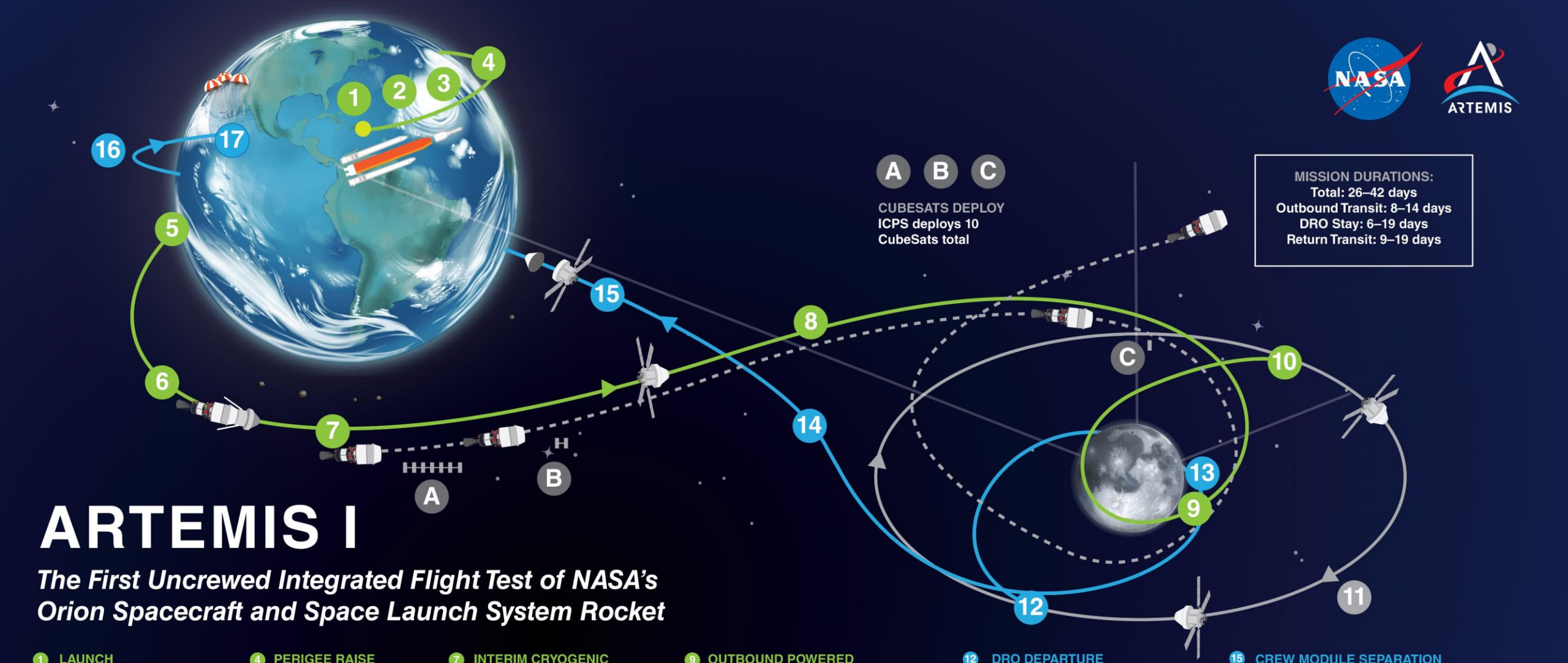
January 2022

NASA's NASA Advisory Committee January 2022 Meeting

Exploration Systems Development (ESD) Update

Tom Whitmeyer, Deputy Associate Administrator, ESD

Amit Kshatriya, Assistant Deputy Associate Administrator, ESD



ARTEMIS I

The First Uncrewed Integrated Flight Test of NASA's Orion Spacecraft and Space Launch System Rocket

1. **LAUNCH**
   SLS and Orion lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **EARTH ORBIT**
   Systems check with solar panel adjustments.
6. **TRANS LUNAR INJECTION (TLI) BURN**
   Maneuver lasts for approximately 20 minutes.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) SEPARATION AND DISPOSAL**
   ICPS commits Orion to moon at TLI.
8. **OUTBOUND TRAJECTORY CORRECTION (OTC) BURNS**
   As necessary adjust trajectory for lunar flyby to Distant Retrograde Orbit (DRO).
9. **OUTBOUND POWERED FLYBY (OPF)**
   60 nmi from the Moon; targets DRO insertion.
10. **LUNAR ORBIT INSERTION**
    Enter Distant Retrograde Orbit.
11. **DISTANT RETROGRADE ORBIT**
    Perform half or one and a half revolutions in the orbit period 38,000 nmi from the surface of the Moon.
12. **DRO DEPARTURE**
    Leave DRO and start return to Earth.
13. **RETURN POWERED FLYBY (RPF)**
    RPF burn prep and return coast to Earth initiated.
14. **RETURN TRANSIT**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere.
15. **CREW MODULE SEPARATION FROM SERVICE MODULE**
16. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
17. **SPLASHDOWN**
    Pacific Ocean landing within view of the U.S. Navy recovery ship.

