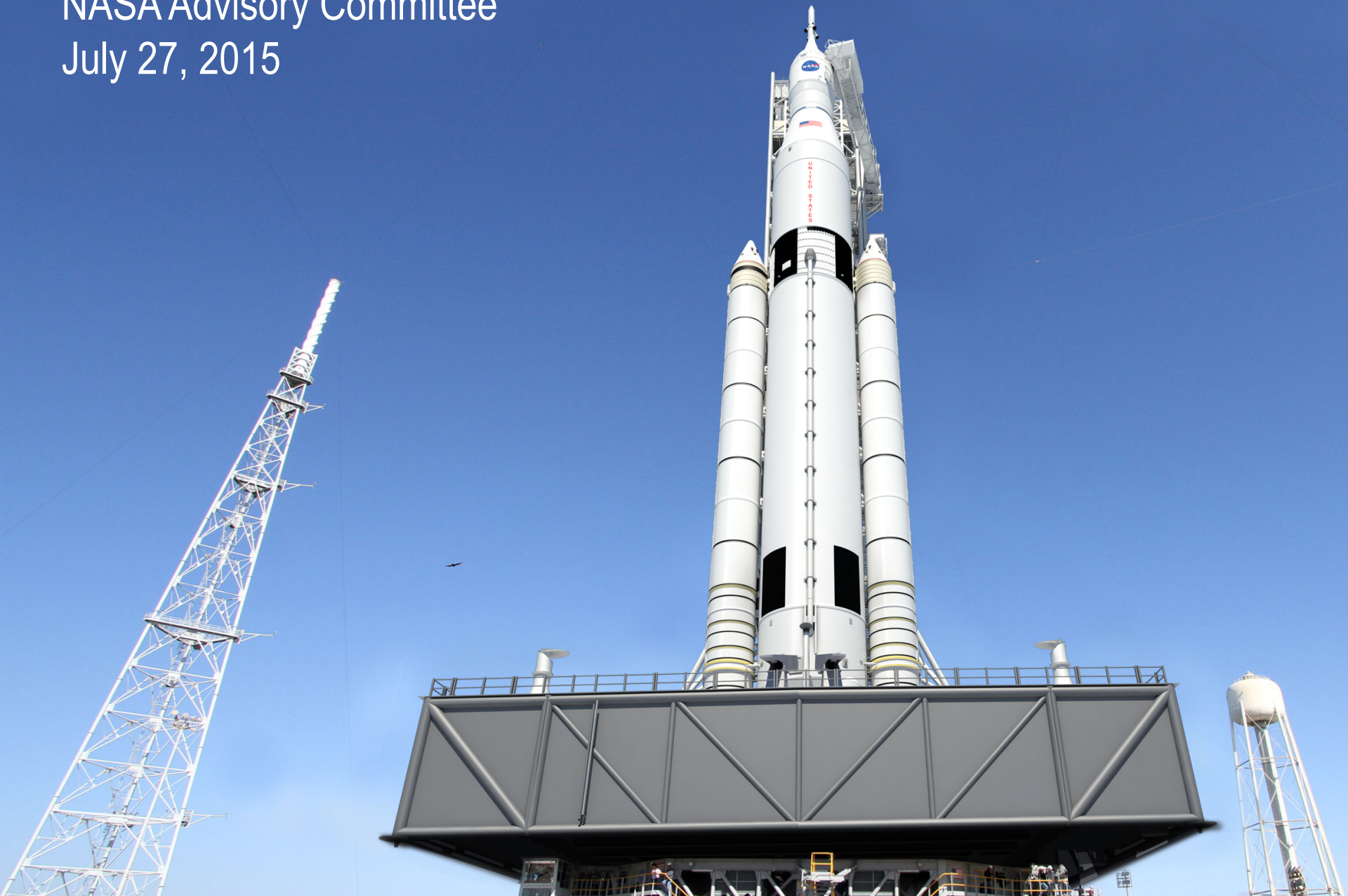
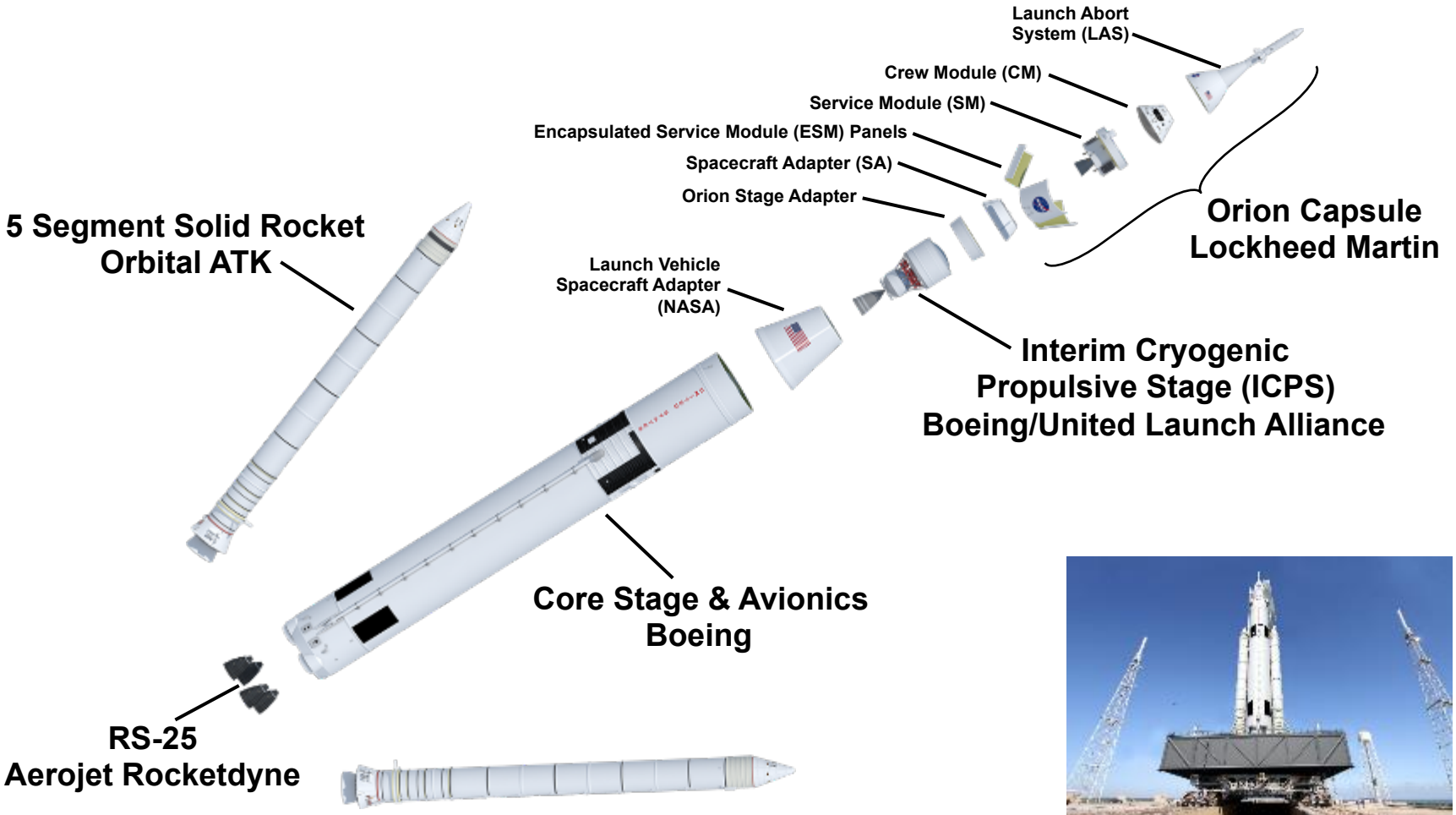
Exploration Systems Development Status
NASA Advisory Committee
July 27, 2015



