

Exploration Systems Development

NASA Advisory Council Meeting
March 2, 2016





Agenda

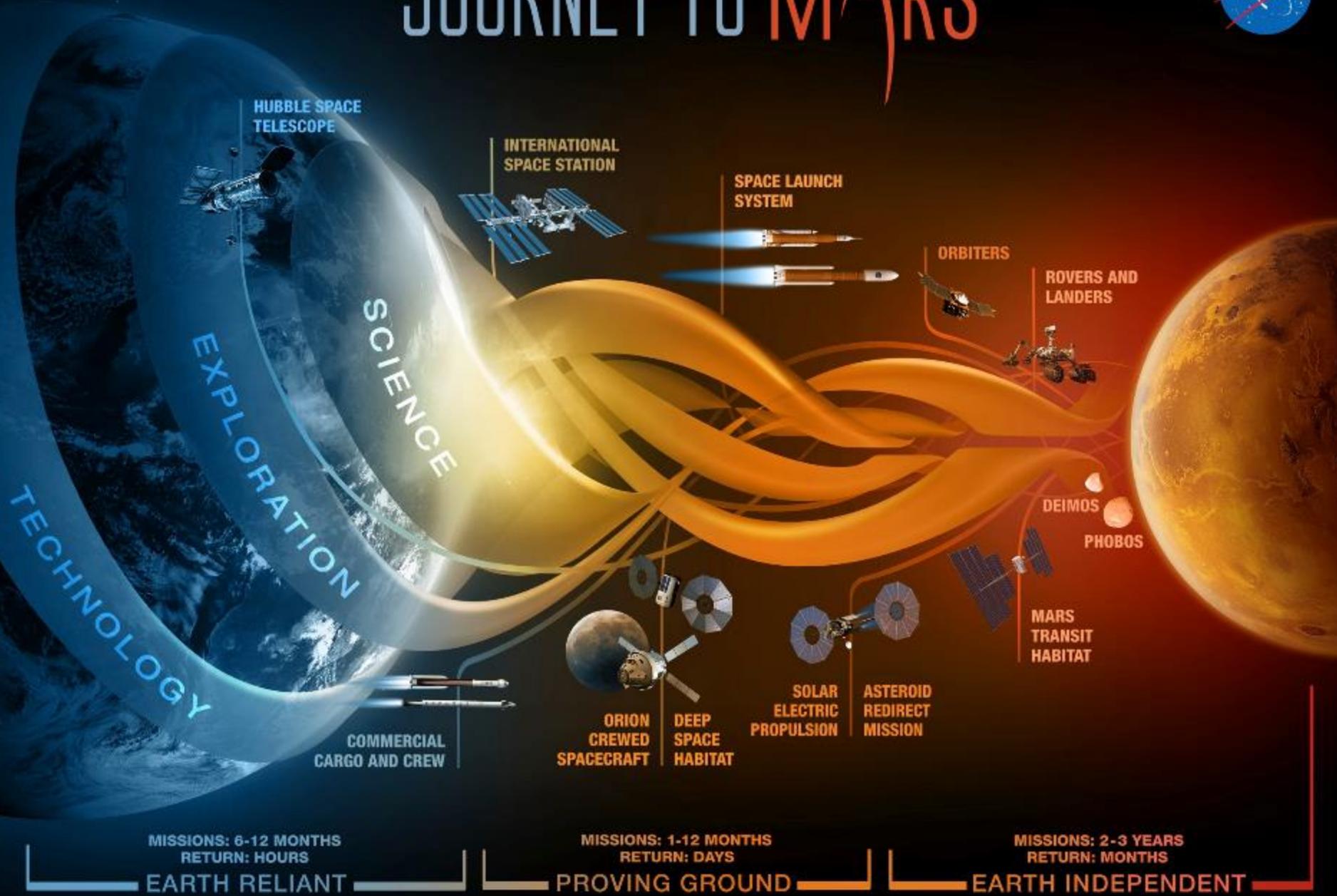
- ESD Overview
- Program Accomplishments and Status
 - Space Launch System (SLS)
 - Ground Systems Development and Operations (GSDO)
 - Orion
- Cross-Program System Integration Status

Exploration Systems Development

OVERVIEW



JOURNEY TO MARS



MISSIONS: 6-12 MONTHS
RETURN: HOURS

EARTH RELIANT

MISSIONS: 1-12 MONTHS
RETURN: DAYS

PROVING GROUND

MISSIONS: 2-3 YEARS
RETURN: MONTHS

EARTH INDEPENDENT

Transition from ISS to Cislunar Space: Framework



Today

Phase 0: Exploration Systems *Testing on ISS*

Ends with testing, research and demos complete*

Asteroid Redirect-Crewed Mission Marks Move from Phase 1 to Phase 2

Phase 1: *Cislunar Flight Testing* of Exploration Systems

Ends with one year crewed Mars-class shakedown cruise

Phase 2: *Cislunar Validation* of Exploration Capability

Mid-2020s

2030

*There are several other considerations for ISS end-of-life

DRAFT: Phase 1 Flight Test Objectives



CATEGORY	FLIGHT TEST OBJECTIVE
Transportation	Demonstrate Orion's capability to extract co-manifested payload from SLS fairing.
Transportation	Determine Orion's ability to support missions with at least 4-Crew longer than 21 days in conjunction with additional elements.
Transportation	Evaluate Orion's depress/repress for EVA contingency operations.
Transportation	Evaluate Orion's off-axis (tail-to-sun) performance.
Transportation	Evaluate EUS TLI Performance with Orion plus Co-Manifested Payload.
Transportation	Evaluate high-power electric propulsion systems.
Transportation	Evaluate high-efficiency, high-power solar arrays in deep space.
Habitation Working in Space	Demonstrate crew accommodations for Beyond-LEO conditions.
Habitation Working in Space	Evaluate the performance of electrical components in a deep-space radiation environment.
Habitation Working in Space	Evaluate cislunar transit habitat airlock and EVA system servicing accommodation for ability to support contingency EVA operations.
Habitation Working in Space	Evaluate cislunar transit habitat airlock and EVA system servicing accommodation for ability to support nominal deep space mission EVA operations.
Operations Working in Space	Demonstrate transition between crewed and uncrewed operations, including configuration for remote/dormant operations and reactivation for crewed support.
Operations Working in Space	Demonstrate human spacecraft operations in the presence of communications latency.
Operations Working in Space	Demonstrate independent (On-board) mission and trajectory design/planning capability.
Operations Working in Space	Demonstrate Earth-independent deep space navigation.
Operations Working in Space	Evaluate stowage strategies to handle logistics and trash within available stowage volume for deep space missions.
Operations Working in Space	Demonstrate side-by-side human and robotic operations.
Exploration Working in Space	Demonstrate collection and return of geologic asteroid samples.
Exploration Working in Space	Demonstrate research sample acquisition, handling, analysis, and curation requiring environmentally controlled conditions with no cross-contamination permitted.
Staying Healthy	Demonstrate/evaluate space radiation protection and monitoring.
Staying Healthy	Demonstrate/evaluate human health, performance, and environmental health in a hostile and closed environment.
Staying Healthy	Evaluate the effects of deep space on complex organisms, plants, food, medicines, and animal models.

SLS, Orion, and Ground Systems



Beginning human exploration beyond LEO as soon as practicable helps secure our future in space.



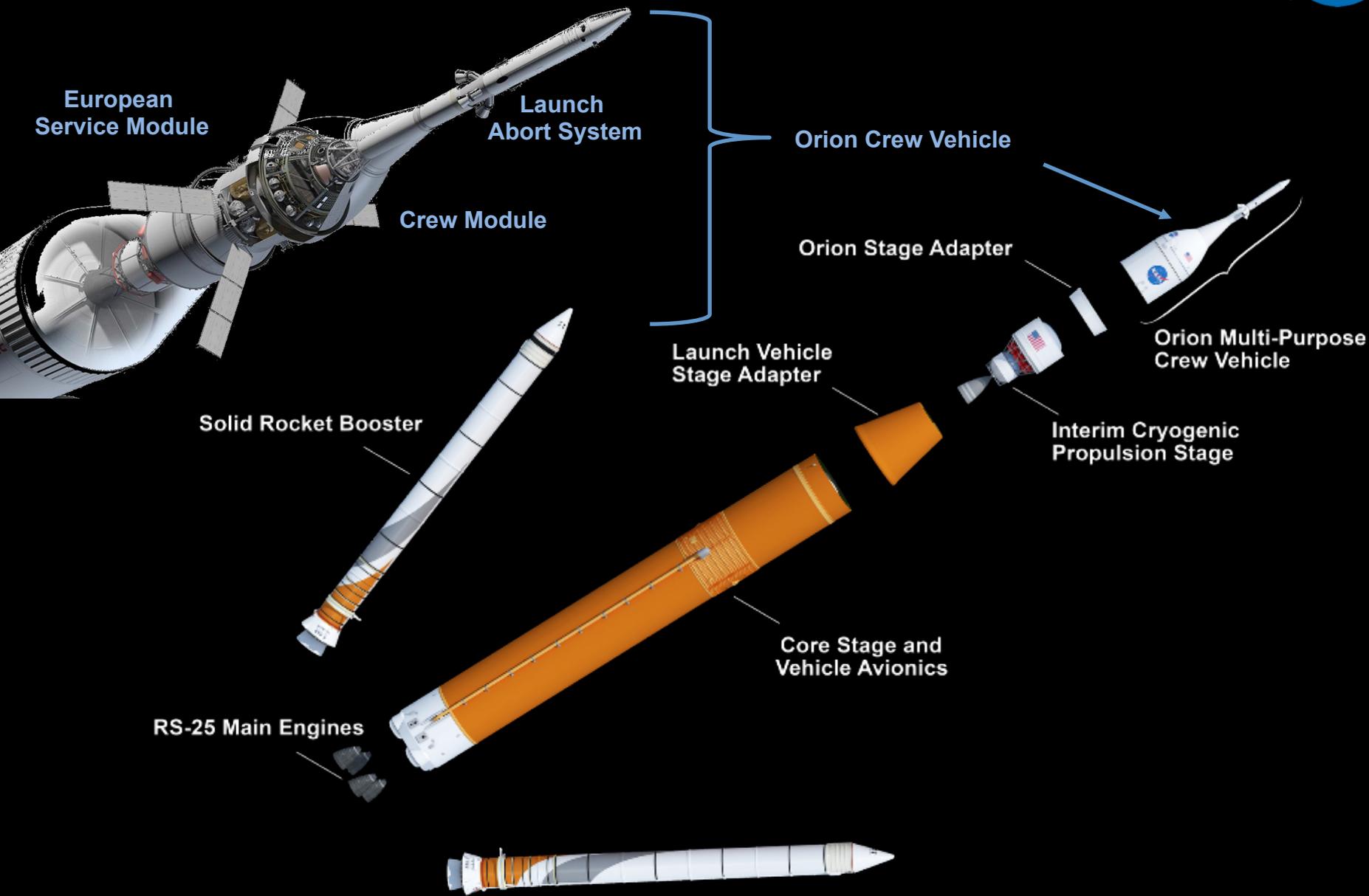
Orion Spacecraft

Space
Launch
System

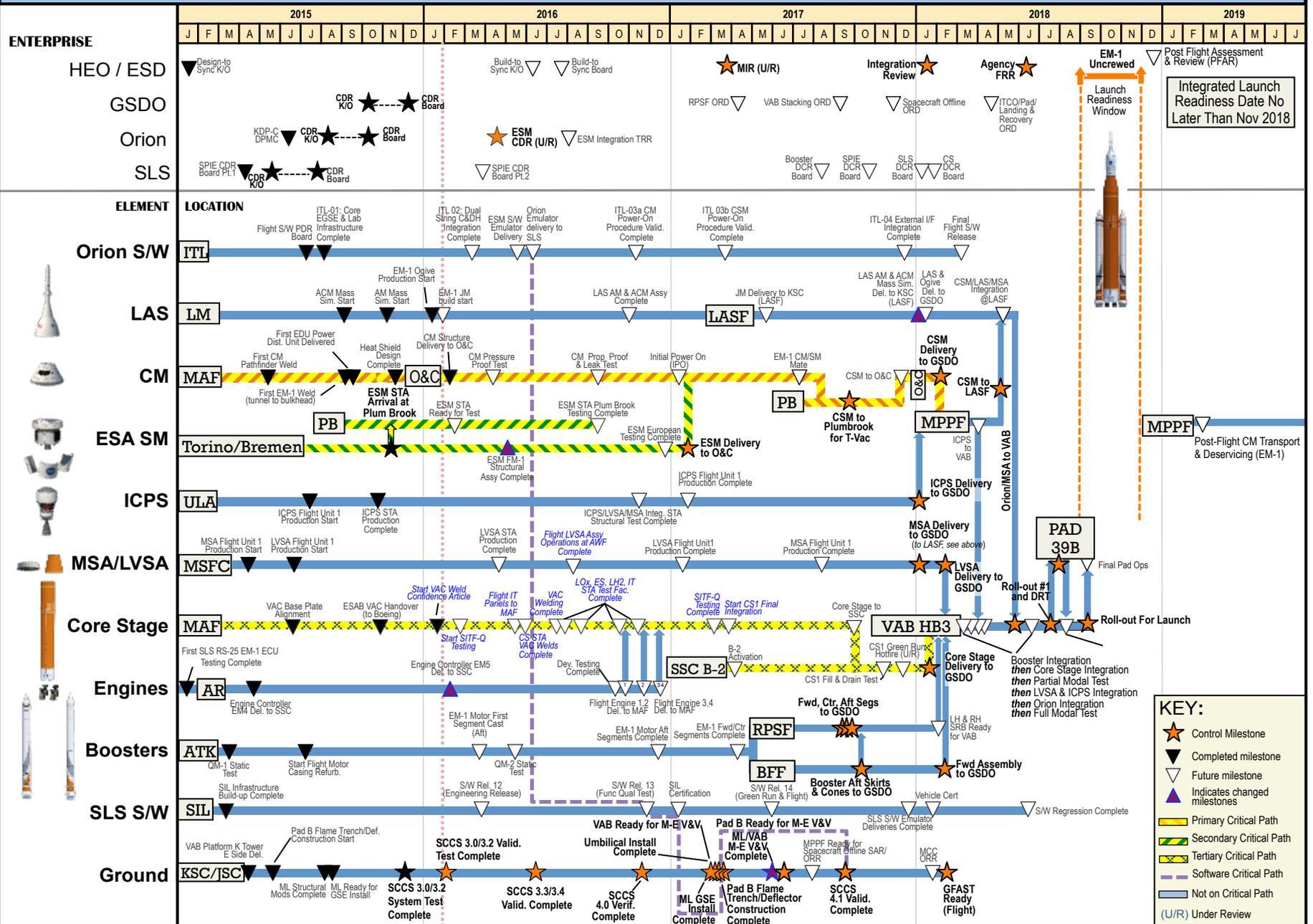


Ground Systems Development & Operations

EM-1 Vehicle Stack



ESD EM-1 INTEGRATED OPERATIONS MISSION MILESTONE SUMMARY





ESD HQ Milestones

Sept 2015-Feb 2016

Date	Program	Program Milestone	Comment
Sep-15	Orion	ACM Mass Sim Start	Complete
	Orion	First EDU Power Dist. Unit Delivered	Complete
	Orion	First EM-1 Weld (Tunnel to Bulkhead)	Complete
Oct-15	SLS	ESAB handover VAC (to Boeing)	Complete
	GSDO	GSDO CDR Kickoff	Complete
	SLS	ICPS STA Production Complete	Complete
	Orion	Orion CDR Board	Complete
Nov-15	Orion	AM Mass Sim Start	Complete
	Orion	ESM STA Arrival @ Plum Brook	Complete
	Orion	Heat Shield Design Complete	Complete
Dec-15	GSDO	GSDO CDR Board	Complete
	Orion	CM Primary Structure Close-Out Weld Start	Complete
Jan-16	Orion	EM-1 Ogive Production Start	Complete
	SLS	Start VAC Weld Confidence Article	Complete. Learning curve with tooling resulted in slower than planned weld ops. Assessing downstream schedule.
Feb-16	Orion	ESM STA Ready for Test	On Track – Test Readiness Review (TRR) scheduled on 2/25/16. Team is working through ESM travelled work combined with Plum Brook Mechanical Vibration Facility (MVF) issues
	SLS	Engine Controller EM-5 Delivery to SSC	Complete
	GSDO	SCCS 3.0/3.2 valid. Complete (Haz Ops C&C S/W)	On Track
	Orion	EM-1 JM Build Start	On Track
	SLS	Start SITF-Q Testing	Under Review. Possible slip to March 2016 due to emulator availability
	Orion	CM Structure Delivery to O&C	Complete. Delivered on 2/1/16 (was January 2016)



ESD HQ Milestones

Mar 2016-Aug 2016

Date	Program	Program Milestone	Comment
Mar-16	SLS	EM-1 Motor First Segment Cast (Aft)	On Track
	Orion	ITL-02: Dual String C&DH Integration Complete	On Track
	SLS	S/W Rel. 12 (Green Run)	On Track
	SLS	SPIE CDR Board Part 2	On Track
Apr-16	Orion	CM Pressure Proof Test	On Track
	Orion	ESM CDR	Under Review – ESA recommending delay to June. Forward plan is under assessment.
	Orion	ESM FM-1 Structural Assembly Complete	Under Review - ESA working to complete structure in Torino in April and holding delivery date to Brehmen. Some traveled work to Brehmen may result. Holding downstream milestones including ESM on dock at KSC in Jan 2017 while working mitigations.
	Orion	CMA Composite Aft Wall Delivery	On Track
	Orion	CMA Inner Wall Delivery	On Track
	SLS	LVSA STA Production Complete	On Track
May-16	SLS	Flight Intertank Panels to MAF	On Track
	Orion	ESM S/W Emulator Delivery	On Track
Jun-16	ESD	Build to Sync Kickoff	On Track. Due to ESA SM CDR slip, team assessing common resource impacts, bottlenecks and mitigations.
	SLS	QM-2 Static Test	Moved to June (from May) to accommodate additional test data collection and instrumentation.
	GSDO	SSCS 3.3/3.4 Valid. Complete	On Track
	SLS	Core Stage STA VAC Welds Complete	On Track
	Orion	Orion Emulator delivery to SLS	On Track
Jul-16	SLS	VAC Welding Complete	On Track
	ESD	Build to Sync Exit Board	On Track
Aug-16	Orion	OMS-E Flight Engine Delivery	On Track. Some schedule threat due to Teflon seal part availability, shelf conditions of OMS engine parts.
	SLS	Flight LVSA Assembly Operations at AWF Complete	On Track
	SLS	Facilities Ready for Engine Section (ES) STA Tests	On Track
	SLS	CoF Facilities Complete for LOX Structural Test	On Track



Exploration Systems Development Top Concerns

Concern	Current Status