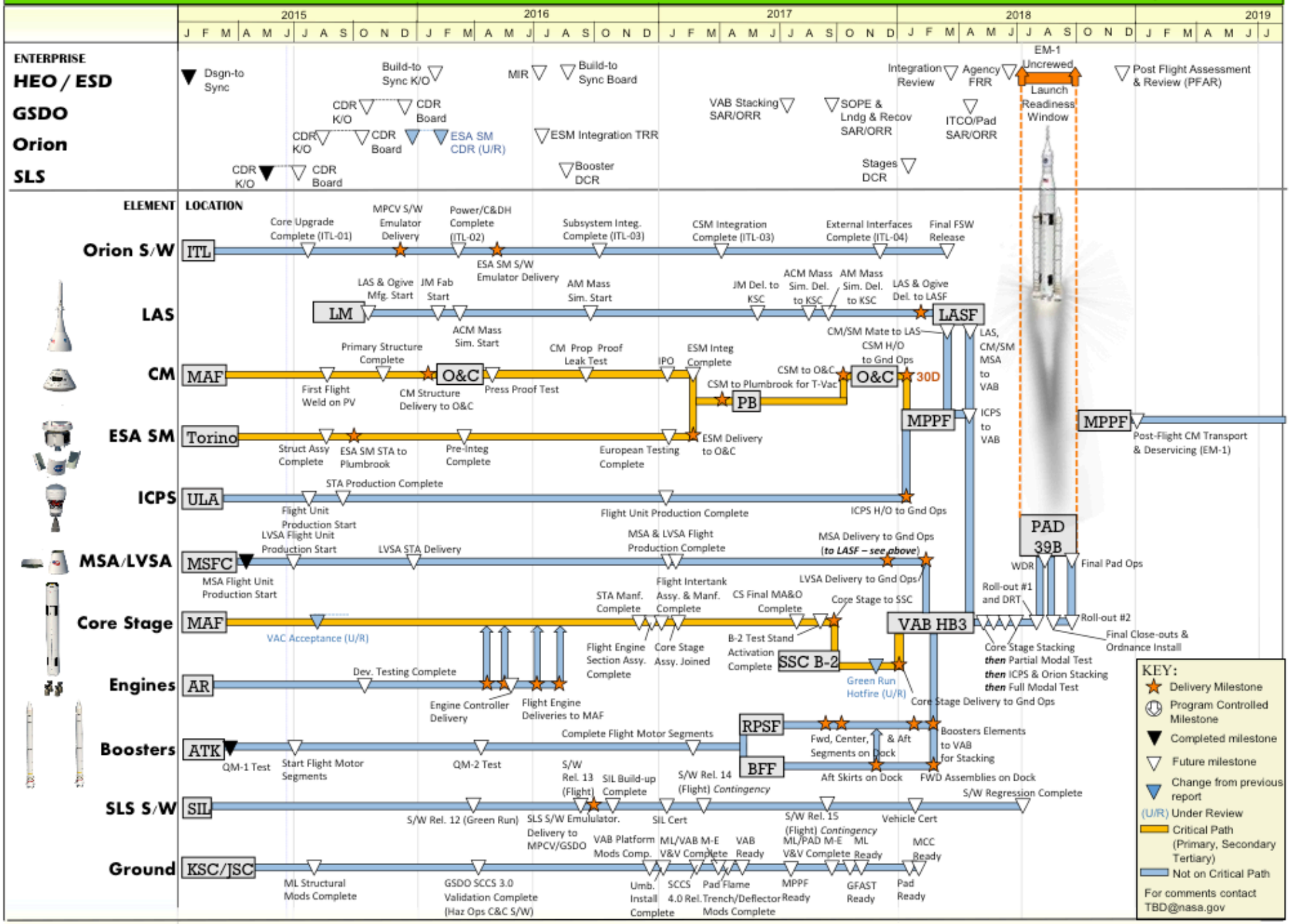
Beyond Low-Earth Orbit



Ground Systems
Vencore Systems and Solutions
Jacobs Engineering Group
Hensel Phelps

ESD EM-1 INTEGRATED MISSION MILESTONE SUMMARY

NASA ESD
Chart Updated: 06/18/2015



ORION AVIONICS & SOFTWARE

Integrated Test Lab

Prime Contractor: Lockheed Martin
Manufacturer Location: Denver, Colorado

Status

- NASA/Lockheed Martin Integrated Test Lab official opening at Lockheed Martin, Denver – July 2015

Upcoming Milestones

- ITL initial power on – August 2015
- ESA avionics and electrical ground support equipment delivery – April 2016
- Command Module subsystem integration completion – November 2016

Orion Integrated Test Lab (ITL)
July 2015

LAUNCH ABORT SYSTEM

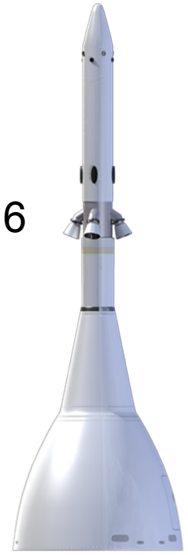
Prime Contractor: Lockheed Martin
Manufacturer Location: Denver, Colorado

Status

- Abort Motor test article case complete.
- Jettison Motor test article case assembly in process.
- Attitude Control Motor re-designed controller Engineering Development Unit initial design complete.

Upcoming Milestones

- Attitude Control Motor hot fire test (HT-11) – April 2016



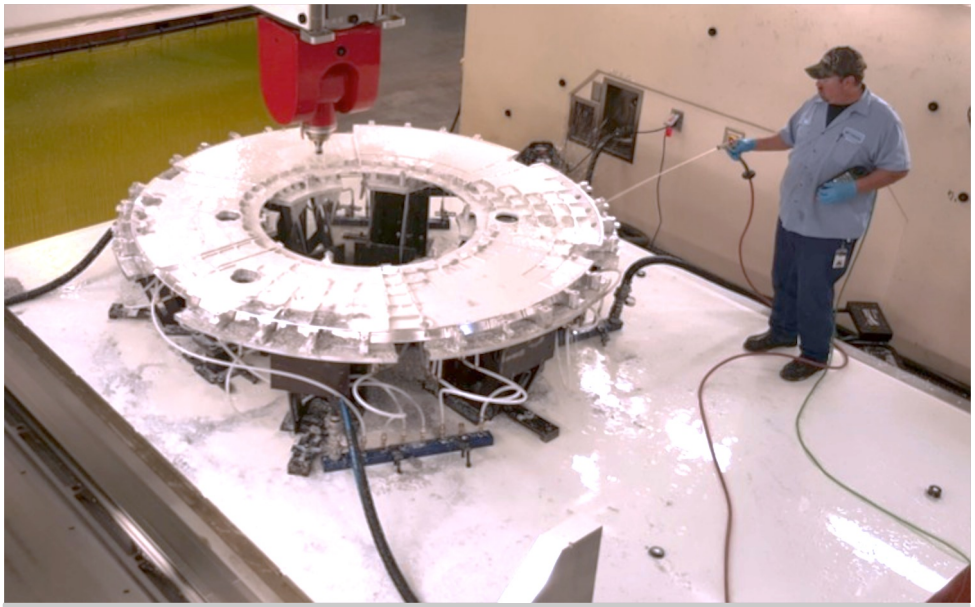
Launch Abort System
July 2015

CREW MODULE

Prime Contractor: Lockheed Martin
Manufacturer Location: Michoud Assembly Facility, Louisiana
Operations & Checkout Facility, Kennedy Space Center, Florida

Status

- EM-1 crew module barrel final milling complete and forward bulkhead arrival at Michoud – July 2015



EM-1 Flight Forward Bulkhead
July 2015

Upcoming Milestones

- First weld on EM-1 crew module – September 2015
- Closeout weld – December 2015
- On-dock at KSC – January 2016

EUROPEAN SERVICE MODULE

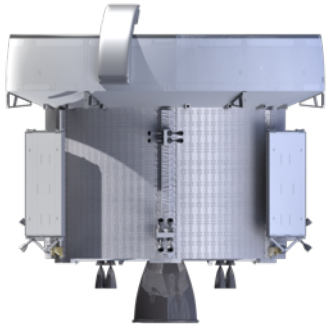
Prime Contractor: Airbus
Manufacturer Location: Bremen, Germany

Status

- ESM Structural Test Article being assembled and tested at Thales Alenia Space Italia (TASI).

Upcoming Milestones

- ESM Structural Test Article testing through September 2015 at TASI.
- ESM structural test hardware ships to Plum Brook, Ohio – October 2015



European Service Module (ESM) Structural Test Article during shock tap test at TASI. July 2015

EUROPEAN SERVICE MODULE

Prime Contractor: Lockheed Martin
Manufacturer Location: Denver, Colorado

Status

- Crew Module Adapter (CMA) delivered to Plum Brook – June 2015
- CMA modal testing began – July 2015

Upcoming Milestones

- CMA Modal testing complete – August 2015
- CM/LAS delivery – August 2015
- CM/LAS modal testing begins September 2015.