Integrated avionics and software verification and validation (V&V), Integrated Test Lab (ITL) capacity, distributed V&V process, emulator performance, agile software development process productively metrics and cross-program interdependencies.	In-work: Limited deferred content and re-planning has occurred and is a watch item, Integrated Avionics Software-Integrated Technical Team (IAS ITT) metrics established. ITL use improving.
Integrated test and verification (T&V) plan involving distributed multi-site activities such as structural dynamics testing, environmental test, and functional check out leading to integrated flight certification traceable to requirements closure and Certification of Flight Readiness (COFR) with sufficient resources and test.	In-work: CDRs data informing T&V, Enterprise V&V Team (EVVT) focus planning in work, T&V resources a watch item, T&V activities are currently in progress.
Funding uncertainty impacts to program/cross-program technical integration.	Improving: favorable FY 2016 appropriations received. Funding uncertainty for out years remains a watch item.
Schedule threats related to integrated critical path: Orion Command Module (CM) and European Space Agency (ESA) service module, core stage delivery for green run, readiness of ground software to support final system integration.	Watch item: ESA SM CDR and FM-1 delivery to Bremen under review. GSDO GFAS re-plan, and SLS post VAC ATP are watch items.
GSDO mobile launch outfitting and V&V including ground system control software/Ground Flight Application Software (GFAS) and dependencies on cross-program flight/ground hardware interfaces and software. Ground processing first flight learning curve.	In-work: GFAS re-plan complete but post re-plan status is a watch item, final dependency agreements are still in work. Platforms and Mobile Launcher are making progress.
Orion ESA Service Module (ESM) prop system redundancy and associated impacts on schedule/CDR completion. CM/ESM structural analysis and environmental T&V planning and resource availability for parallel Operations and Checkout (O&C) and GRC work, flight computer processor throughput, preparations for CM outfitting at O&C.	Orion T&V plan to be completed by March, ESA CDR delay and FM delivery to Bremen under review, ESM prop redundancy issues resolved by NLT design implementation, T&V resources a watch item.
SLS implementation of post VAC ATP welding and assembly operations at MAF through green run test. SLS ascent acoustic loads analysis. Interim Cryogenic Propulsion Stage (ICPS) safety analysis to support EM-1. EUS design development for EM-2.	Improving: VAC weld schedules complete, weld confidence articles in work. EUS is baseline for EM-2. Green run test schedule under review.
Long term productions and operations sustainability at the rate of 1 flight per year after EM-2 by reducing cost. Mission planning for EM-2 and beyond including on-ramp for low-cost opportunities for development tech objectives and capability enhancements. EM-2 co-manifested payload options being evaluated.	P&O Study as part of PPBE to further identify cost reduction opportunities, numerous program efforts also in work. Dedicated mission planning team established. Mission planning resources - watch item.
On-orbit Micro Meteoroid and Orbital Debris (MMOD) exposure risk and related mission planning including EM-2 first crewed flight trajectory options.	In-work: MMOD environment, vehicle susceptibility, and EM-2 mission profile being evaluated.

SLS Program Status



Space Launch System Accomplishments



Launch Vehicle Stage Adapter
Test Article Fabrication



Nozzle installation into the aft
booster segment for QM-2



RS-25 flight engine 2059 installed for
testing at Stennis Space Center



Steel towers rising for new SLS test
stands at Marshall Space Flight Center



SLS Core Stage test article progress,
Michoud Assembly Facility



Interim Cryogenic Propulsion Stage test
article complete



SLS Recent Performance

Program

- ✓ SLS CDR briefings complete – October 2015
- SLS Design Certification Review (DCR) – January 2018

Interim Cryogenic Propulsion Stage (ICPS) & Adaptors

- ✓ ICPS structural test article (STA) production complete – October 27
- ✓ Completed forward cone to forward ring weld of Launch Vehicle Stage Adaptor (LVSA) Structural Test Article (STA) – December 2015
- ✓ Began EM-1 ICPS LOX Tank Build-up – December 2015
- ✓ Completed LVSA STA aft cone welding – January 2016
- ✓ Completed STA Final Test Design Review – January 2016
- ✓ Completed LVSA C2 Confidence Weld – February 2016
- SPIE CDR 2 Board planned for March 2016 (Kickoff held February 2016)



LVSA Structural Test Article Forward & Aft Cones



ICPS STA Acceptance @ ULA

Stages

- ✓ Engine Section Weld Confidence Article (WCA) Vertical Assembly Center (VAC) Weld Complete – December 28
- ✓ CS Pathfinder Awarded to Radiance Technologies – January 19
- ✓ LH2 Tank WCA VAC Welds Complete – January 22
- ✓ Started LOX Tank WCA VAC Welds – February 2016
- Engine Section Structural Qualification Article Weld on VAC – March 2016



Liquid hydrogen tank weld confidence article completed



SLS Recent Performance (cont.)

Booster

- ✓ Qualification Motor 2 (QM-2) nozzle assembled and installed
- ✓ Production Simulation Hardware for Booster Processing (Pathfinder) Delivered to GSDO
 - ✓ Pathfinder aft skirt delivered to GSDO Jan 20th
 - ✓ One inert aft and center segment delivered via rail to KSC on Feb 2nd
- ✓ EM-1 Left & Right Hand Booster Production progressing
 - ✓ EM-1A (left) forward segment cylinders complete refurbishment; ready to begin insulation
 - ✓ EM-1B (right) center forward segment completed insulation X-ray with no indications
- ✓ Started EM-1 Aft Skirt refurbishment – Feb 2016
- QM-2 Test Firing - June 2016



Pathfinder segments delivered to KSC



Installation of Forward Exit Cone into Nozzle Assembly

Engines

- ✓ RS-25 production restart contract signed – Nov 19, 2016
- ✓ RS-25 Engine 2059 installed into SSC Test Stand A-1 for testing – Nov 2016
- ✓ Flight Engine Control Unit (ECU) Production began – Jan 2016
- ✓ Completed Engineering Model 5 Controller ship to SSC – Feb 2016
- ✓ Completed ECU Software Build 3 Hardware-in-the-Loop verification & validation – Feb 2016
- Start of next round of RS-25 Tests – Mar 2016



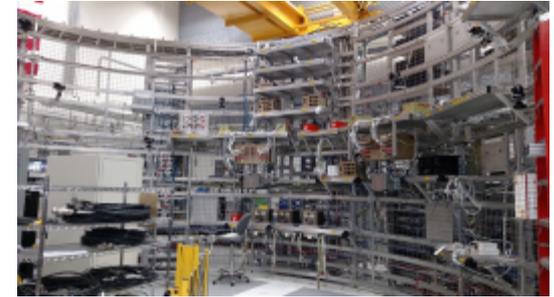
RS-25 Engine 2059 installed in SSC A-1



SLS Recent Performance (cont.)

Avionics / Software

- ✓ Complete development testing of Core Stage Avionics in Software Integration Test Facility – Development (SITF-D) – Dec 2015
- ✓ Stages Redundant Inertial Navigation Unit (RINU) Development Test data delivered to support validation & verification – Jan 14, 2016
- ✓ Began formal testing on Flight Software Release 12 – Jan 22, 2016
- On track to begin qualification testing of Core Stage Avionics in Software Integration Test Facility – Qualification (SITF-Q) – Mar 2016



SITF-Q Facility Testing

Facilities

- ✓ Official Start of SSC B2 Activation – Jan 2016
- ✓ 6 of 7 tiers of LH2 Test Stand (4693) erected – Jan 2016
 - Preparation in work to begin Crosshead & Final Tier installation - April 2016
- ✓ Complete erection of LOX Test Stand (4697) all three tiers– Feb 2016



Test Stand B-2 at Stennis Space Center



Test Stand 4693 (LH2) at Marshall Space Flight Center

GSDO Program Status



Ground Systems Development & Operations Accomplishments



First Work Platform for Space Launch System Installed in VAB



Conducted the Critical Design Review



Completed Phase A Testing of the Orion Service Module Umbilical



Started Construction of Flame Trench at Launch Pad B



Completed Command and Control Software Release 3.2



Received First Shipment of Booster Pathfinder Hardware for V&V Testing at RPSF



GSDO Recent Performance

Vehicle Assembly Building

- Platform K-South installation lifting proved problematic during the final pin insertions into the corbel rails platform due to alignment and rotation issues
- A spreader beam tool (currently being fabricated) will be used to keep the corbels aligned during lifting and installation operations
- Platform installation completion by March 2017 will be a challenge and GSDO is working to minimize the impact

Mobile Launcher

- Potential impact to ground support equipment (GSE) install schedule due to additional scope required for Installation Construction Contract – delays attributed to greater than expected magnitude of changes as well as GSE sub-system ICD changes
- Issues and concerns for using scaffolding to access aft end of integrated launch vehicle are emerging and being studied

LETF Umbilical Testing

- ✓ Orion Service Module Umbilical (OSMU) Phase A Testing complete (simulated plates, winch testing)
- ✓ OSMU Phase B preparations are in-work
- ✓ ICPS umbilical test set-ups are in-work – serial schedule with OSMU



Installing VAB Platform K above HP3



Umbilical Testing



GSDO Recent Performance (cont.)

Multi-Purpose Processing Facility (MPPF) Development

- ✓ Ground Support Equipment (GSE) Installation 90% complete – all GSE installed by July 2016
- MPPF verification and validation (V&V) planning and Site Activation efforts are well underway
 - GSE Subsystem (V&V) test design/review activities are in progress
 - Integrated Site Activation Team was kicked-off on January 25 to ensure daily integration of activities leading up to and throughout the V&V phase
 - V&V Phase is scheduled to start in July 2016



Steering Arm Refurbishment

Crawler Transporter

Recently completed:

- ✓ Gearbox Assemblies refurbishment are substantially complete

On-going work:

- Steering Arm refurbishment - 7 of 8 complete and re-installed
- Jacking, Equalizing, Leveling (JEL) cylinder upgrade replacements. All new cylinders have been installed – final hook-ups are in-work. Two spares are on-hand and placed into stores

Future:

- Initial standalone V&V starts in April



MPPF Highbay



JEL Cylinder replacement



GSDO Recent Performance (cont.)