Crew Module Adapter Structural Test Article. June 2015

FAIRINGS

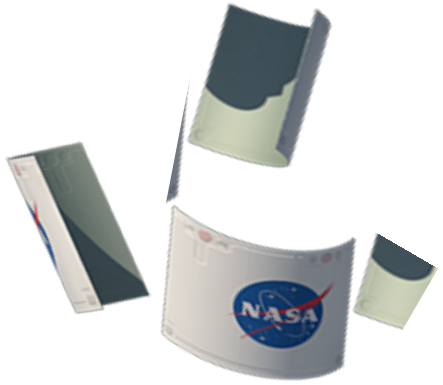
Prime Contractor: Lockheed Martin
Manufacturer Location: Sunnyvale, California

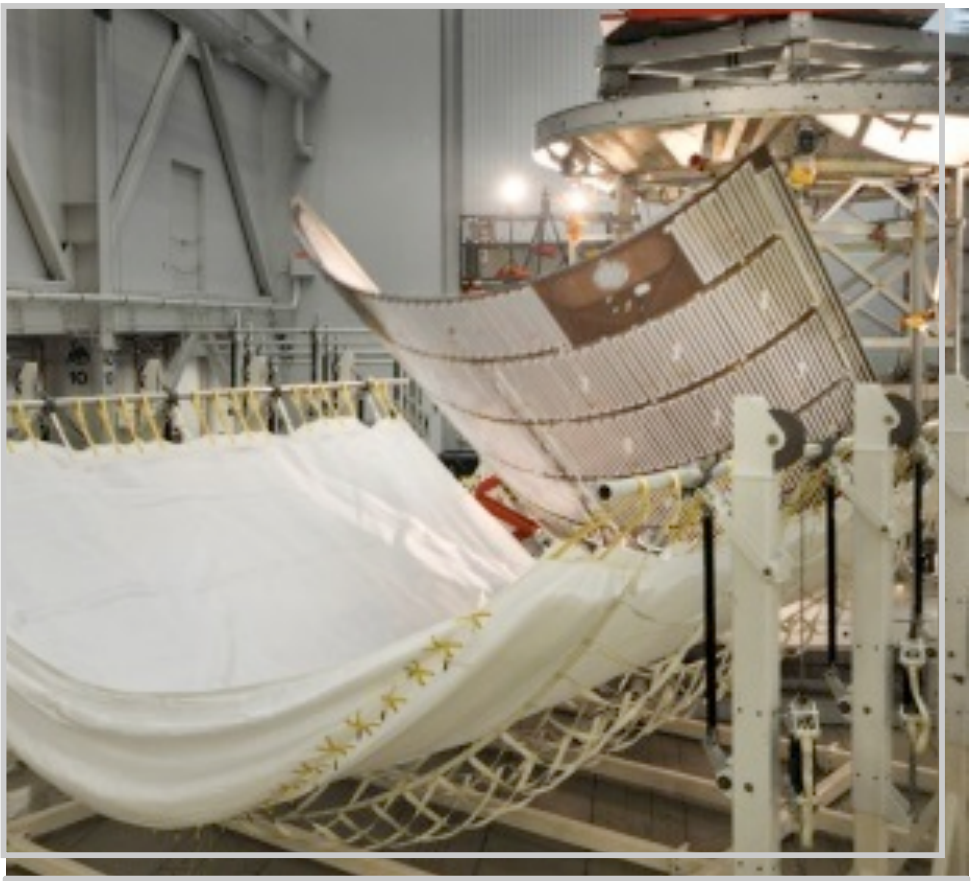
Status

- Early EM development test conducted using EFT-1 test fairings with no issues.

Upcoming Milestones

- Critical Design Review – December 2015
- Assembly and build on track for on-time delivery early 2017.
- EM qualification test at Plum Brook in Sandusky, Ohio – April 2017





First EM-1 Fairing Separation Test.
June 2015

ORION STAGE ADAPTER (OSA)

Prime Contractor: None (MSFC Engineering Directorate)
Manufacturer Location: Marshall Space Flight Center

Status:

- First OSA flew successfully on EFT-1 in December 2014
- OSA EM-1 test article currently complete

Upcoming Milestones:

- Panels for EM-1 OSA scheduled for delivery – August 2015
- Rings for EM-1 OSA scheduled for delivery – September 2015

Test article stage adapter being readied for structural testing at Marshall Space Flight Center. February 2014

INTERIM CRYOGENIC PROPULSION STAGE (ICPS)

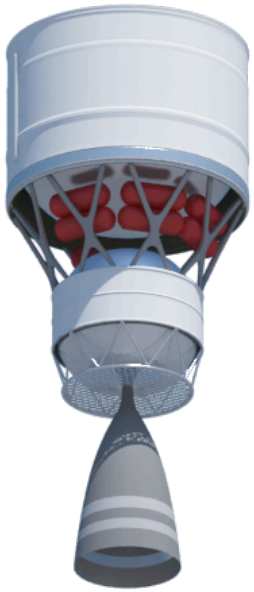
Prime Contractor: Boeing / United Launch Alliance
Manufacturer Location: Decatur, Alabama

Status:

- Production of ICPS test article is currently ongoing
- Production of EM-1 ICPS begins – July 2015

Upcoming Milestones:

- ICPS flight software PDR – August 2015
- Delivery of ICPS test article to MSFC – October 2015



ICPS dome test articles complete at ULA in Decatur, Alabama. October 2014

LAUNCH VEHICLE STAGE ADAPTER (LVSA)

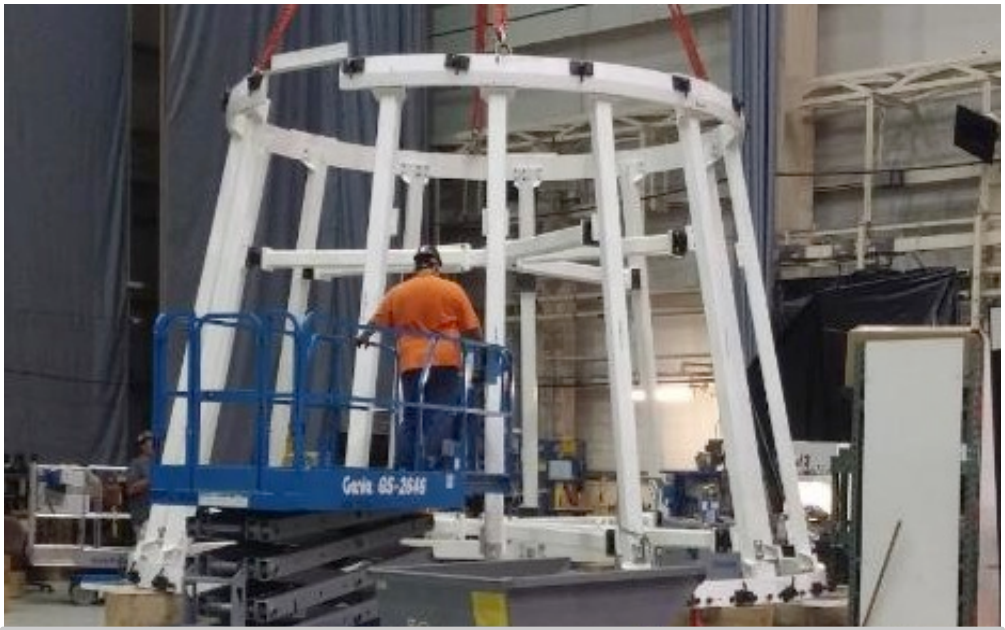
Prime Contractor: Teledyne Brown Engineering
Manufacturer Location: Marshall Space Flight Center

Status:

- Contract awarded to Teledyne Brown Engineering – January 2014
- Panels for test article delivered – June 2015

Upcoming Milestones:

- Test article scheduled for completion – March 2016



Vertical Weld Tool (VWT) forward basket tooling at Marshall Space Flight Center – July 2015

CORE STAGE

Prime Contractor: Boeing
Manufacturer Location: NASA Michoud Assembly Facility, New Orleans, Louisiana

Status:

- Foundations completed for new structural test stands at Marshall – January 2015
- Qualification rings completed, and 4 of 8 flight rings completed
- LOX (liquid oxygen) tank qualification barrels completed
- LH2 (liquid hydrogen) tank qualification barrels completed
- Engine section barrels completed

Upcoming Milestones:

- Vertical Assembly Center (VAC) hand-over to NASA – September 2015
- First structural test stand complete – November 2015
- Core Stage structural testing to begin at Marshall – November 2016

6 of 6 CS qualification rings completed at Michoud Assembly Facility – March 2015

SOLID ROCKET BOOSTERS

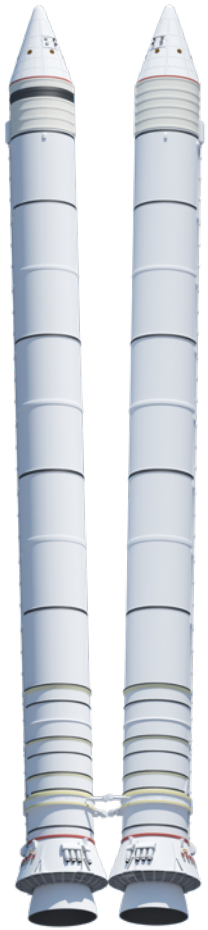
Prime Contractor: Orbital ATK
Manufacturer Location: Promontory, Utah

Status:

- Successful test firing of Qualification Motor-1 demonstrated 5-segment solid rocket motor to high temperature operation conditions – March 2015
- Completed the QM-2 aft segment propellant casting – May 2015

Upcoming Milestones:

- EM-1 booster aft skirt and nose cone refurbishment begins – August 2015
- QM-2 – April 2016



Qualification Motor-1 test at Orbital Aft Segment Cast for Second SLS Booster Qualification Test. March 2015

RS-25 ENGINES

Prime Contractor: Aerojet Rocketdyne
Manufacturer Location: Canoga Park, California

Status:

- Engine adaptation hot-fire testing February 2015 through the summer 2017
- Engineering Model – 1 Controller to the Software Integration Laboratory (SIL) – July 2015
- Engineers at Marshall Space Flight Center are developing and testing 3-D printing technologies to reduce cost of engine parts

Upcoming Milestones:

- EM-2 flight engines begin hot-fire testing – October 2015
- RS-25 production restart contract signing – October 2015

Successful RS-25 engine testing on the refurbished A-1 test stand at Stennis Space Center. Tests ongoing through the summer of 2015.

SLS SOFTWARE AND AVIONICS

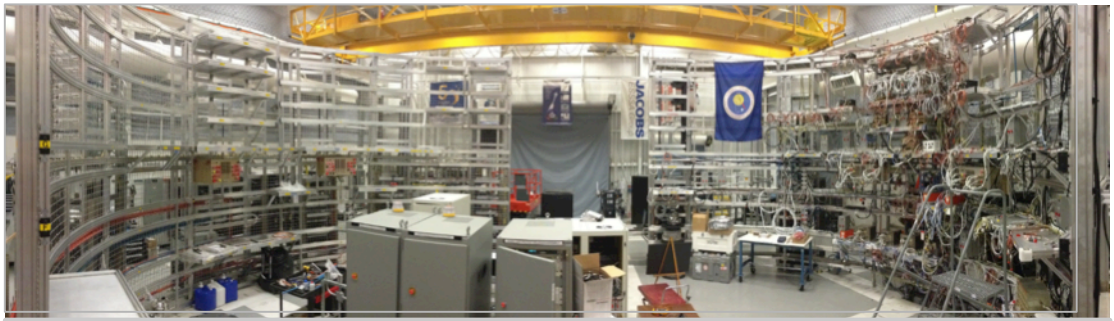
Prime Contractor: Boeing, Orbital ATK
Manufacturer Location: Huntsville, Alabama and Clearfield, Utah

Status:

- Currently on Release 11 of the avionics software – July 2015
- Booster avionics system was shipped to Marshall from Orbital ATK's Avionics Lab in Clearfield, Utah – February 2015

Upcoming Milestones:

- Flight Imaging Launch Monitoring Real-Time System (FILMRS) for cameras to Software Integration Test Facility – June 24



The Software Integration Test Facility (SITF) at Marshall Space Flight Center – First Light kickoff began the facility integration testing and checkout. SLS Core Stage will use the SITF to perform vehicle-level avionics verification. January 2014

GROUND SYSTEMS

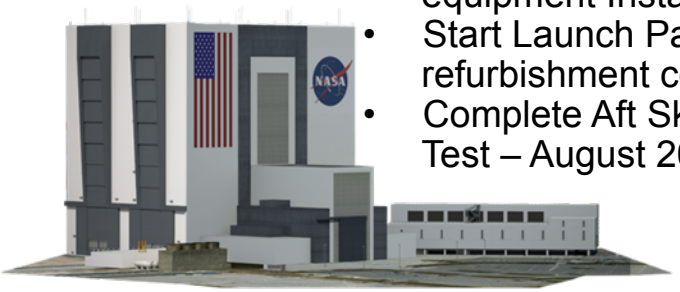
Prime Contractor: Multiple
Manufacturer Location: Multiple

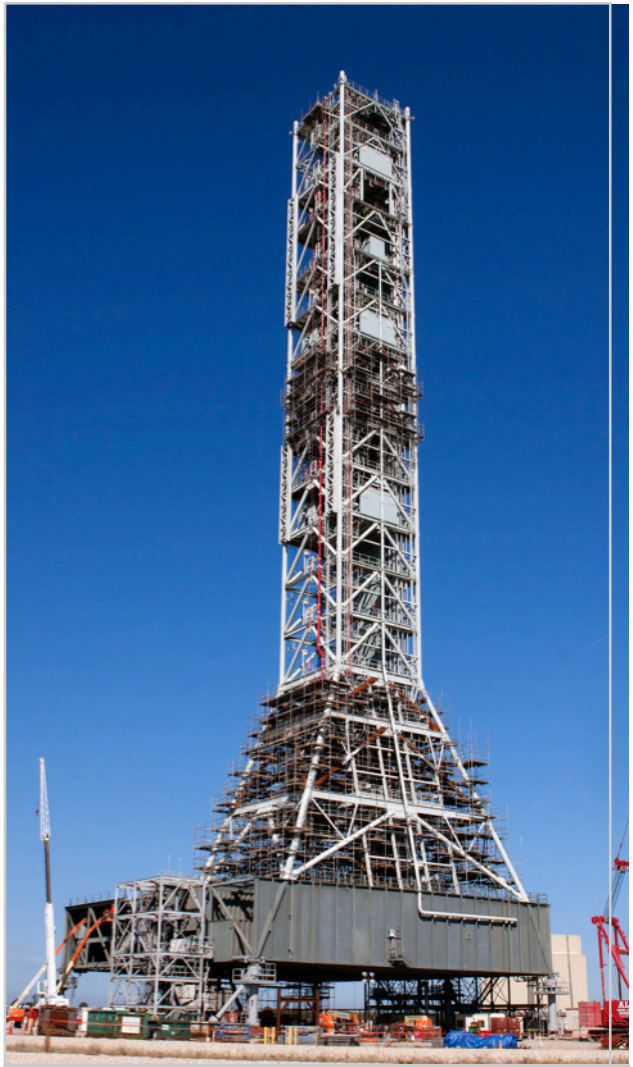
Status:

- Umbilical testing in the Launch Equipment Test Facility (LETF) is well underway
- Mobile Launcher structural modifications are complete and ready to start Ground Support Equipment installation after contract award in August
- 11 different construction contracts are in-work on various modifications at Launch Pad 39B, including flame trench and sound suppression system
- Crawler-transporter gearbox refurbishment and hydraulic lift cylinder upgrades are going well
- Vehicle Assembly Building High Bay 3 platform construction is ~30% complete with first pair of platforms on-site
- Multi-Payload Processing Facility modifications and ground support equipment installations are ~80% complete

Upcoming Milestones:

- Award Mobile Launcher ground support equipment Installation contract – August 2015
- Start Launch Pad 39B flame trench refurbishment construction – August 2015
- Complete Aft Skirt Electrical Umbilical Structural Test – August 2015



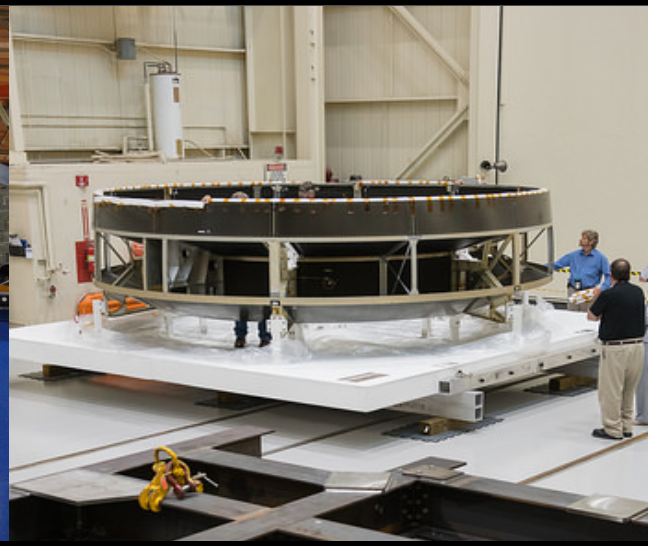


Mobile Launcher structural modifications are complete. July 2015

Orion Accomplishments

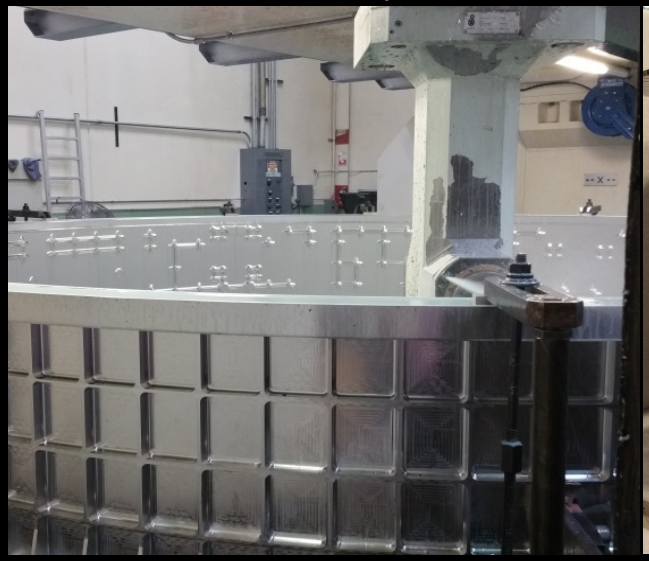
Integrated Test Lab Mockup, Denver, Colorado