Pad B Development Status

Recently completed projects:

- ✓ New liquid oxygen (LO2) vaporizer system (supports LO2 sphere) is complete
- ✓ Heating, ventilation, and air conditioning (HVAC) upgrades are substantially complete

On-going Projects:

- Environmental control system (ECS) Refurbishment project is ~50% complete
- Water supply refurbishment/upgrade projects are ~90% complete
- Bypass piping/valves project is ~40% complete
- Flame trench/flame deflector project is ~9% complete

Future projects:

- New liquid hydrogen (LH2) separator system and the catacomb roof reinforcement projects are currently in the procurement process
- New LH2 sphere for EM-2 – design requirements and statement of work for A&E contract are in-work – target award for design in Spring





GSDO Recent Performance (cont.)

Spaceport Command and Control System (SCCS)

Current Releases:

- ✓ SCCS 3.2 Validation testing completing; no significant problems noted
- ✓ SCCS 3.3 development completed successfully on schedule January 15

Future Releases:

- SCCS 3.4 will have all required content to support hazardous operations verification and validation testing -- complete by 3/11/16
- SCCS 4.0 Schedule challenges
 - SCCS 4.0 will have required content for ground operations support
 - SCCS 4.0 start date threatened due to delayed transition of SCCS 3.2 and SCCS 3.3 developers to SCCS 4.0 content
 - Overall schedule is challenged by contractor hiring difficulties for software developers in a highly competitive environment

Ground and Flight Application Software Teams (GFAST)

- Successfully incorporated the updated GFAST schedule into the integrated master schedule to support GSDO critical path analysis
- Collaboration between GFAST and other Programs has improved significantly
 - GFAS team members working closely with SLS/Orion flight system counterparts to determine specifics of ground-to-flight interfaces and cross program dependencies
 - GSDO/GFAST tracking ground-to-flight software dependencies with respect to planned GFAS software drop requirements



Firing Room 1 software testing activities

Orion Program Status



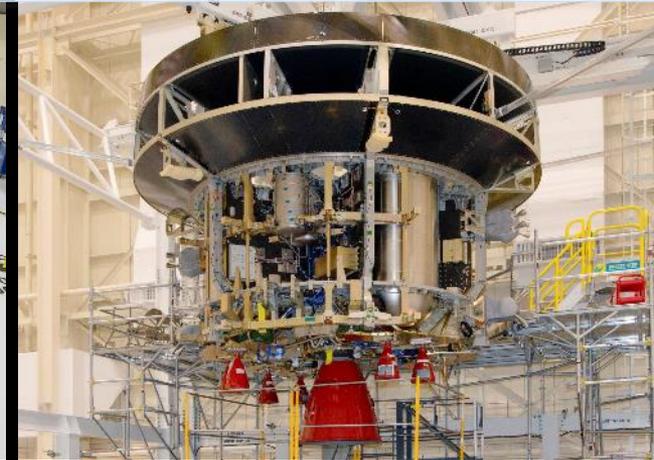
Orion Accomplishments



Orion EM-1 crew module pressure vessel welding is completed at Michoud Assembly Facility in New Orleans



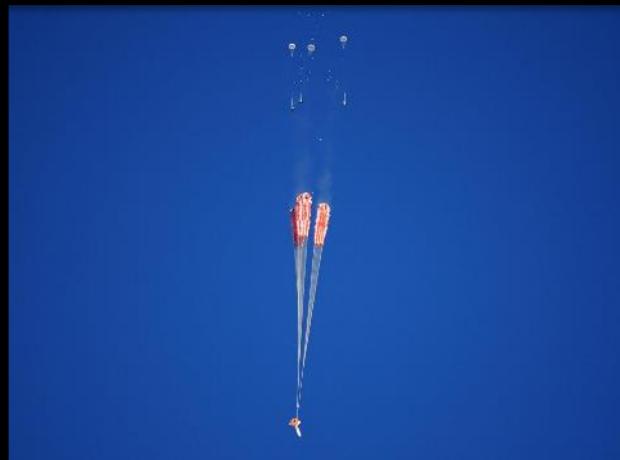
The completed pressure vessel arrives at the Operations and Checkout Building at the Kennedy Space Center



European Service Module Structural Test Article (ESM STA) at Glenn Research Center Plum Brook Station in Ohio



Launch Abort Motor structural qualification test at Orbital ATK in Utah



Final Engineering Parachute Drop Test, Army Yuma Proving Ground in Arizona



Orbital Maneuvering Engine on the ESM STA at Glenn Research Center Plum Brook Station in Ohio



Orion Recent Performance

Program

- ✓ Orion CDR board held October 2015
- ✓ Orion DPMC December 2015
- Orion Orion APMC March 2016
- ESM CDR April 2016
- Post CDR Program Sync May 2016

Crew Module (CM)

- ✓ Finished welding EM-1 pressure vessel that is the CM primary structure
- ✓ Shipped pressure vessel to KSC to begin spacecraft assembly February 2016
- Proof pressure test in April 2016
- Initial power-on by January 2017

Launch Abort System (LAS)

- EM-1 Jettison Motor build starts February 2016
- Attitude Control Motor hot fire test (HT-11) October 2016

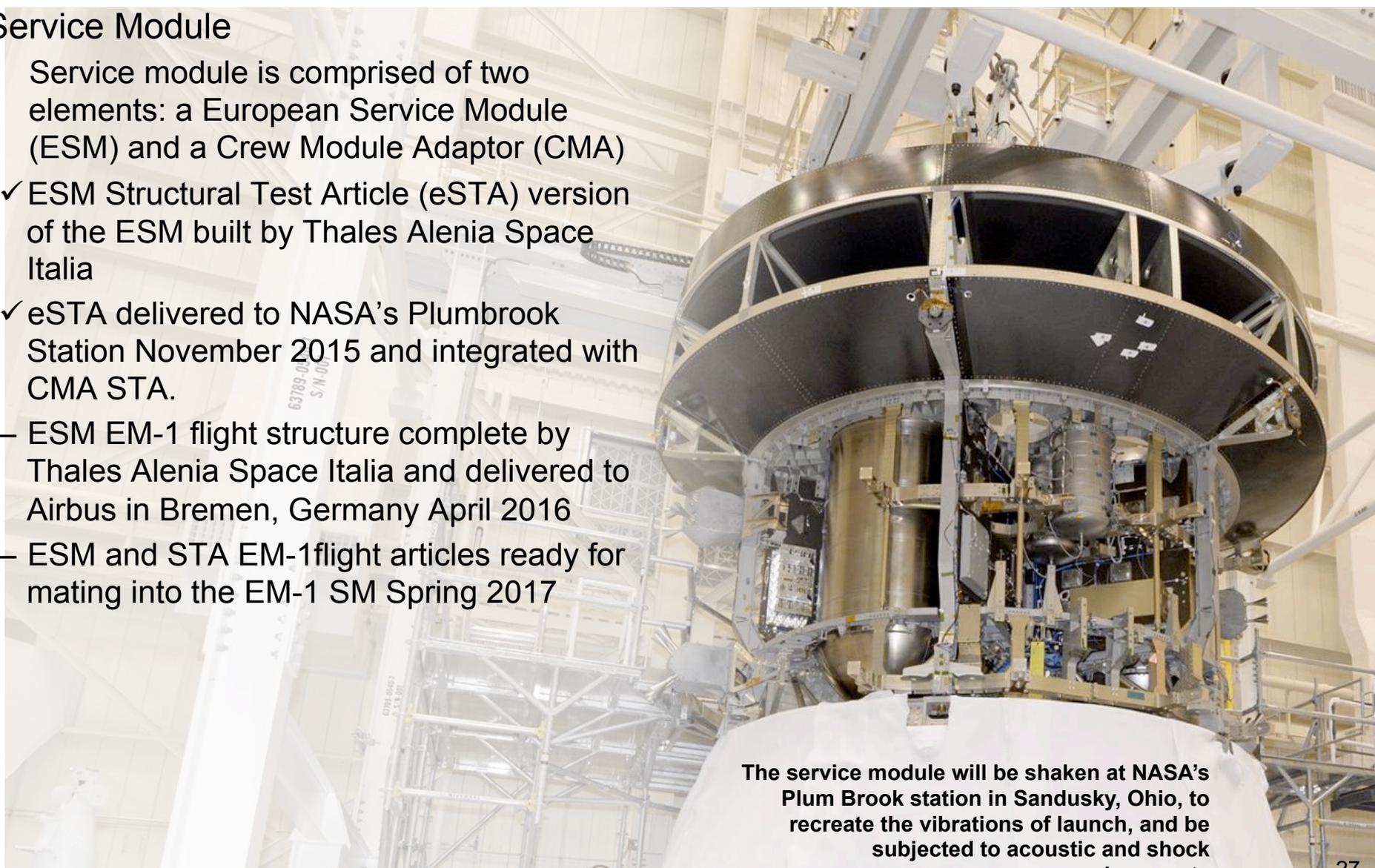
Orion's Exploration Mission-1 crew module pressure vessel arrives at NASA's Kennedy Space Center Operations and Checkout building.