EM-1 Pathfinder First Weld at Michoud Assembly Center



Crew Module Structural Test Article arrives at GRC

EM-1 Flight Aft Bulkhead

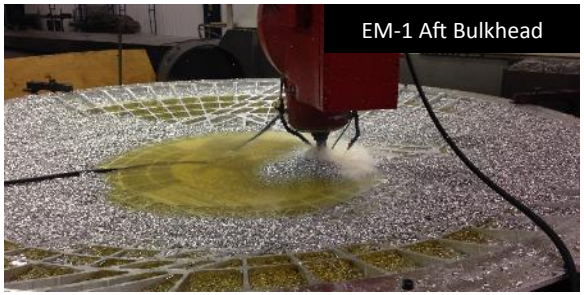


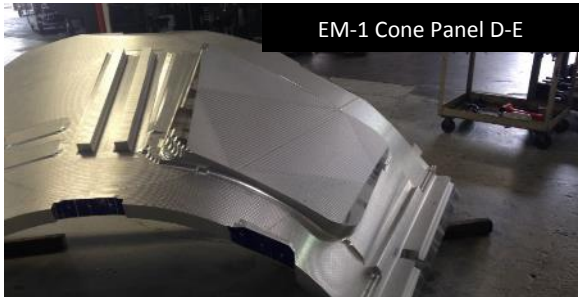
EM-1 Flight Barrel machining

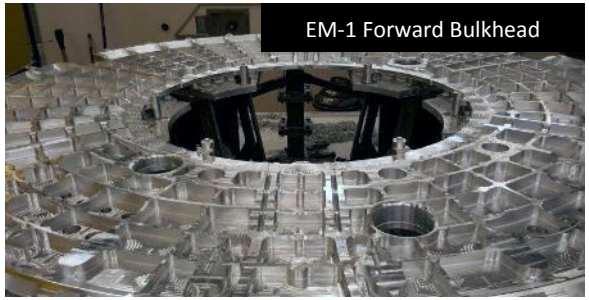
EM-1 Flight Tunnel

Orion – EM-1 Manufacturing Progress

- All EM-1 flight primary structure is in machining and pathfinder machining is complete
- All pathfinder parts delivered to MAF and welding in progress







- Some machining issues experienced at primary structure suppliers, with corrective actions as follows:
  - LM/NASA machining team established with weekly supplier meetings and regular site visits
  - Cross vendor communication established to address issues in real-time
  - Delta Manufacturing Readiness Reviews required prior to machining restart
  - Reassigned the Cone Panel Contract Management from Arcata to LM

Strategy will establish a collaborative advanced manufacturing capability for future missions

Orion: Major Schedule Milestones

FY 2016

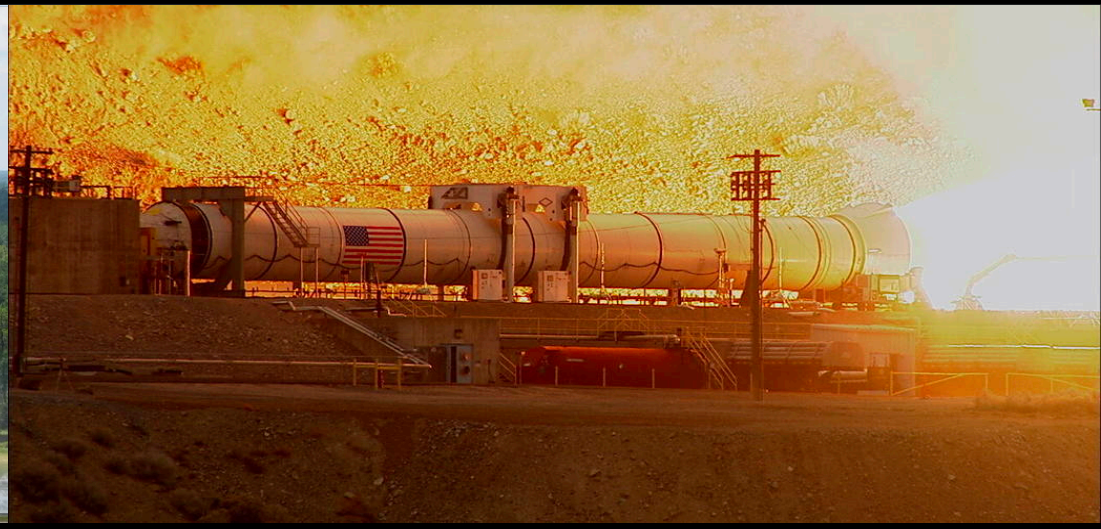
- Orion CDR board, 1st Qtr
- Complete EM-1 crew module (CM) pressure vessel welding operations, 1st Qtr
- ESA portion of European structural test article ready for test, 1st Qtr
- ESA CDR board, 2st Qtr
- EM-1 orbital maneuvering system: engine on dock at ESA, 2nd Qtr
- Ship EM-1 crew module pressure vessel to KSC, 2nd Qtr
- EM-1 CM proof pressure test complete, 3rd Qtr
- EM-1 CM propulsion proof and leak test, 4th Qtr
- Ground test article water impact testing at LaRC, 4th Qtr

FY 2017

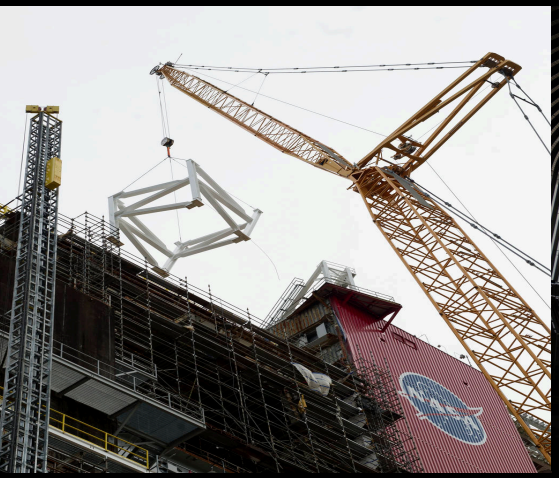
- EM-1 ESM delivery to KSC, 2nd Qtr
- Installation of EM-1 heatshield, 2nd Qtr
- Begin structural test article mate and testing, 3rd Qtr
- Begin EM-2 crew module pressure vessel fabrication, 3rd Qtr
- Launch abort system available to GSDO, 3rd Qtr
- Mate EM-1 CM and ESM, 3rd Qtr
- EM-1 ogive assembly complete, 3rd Qtr
- Deliver EM-1 flight article to Plum Brook for integrated testing, 3rd Qtr
- EM-2 Delta CDR board, 4th Qtr

Space Launch System Accomplishments

The RS-25 engine fires up at the beginning of a 500-second test June 11



At the Promontory, Utah test facility of Orbital ATK, the booster for NASA's Space Launch System rocket was fired for a two minute test on March 11



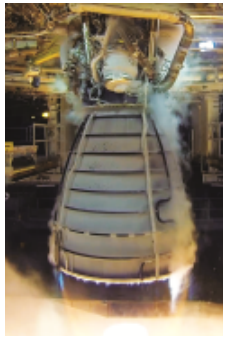
On May 13, a major milestone in its preparation for testing the core stage

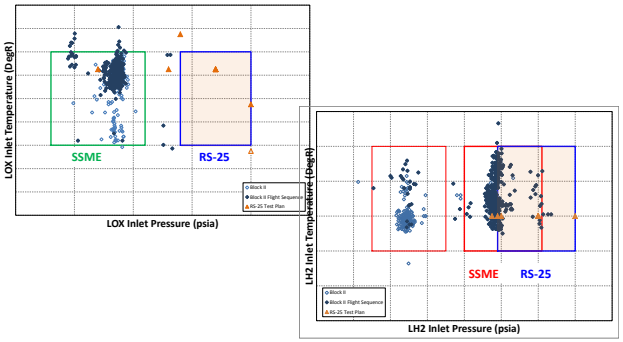
Crews complete a 250-foot-long metal canopy for NASA's Pegasus barge.

Hydrogen burn-off igniter test is conducted May 5 at the Redstone

RS-25 Engine Test Plan Objectives

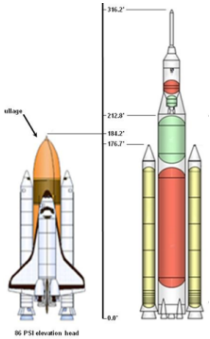
Validate New Propellant Inlet Conditions

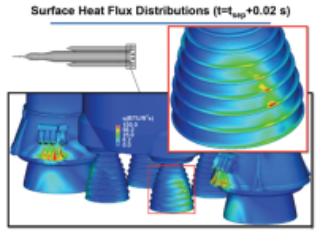




- New engine propellant inlet conditions result in changes to start sequence
- Multiple test samples of new start sequence validates start box
- Testing of higher mainstage pressures validates structural and operational analyses

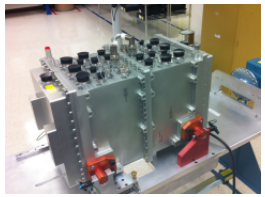
Validate Interface Condition Changes





- SLS Vehicle/Engine interface changes require testing for flight validation
- Increased base heating from boosters – new thermal protection needed for nozzles

Develop and Certify New Controller & Software



- New controller required for obsolescence and interface changes from Shuttle
- Modernized design with new software
- Multiple engine samples required to validate mixture ratio and thrust control precision

Hardware Acceptance Test & Life Extension

- Life extension testing required to fly some existing hardware
- New hardware acceptance testing - 16 controllers, 2 engines & 1 high pressure fuel turbo pump
- Flow dynamics testing required to demonstrate life with new operating conditions

SLS: Major Schedule Milestones

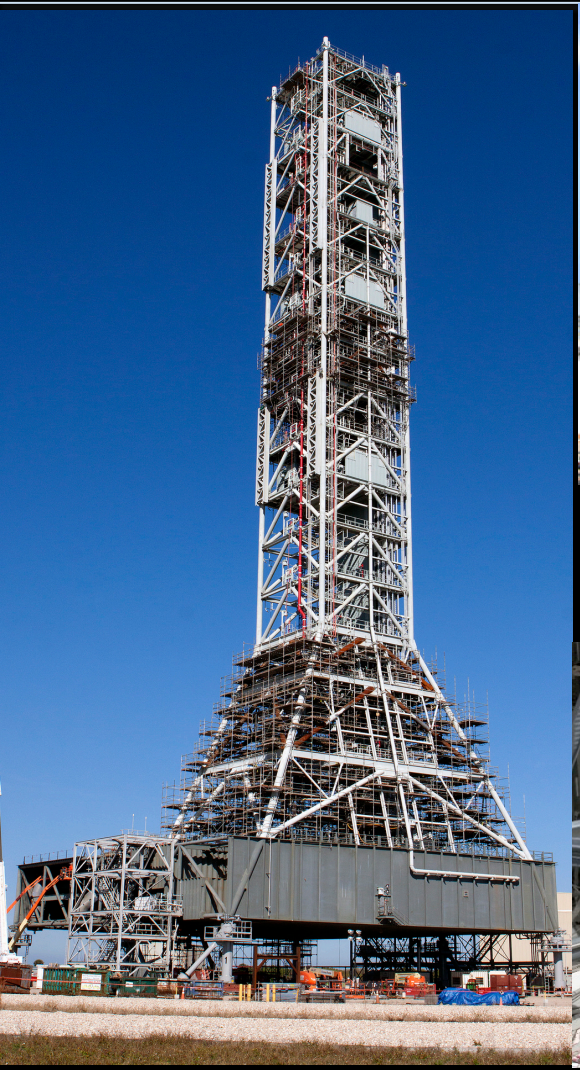
FY 2016

- Conduct SLS Booster Qualification Motor-2 test at Orbital/ATK, 2nd Qtr
- B-2 Test Stand Activation at SSC, 3rd Qtr
- Conduct Exploration upper stage PDR
- Launch Vehicle/Stage Adapter structural test article test complete, 4th Qtr
- EM-1 flight RS-25 engines testing complete, ready for integration, 4th Qtr
- ICPS structural test article test complete, 4th Qtr
- MPCV Stage Adapter structural test article test complete, 4th Qtr

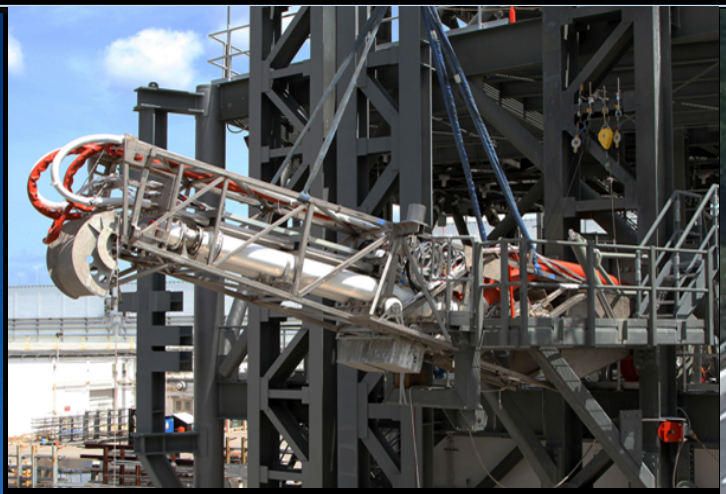
FY 2017

- EM-1 ICPS Production Complete, 2nd Qtr
- Deliver Booster Solid Rocket Motor Aft Segment to KSC, 2nd Qtr
- Deliver Booster Aft Exit Cone and Skirts to KSC, 2nd Qtr
- Core Stage available to ship to SSC for green run testing, 3rd Qtr
- Deliver Booster Solid Rocket Motor Forward Segments to KSC, 4th Qtr
- Deliver Booster Solid Rocket Motor Center Segments to KSC, 4th Qtr
- Deliver Interim Cryogenic Propulsion Stage to KSC, 4th Qtr

Ground Systems Accomplishments



Mobile Launcher structural modifications are complete. Ground subsystem installation contract award planned for August



The Orion Service Module Umbilical (OSMU) is being installed at the Launch Equipment Test Facility. Testing begins in August

The first work platforms have been delivered to the VAB

Testing of the Aft Skirt Electrical Umbilical (ASEU) was successfully completed at the Launch Equipment Test Facility in June

Upgrades and modifications to the 175-ton crane are complete; the crane has been placed back to its original position

GSDO: Major Schedule Milestones

FY 2016

- Complete Multi-Payload Processing Facility (MPPF) phase 2 facility GSE installation – 2nd Qtr 2016
- Spaceport Command and Control System 3.4 validation complete – 3rd Qtr 2016

FY 2017

- Complete Pad B construction – 2nd Qtr 2017
- Complete MPPF V&V – 4th Qtr 2017
- Complete VAB Platforms and VAB/ML Integrated V&V
  - Platforms—1st Qtr 2017
  - ML/VAB V&V—2nd Qtr 2017
- Complete Landing and Recovery Underway Recovery exercise– 1st Qtr 2017
- Complete Vehicle Assembly Building (VAB) High Bay 3 construction – 1st Qtr 2017
- Complete Mobile Launcher (ML) Ground System Equipment (GSE) installation – 1st Qtr 2017
- Complete Pad/ML Integrated V&V – 4th Qtr 2017

progress [video]

BACK UP

Cross-Program System Integration

Cross System Integration Status Agenda

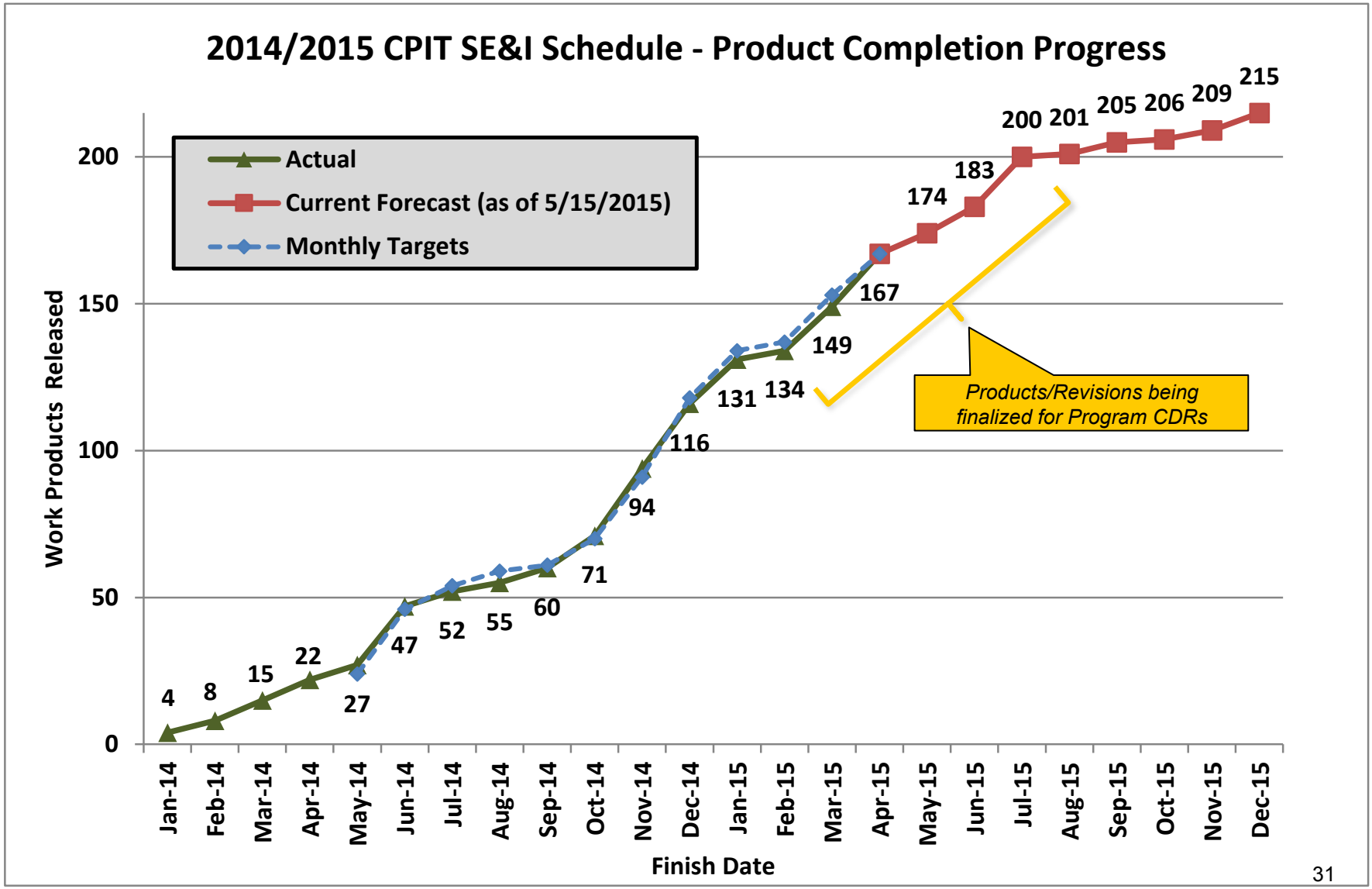
- **CSI technical performance and accomplishments**
- **CSI products schedule**
- **Interdependencies**
- **Cross-Program Integration Team top technical issues**
- **Technical performance metrics**
- **Independent Assessments**
- **ESD CE watch and worry list**