Orion Recent Performance (cont.)

Service Module

- Service module is comprised of two elements: a European Service Module (ESM) and a Crew Module Adaptor (CMA)
- ✓ ESM Structural Test Article (eSTA) version of the ESM built by Thales Alenia Space Italia
- ✓ eSTA delivered to NASA's Plum Brook Station November 2015 and integrated with CMA STA.
- ESM EM-1 flight structure complete by Thales Alenia Space Italia and delivered to Airbus in Bremen, Germany April 2016
- ESM and STA EM-1 flight articles ready for mating into the EM-1 SM Spring 2017



The service module will be shaken at NASA's Plum Brook station in Sandusky, Ohio, to recreate the vibrations of launch, and be subjected to acoustic and shock environments

Cross-Program System Integration Status





Cross-Program System Integration Status Agenda

- CSI technical performance and accomplishments
- CSI products schedule
- Interdependencies
- Cross-Program Integration Team top technical issues
- EM-2 Planning
- Technical performance metrics
- Independent assessments



CSI Technical Performance and Accomplishments

- **Recent Major Cross-Program Accomplishments (November – February)**
 - Baseline Cross-Program Flight Safety System (FSS) Test Plan (November)
 - Baseline Cross-Program Integrated Launch Operations Implementation Plan (December)
 - Cross Program Integrated Vehicle Model Test Plan (December)
 - Completed GSDO CDR (December 2015)
 - Manifested EM-1 Secondary Payloads at the HEO Flight Planning Board (January)
 - Hydrogen Burn-Off Igniter (HBOI) fix, to angle each RS-25 directed upward 6-deg relative to Baseline Design to ensure excess hydrogen burn-off (January)
 - Baseline the Umbilical Release and Retract Test (URRT) Plan (February)
 - Baseline the VAB Program Specific Engineering Test (PSET) Plan (February)
 - Baseline Cross-Program Integrated Vehicle Loads Control Plan (February)
 - Baseline Cross-Program Integrated Verification Test (IVT) Plan (February)
- **Near-term forward work**
 - Update Cross Program S&MA Plan Rev B (March)
 - Baseline ESD Mishap Preparedness and Contingency Plan (March)
 - Complete SLS SPIE CDR2 (March)
 - Baseline Cross-Program Pad Program Specific Engineering Test (PSET) Plan (March)
 - Baseline Cross-Program Comm System End-to-End (CS ETE) Test Plan (March)
 - Baseline Certification of Flight Readiness (CoFR) Plan (March/April)
 - Baseline Cross-Program Countdown Sequencing Test (CST) Plan (April)
 - Complete Orion ESM CDR (April/May)
 - Baseline Cross-Program Dynamic Rollout Test (DRT) Plan (May)
 - Baseline Cross-Program Wet Dress Rehearsal (WDR) Test Plan (May)



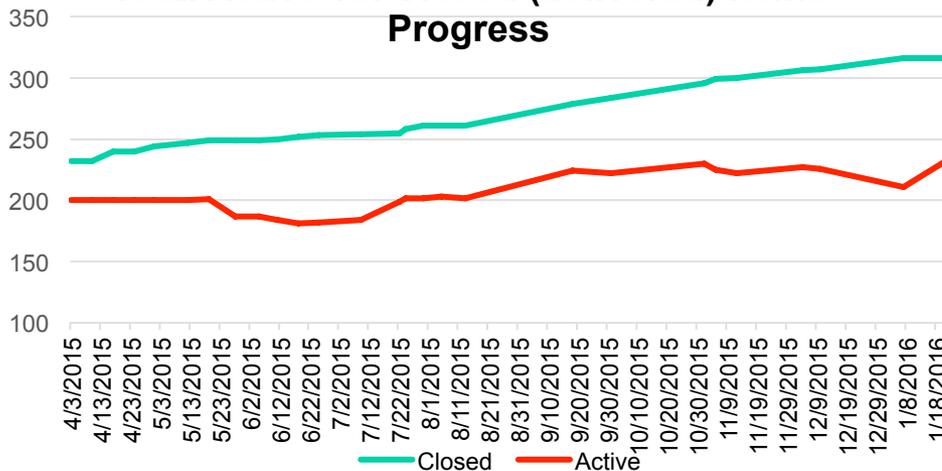
Cross Program Interdependencies – Metrics

77 active Interdependencies; 155 active Cross-Program Control Milestones

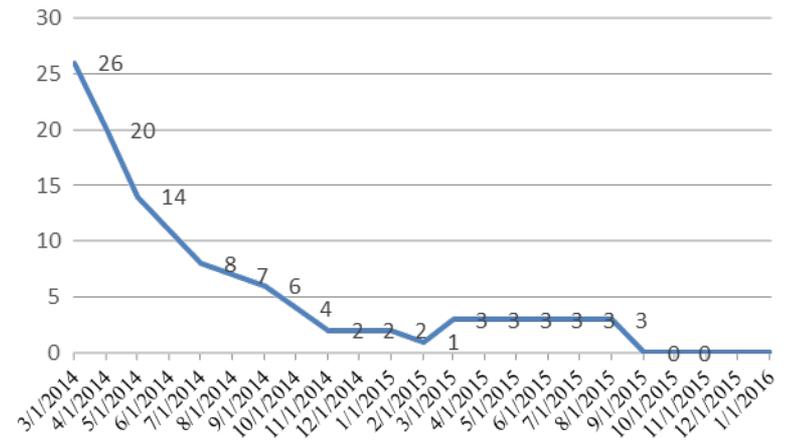
Cross-Program Agreements Progress

Date Reported	Total Items		Total Active				Deferred	Total Closed/Withdrawn					
	Interdependencies	CPMs	Elevated	Candidate	Partnered	Under Review		Baselined	BL (change proposed)	BL Under review	Interdependencies Closed	CPM Closed	Total Withdrawn
1/22/2015	732 (+57)		232 (+20)				8	492 (+37)					
10/15/2015	502	173	0	39	29	7	133	2	2	8	256	36	163
1/22/2015	532	200	0	16	57	4	144	3	8	8	271	45	176