CSI Technical Performance and Accomplishments

- **Recent Major Cross-Program Accomplishments (March-May)**
  - Orion/SLS IRD update (June 4)
  - Orion/GSDO ICD update (June 4)
  - Joint Launch Accessories V&V Strategy Document (Mar 3)
  - Range Safety Agreement updates (Mar 3-June 3)
  - GH2/LH2 Separator/Burn Stack decision (May 7)
  - Partial Stack Modal Test @VAB Decision by ECB (May 21)
  - NESC Assessment of SLS and Orion Modal Test, Development Flight Instruments, and Dynamic Model Correlation Plans (May 18)
  - NESC Assessment of Avionics and Software (April 15-16)
  - Annual OCE/EMB Risk Assessment of Technical Integration of ESD's three Human Spaceflight Programs (May 7)
  - Payload opportunities due to excess SLS launcher performance (Mar 19)

- **Near-term forward work**
  - Review and respond to Design-to-Synch RFA's from the SRB
  - Preparation, review, and approval of products in preparation for the upcoming SLS, Orion and GSDO CDRs
  - Requirements development for potential Exploration Upper Stage decision

CPIT SE&I Schedule
Product/Revision Completion Progress

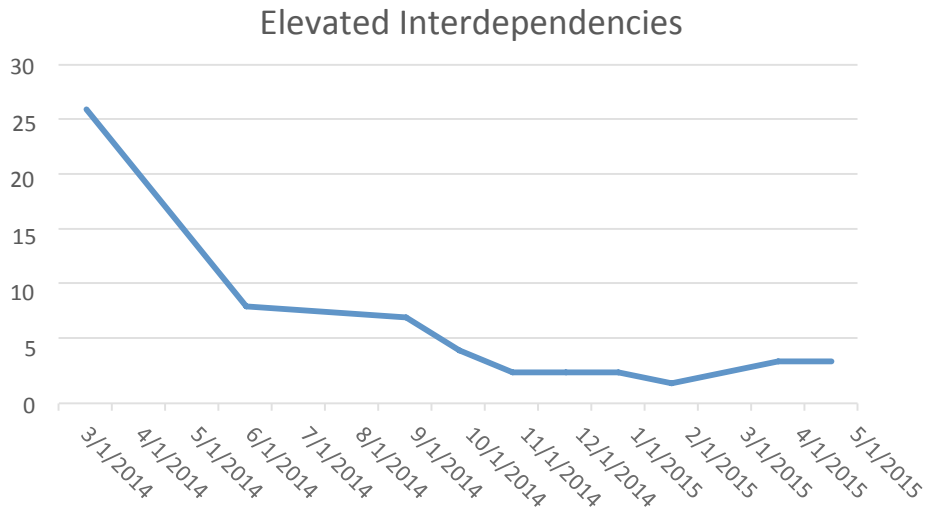


Cross Program Interdependencies – Metrics

Effective progress is being made in resolving interdependencies

- **Changes made to the interdependencies management process have had a real effect**
- **The agreements process allowed for timely resolution of SLS re-plan changes prior to the SLS CDR**

Date	Active	Elevated
3/7/2014	195	26
6/12/2014	176	8
8/28/2014	164	7
9/30/2014	173	4
10/28/2014	170	2
11/17/2014	145	2
12/5/2014	140	2
1/5/2015	77	2
2/2/2015	70	1
5/20/2015	39	3



<u>Interdependencies Elevated to CPIT</u>:

- **(1) previous elevated item remains: MPCV CUI Count (Cross-program risk 12209)**
- **(2) new elevated items: ICPS umbilical loads (Cross-Program Risk 11881)**

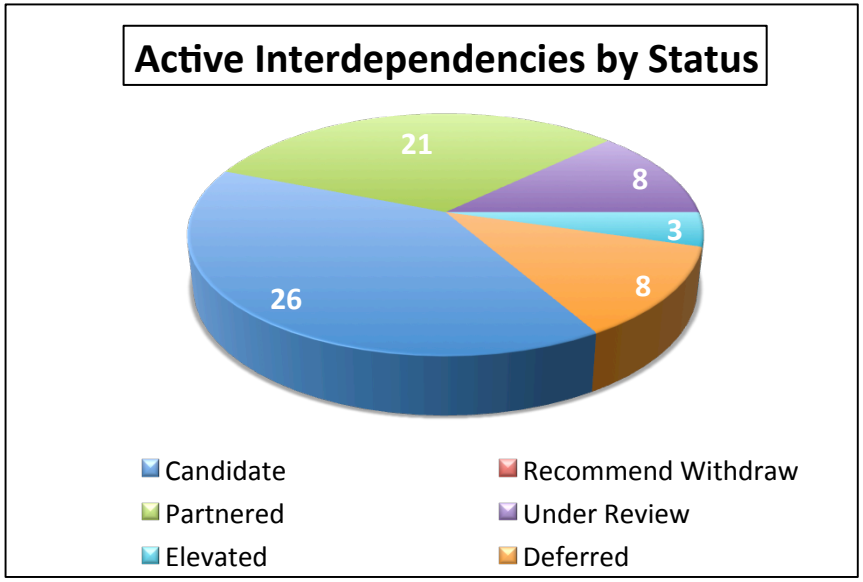
Cross Program Interdependencies – Metrics

66 active interdependencies; 134 active Cross-Program Control Milestones

Cross-Program Interdependency Progress					
Date Reported	Total Items	Active	Elevated	Candidate	Closed or Withdrawn
2/2/15	419	70	1	18	349
5/4/15	438 (+19)	66 (-4)	3 (+2)	26 (+8)	371 (+22)

Interdependencies Elevated to CPIT:

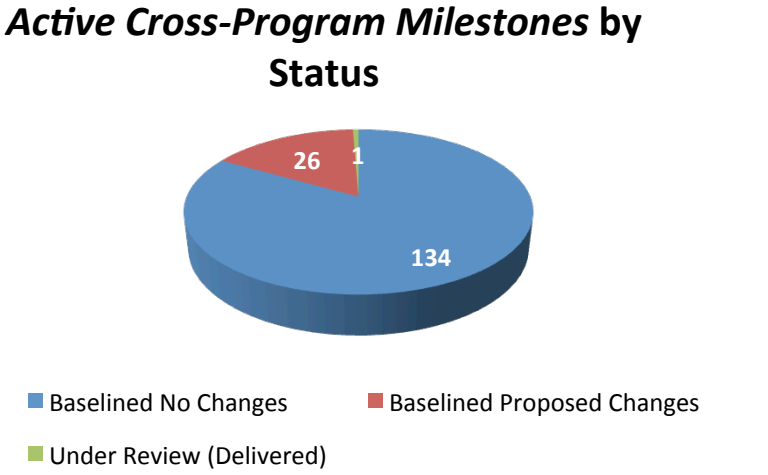
- (1) MPCV CUI Count (Cross-program risk 12209)
- (2) ICPS umbilical loads (Cross-Program Risk 11881)