Total Active vs. Closed (delivered) Items Progress



Elevated Interdependencies





CPIT Top Technical Issues

- **Hydrogen Burn Off Igniter (HBOI) / Hydrogen Pop loads on the core stage**
 - Concern over GH2 build up prior to RS-25 ignition
 - HBOIs will be canted 6 degrees upward to counter downdraft effect. Crosswinds did not require any changed in HBOI position
 - GSDO assessing the impact of vertically staggering the nozzles under the core stage engine to counter the effect of water (rooster tail) on HBOI particles (while maintaining 6 degree upward cant).
- **Integrated Test Lab (ITL) Capacity/throughput**
 - Original ITL oversubscription reduced from >1000 shifts to approximately 34 shifts over
 - Managing residual threats of ground and flight software testing tracked as TPR 12543



Emerging Cross Program Issues/ Concerns

- **Orion-GSDO ICDs, Volume 1 (Hardware)**
 - 30 TBX's remaining to be burned down by March; 81% of TBXs have been successfully closed
 - Continue to work with ESM to gain concurrence of ICD updates as part of the ESM CDR
- **ESM procured design incorporates single fault tolerant bellows propulsion design**
 - GSDO set up a team to assess impact and any potential hazard mitigations (continuous leak monitoring and contingency depress and de-service at all KSC facilities), Feb, 2016
 - GSDO recommended addition of isolation valve upstream of bellows; Orion investigated but was found to not be practical to implement for EM-1
 - Orion proceeding with 0 Fault Tolerance bellows for EM-1; Reviewed by JPCB for approval, Feb, 2016



Emerging Cross Program Issues/ Concerns

- **Orion Avionics Command Parameter Definition Disconnect**
 - Orion command parameters do not meet C3I Volume 4 approved specifications
 - Potential impact to GSDO critical path for Operational Readiness
- **Orion Flight SW emulator Updates (SOCCRATES)**
 - SOCCRATES needs to be upgraded to Class C, Safety Critical for formal GFAST software verification testing
 - GSDO has requested several functionality updates
 - LM/Orion is reviewing changes for contractual considerations
- **SLS Flight SW Release 14 delivery date delay**
 - SLS estimates work required for FSW Release 14 and associated emulator updates and additional content will impact schedule 8 weeks
 - SLS will discuss impact to the JICB accordingly
- **GSDO Ground Operations Software (GFAST)**
 - GFAST development is highly dependent on agreements for products (CUI, OMRS, LCC, XTCE) to be delivered on time by other programs.
 - OMRS and LCC development supports GFAS personnel have access for early review of developing OMRS from Orion and SLS.



Emerging Cross Program Issues/ Concerns

- **OSMU Involvement with URRT**
 - Performing the mechanical release and retract with the OSMU could damage the ground and/or flight plate and cause a significant risk to continued processing and launch
 - Trade study results, including S&MA risk assessment, planned for JICB / JPCB in May timeframe
- **Production Umbilical Plate Collet Delivery**
 - Redesign in mid-2015 was performed to minimize the amount of movement of the plungers and prevent premature release of the mechanism.
 - Flight hardware deliveries sliding into July/August timeframe due to design issues seen during development testing.
 - Collet would not release properly during Boeing testing.
 - Progress status reviewed on January 28th



EM-2 Mission Planning

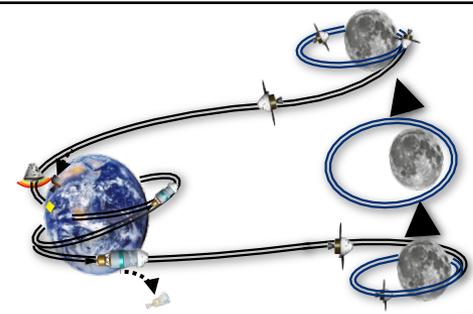
- **With the selection of the EM-1 Mission being a DRO mission the goal of EM-2 is:**
 - Complete residual FTO's not accomplished on EM-1
 - Accomplish risk reduction activities for future more complex missions for EM-3+
- **Missions should include capabilities relevant to potential near term deep-space missions**
 - DRMs in the ESD ConOps are intended to be design driving cases not the mission selected
 - Goal is to maintain current SLS/Orion FTO's while demonstrating as many Exploration Objectives on EM-1 and EM-2 as cost, schedule and risk allows
- **Need to resolve the crew risk issues for first flight and select a mission that meets FTOs with acceptable risk posture**
 - Radiation
 - MMOD
 - ECLSS
 - Abort capability
 - Etc.



EM-2 Mission Options

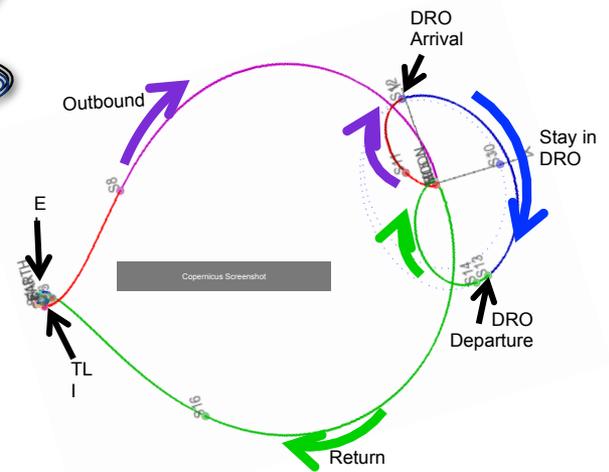
- **EM-2 Baseline DRM**

- High Lunar Orbit (HLO)



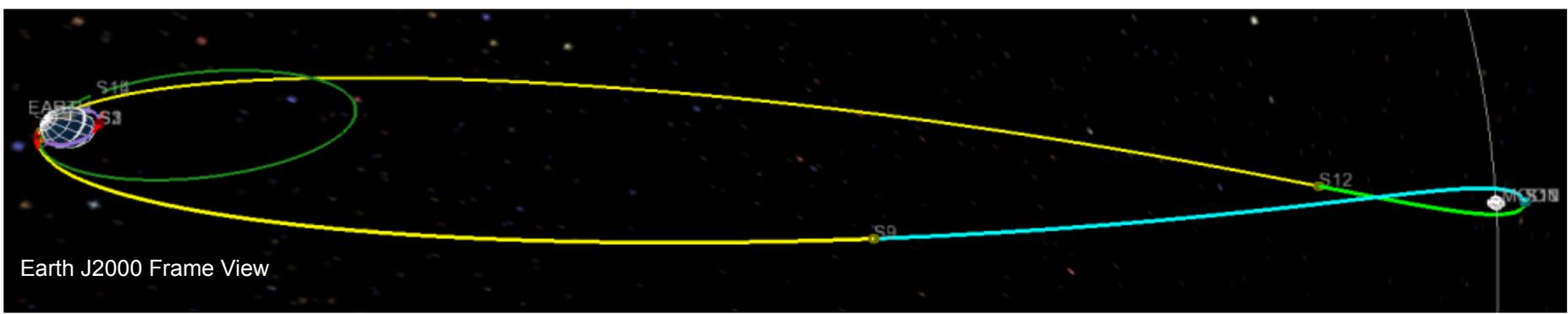
- **EM-2 Option 1 DRO/NRO**

- Executes the DRO mission (EM-1 repeated)



- **EM-2 Option 2 Hybrid**

- Hybrid mission to complete the remaining FTO's
- Options to check-out ARCM capabilities will be developed separately