Cross-Program Control Milestones Progress						
Date Reported	Total Items	Active	Baselined	Proposed Changes	Under Review	Closed
2/2/15	133	124	85	26	1	9
5/4/15	158 (+25)	134 (+10)	89 (+4)	26	1	24 (+13)

Baselined items:

The proposed changes were realized through the SLS-GSDO BSHEALS Rev. A, and GSDO-MPCV BSHEALS



CPIT Top Technical Issues
(closed since last Quarter)

- **Orion Service Module (SM) hazardous servicing**
  - Time criticality made this a top technical issue. Face-to-Face TIM resulted in developing SM servicing plans at KSC. ESA agreed to the updated plan

- **Disconnect of Core Stage umbilical loads between GSDO and SLS/Stages**
  - Issue was resolved by further refining analysis, coupled with stiffness testing of vacuum jacket (VJ) hoses and minor design changes to small cable supports

- **Lack of ICPS Emulator for ground software development**
  - ULA agreed to provide a system normally used for Delta development and servicing. This will allow GSDO to check out it's software during development
  -
- **Potential Interference of ICPS telemetry with Orion**
  - A new frequency was selected and the potential interference was resolved

CPIT Top Technical Issues
(all new since March)

- **Hydrogen Burn Off Igniter (HBOI)/Hydrogen Pop loads on the core stage**
  - Concern over GH2 build up prior to RS-25 ignition
  - Detailed loads and timing analysis in progress
  - HBOI testing in progress for wind effects on sparklers
  - Update CFD analysis with correlated wind-effects model

- **Crew recovery in allotted 2 hr timeframe may not be possible**
  - Data from EFT-1 indicates that crew recovery within 2 hours of landing is unlikely
  - Landing and Recovery Team was formed to develop options to recover crew ASAP, nominally within 2 hours
  - Team has met, developed FOMs for options assessment and are conducting detailed evaluations on 20 options.
  -

- **Upper Stage MMOD**
  - Updated ORDEM 3.0 models drive ICPS MMOD to be a large contribution to overall mission LOC. Trade study in progress to examine several options:
    - Double foam insulation on cryo tanks
    - Alternate mission low apogee
    - Shield hardening
    - Attitude parametric studies in progress

CPIT Top Technical Issues (continued)

- **Collet Vibration Test Failure**
  - Premature disengagement during Orion vibration qualification test
  - Investigation is still on-going
  - New Boeing test planned for July
  - This collet is used in multiple umbilical assemblies (Orion and Core Sage)
    - Understanding the root cause and its solution is critical

- **Integrated Test Lab Capacity/throughput**
  - Cross program testing needs exceed the allocated availability of the ITL lab (integrated avionics and software high fidelity testing)
  - Orion is developing a test consolidation plan
    - Options available to move some testing out of the ITL to other facilities
    - Provide more capability (test rigs) to the ITL

May 2015 ESD TPM Summary Report
Changes since Feb QPSR

Updated */New TPMs since last QPSR*

Discipline	ESD TPM ID	TPM Title	Threshold (T) Objective (O)	Previous Value	Current Value	Change	Comment
Ops	ESD-7A	EM-1 Launch Probability	T = 85% O = 90%	84%	82%	↓	May 2015: - Launch month changed from December to worst Feb. - 24-knot wind placard added. - Monthly average launch probability is 87%.
	ESD-7B	EM-2 Launch Probability	T = 85% O = 90%	N/A	73%	n/a	May 2015: Revised metric from Strategic era to Tactical with specific focus on EM-2. - Launch month changed from December to worst case Feb. - Monthly average launch probability is 82%.
	GSDO-VIL-02a	LH2 Storage Demand (EM-1)	T = 815, 000 gal O = 765,000 gal	781,236 gal	755,820 gal	↑	GSDO-VIL-02 is managed by GSDO, reported in parallel to ESD for insight into LH2 concern. April 2015: Pending JPCB decision on core stage engine LH2 bleed parameters (SLS CR 00357).
Performance	ESD-14	EM-1 Mission Mass/Performance Margin	T = 1.0% O = 3.0%	4.3%	4.5%	↑	May 2015: Margin increase resulted from Orion net TLI mass decrease due mainly to SM mass decrease. Note: TPM Assumes 22 x 975 nmi MECO orbit.
Other	ESD-15	EM-2 Mission Mass/Performance Margin	T = 1.0% O = 3.0%	5.5%	5.8%	↑	May 2015: Margin increase resulted from Orion net TLI mass decrease due mainly to SM mass decrease and SM prop offload. Note: TPM Assumes 19x1175 nmi MECO orbit.
Other	ESD-13a	Milestone Review Request for Action Burn-Down (ESI SDR)	n/a	3 open	2 No longer in work per ESD agreement	↑	TPM showing closure status of SDR RFAs. A total of 35 RFAs were received. Of those, 33 RFAs have been closed with remaining 2 no longer in work. Last reporting of ESD-13a since RFAs no longer in work.
Other	ESD-13b	Milestone Review Request for Action Burn-Down (DTS)	n/a	New	19 open	N/A	TPM showing closure status of DTS RFAs. A total of 21 RFAs were received. Of those, 3 RFAs has been closed.

Meets Objective

Meets Threshold

Does Not Meet Threshold

White- Threshold/ Obj. TBD or n/a

- Blue Text indicates changes from last report
- Direction of arrow indicates trend from last report. Up is improved. Down is worsened. Right/Left is unchanged.

May 2015 ESD TPM Summary Report
Changes since Feb QPSR

Discipline	ESD TPM ID	TPM Title	Threshold (T) Objective (O)	Previous Value	Current Value	Change	Comment
S&MA	ESD-1a	Launch & Ascent Probability of LOC	T = 1:400 O = n/a	1:770	No Update - Same as Previous	n/a	July 2014: Current values based on the Integrated Design Analysis Cycle-2a (IDAC-2a) Ascent Probabilistic Risk Assessment (PRA). Next report planned for August 2015, based on IDAC-3 PRA.
	ESD-2	Launch & Ascent Probability of LOM	T = 1:n (TBD) O = n/a	1:130	No Update - Same as Previous	n/a	July 2014: Current values based on the Integrated Design Analysis Cycle-2a (IDAC-2a) Ascent Probabilistic Risk Assessment (PRA). Next report planned for August 2015, based on IDAC-3 PRA.
Ops	ESD-8	Launch-to-Launch Interval (strategic)	T = 120 days O = 80 days	112 days*	No Update - Same as Previous	n/a	Metric is currently only met with shifting beyond the 6/2 nominal processing baseline of GSDO. Feb 2015: Updates based on GOPD Drop 8. Discrete Event Simulation (DES) calculation now being used to compute TPM. Asterik indicates adjustment of previous value based on DES result for GOPD Drop 7. Next report will be in June based on GOPD Drop 9 .
	ESD-16	Launch Scrub Turnaround	T = Attempt 2 occurs within 48 hrs of scrub decision O = Attempt 3 occurs within 96 hrs of second scrub decision	Attempt 2: 36 hrs Attempt 3: 216 hrs	No Update - Same as Previous	n/a	February 2015: No significant changes seen in refinement of GOPD Drop 8 scrub timeline data. Next report will be in July based on GOPD Drop 9 .

Meets Objective
Meets Threshold
Does Not Meet Threshold
White- Threshold/ Obj. TBD or n/a

- Blue Text indicates changes from last report

Independent Assessment of CSI Activities

- **14 ESD/Integrated independent assessment in progress or recently completed**
  - NESC and Aerospace Corporation

- **Significant recent findings**
  - SLS Booster re-contact assessment
    - No re-contact predicted
  - Orion Service Module panel jettison analysis
    - Significant margin for panel re-contact
  - ESD and Programs Requirements “completeness” review
    - Recommend adding one requirement for re-contact avoidance maneuver (post core stage separation)
  - Cross Program System Integration functional assessment
    - 190 functions identified and reviewed, 2 not found in current ESD and Program function suite
    - Final findings and recommendations in work
  - Integration and Avionics and Software V&V Risk Assessment
    - Strengthen S/W management/coordination across the enterprise
      - Cross program software testing planning and execution, schedule development/analysis
    - Final findings and recommendations in work

ESD CE High-level Worry and Watch List

- **Issues/Concerns**
  - Integrated Avionics and Software “distributed” V&V plan and resources
  - Integrated V&V plan/gap analysis and execution of cross-program V&V
    - Interface maturity and interface V&V
  - Proto-flight/proto-qualification hardware used for V&V for EM-1
  - Cost and schedule pressures impacting V&V testing plans for EM-1
  - Transition of CSI design effort to hardware production and EM-1 Mission Operations
- **EM-2 Specific Concerns**
  - EM-2 vehicle configuration
  - EM-2 Mission Profile
  - CSI SE&I workforce for EUS integration concurrent with Block 1 verification
- **Recommendations**
  - Maintain current approach through CDR’s
  - Post-CDR’s - adapt current CSI approach to Production/ops model