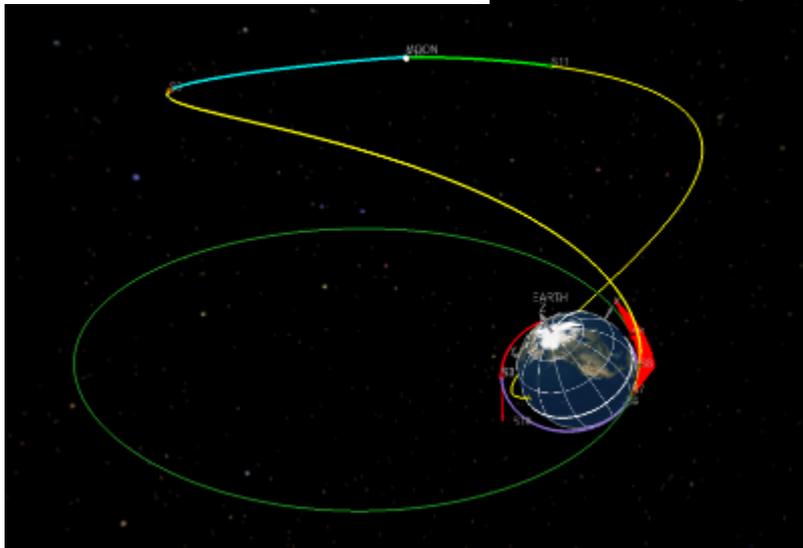
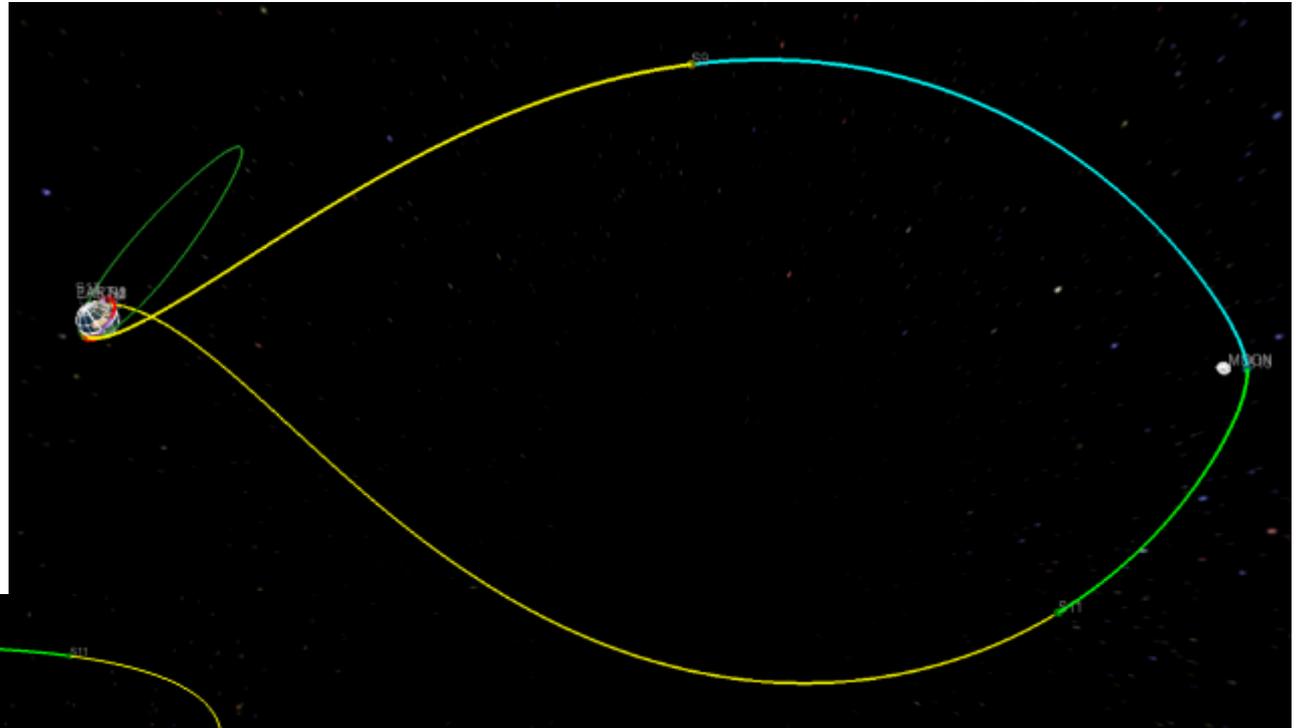


Earth J2000 Frame View



EM-2 Mission - HEO/Lunar Flyby

1 Orbit in HEO
(~30 hour period)
1 Orbit Around
Moon (~10.8
days)



2 Views (Earth-Moon Rotating, Pulsating
Frame)



EM-2 Mission Planning Summary

- **EM-2 mission is not finalized**
 - Programs are using the HLO as a “baseline” to develop capability
- **A detailed risk reduction activity to understand risk posture and impact on ground and flight test plans is underway**
 - Mission Analysis and Integrated Architecture (MAIA) team contains representatives from ESD, SLS, Orion and GSDO as well as OS&MA, OCE, HMTA and the Crew Office
 - Final mission selected will involve ESD and HEOMD
- **EM-2 mission baselined will factor in**
 - Mission requirements will be governed by ESD and HEOMD Flight Test Objectives and risk posture for crew and mission
 - Current mission planning would allow the test and demonstration of the capabilities desired by Agency



Major ESD/CSI Independent Assessments In Progress

- End-to-End trajectory optimization ongoing and performing trade studies in launch period and launch window
- Combined Modeling & Simulation of System Behavior at SLS/MPCV/GSDO Interfaces
- NESC Modeling of Crawler/Transporter (CT), Mobile Launcher (ML), and Forcing Functions
- Peer Review of SLS and Orion Programs Modal Test, Development Flight Instrumentation, and Dynamic Model Correlation Plans – ESD impacts in work
- Evaluation of ORDEM 3.0 with Available On-Orbit Assets
- Enterprise Verification and Validation Assessment – newly started by NESC
- Review of the Orion-ESM Interfaces
- Independent Verification of Abort Loads (NESC work deferred until FY17 due to cost)
- ESD Data Solution Architecture (ARC/NESC)*
- Cross-functional Closure Processes (ARC)*



Backup



Acronyms

- HBOI- Hydrogen Burn Off Igniter
- ITL- Integrated Test Lab
- ESM- European Service Module
- GCS- Guidance Control System
- GFAST- Ground Flight Application Software Team
- CUI- Controlled Unclassified Info
- LCC- Launch Commit Criteria
- XTCE- Telemetry & Command Exchange
- OMRS- Operational Maintenance Requirements and Specifications
- SCCS- Spaceport Conditioning and Control System
- EGSE- Electrical Ground Support Equipment
- C3I- Command Control Communication
- FSW- Flight Software
- OSMU- Orion Service Module Umbilical
- VSS- Variable Stiffness Span
- ICPSU- Interim Cryogenic Propulsion Stage
- EUS- Exploration Upper Stage
- ICD- Interface Control Document
- IRN- Interface Revision Notice
- HIS- Human Systems Integration
- HF- Human Factors
- ACO- Architectures & ConOps
- FEM- Finite Element Models
- VAC- Verification Analysis Cycle
- FRC- Flight Readiness Cycle
- URRT – Umbilical Release and Retract Test
- CAIDA – Customer Avionics Interface Development and Analysis -- KSC Ground System Simulation Lab
- SOCCRATES – Orion Flight Software Simulator