10/7/2021

Recent Artemis I Accomplishments

January 2022


Integrated Modal Test Complete


Core Stage Access Established


Stack Orion to SLS


Umbilical Remates


Integrated Vehicle Interface Verification Test


Communications End-to-End Test Complete


CST Run 1 Complete

REV Q
As of 1/5/2022

MAJOR MILESTONES FOR ARTEMIS KSC FLOW

Status – Jan 5 – Will Be Updated As Risk Is Realized

DATE KEY:
Forecast Date/Actual Date


Nov 15, 2019
LAS HANDOVER TO EGS (Planned 11/15/19)


Nov 20, 2020
ML READY FOR BOOSTER STACKING (Planned 11/2/20)


Nov 20, 2020
BOOSTER STACKING ON ML BEGINS (Planned 11/21/20)


Jan 14
ORION CSM HANDOVER TO EGS (Planned 12/4/20)


Mar 30
START OF ORION HYPERS SERVICING (Planned 3/26)


Apr 16
ORION SERVICE MODULE FUELING COMPLETED (Planned 4/17)


Apr 29
CORE STAGE ARRIVES AT VAB FROM SSC (Planned 4/26)


May 17
ORION CREW MODULE FUELING COMPLETE (Planned 5/14)


Jun 4
ICPS FUELING AT MPPF COMPLETED (Planned 6/4)


Jun 6
CS TRANSFER AISLE WORK COMPLETED (Planned 6/4)


Jun 9
START OF CORE STAGE MATE (Planned 6/7)


Jun 15
START INSTALL OF INTERNAL PLATFORMS


Jun 21
START OF LVSA MATE (Planned 6/16)


Jul 5
STACK ICPS (Planned 6/26)

Jul 10
ORION TO LASF (Planned 6/24)


Aug 6
CORE STAGE POWER UP (Planned 7/19)


Aug 10
STACK ORION STAGE ADAPTER STRUCTURAL TEST ARTICLE (Planned 6/25)


Aug 13
STACK MASS SIMULATOR FOR ORION (Planned 7/2)


Aug 13
COMPLETE SLS PREVALVE CLUTCH CHANGEOUT


Aug 17
MODAL TAP TEST (Planned 7/26)


Aug 23
FIRST INTEGRATED POWER UP


Aug 30
UMBILICAL CONNECTS COMPLETE (Planned 7/10)


Sep 19
START OF UMBILICAL RELEASE AND RETRACT TEST (URRT) (Planned 8/11)


Sep 28
INTEGRATED MODAL TEST (IMT) COMPLETED (Planned 8/20)


Oct 1
DESTACK MASS SIMULATOR FOR ORION (Planned 8/24)


Oct 4
ORION STAGE ADAPTER TO VAB HIGH BAY 4


Oct 4
DESTACK ORION STAGE ADAPTER STRUCTURAL TEST ARTICLE (Planned 8/26)


Oct 6
ESTABLISH CORE STAGE ACCESS COMPLETED (Planned 8/28)


Oct 9
STACK OSA (Planned 8/27)


Oct 19
ORION TO VAB HIGH BAY 4 (Planned 8/30)


Oct 22
STACK ORION TO SLS (Planned 9/3)


Nov 28
UMBILICAL REMATES


Dec 7
INTEGRATED VEHICLE INTERFACE VERIFICATION TEST (IVT) PT 1 (Planned 9/9)


Dec 17
COMM END-TO-END (LIVE) COMPLETE (Planned 9/24)


Dec 20
COUNTDOWN SEQUENCE TEST (CST) PT 1 (Planned 9/25)

PROGRAM SPECIFIC ENGINEERING TESTING (PSET) COMPLETE

CORE STAGE FLIGHT BLANKET INSTALL

FLIGHT TERMINATION SYSTEM TEST PART 1

PREPS FOR ROLLOUT

ROLL TO PAD B

START OF WET DRESS REHEARSAL (WDR)

LAUNCH DATE SET AFTER SUCCESSFUL WDR

START OF FINAL CLOSEOUTS FOR LAUNCH & FLIGHT SAFETY SYSTEM

CREW MODULE STOW COMPLETE

FLIGHT TERMINATION SYSTEM 10 DAY REQUIREMENT

ROLL TO PAD B

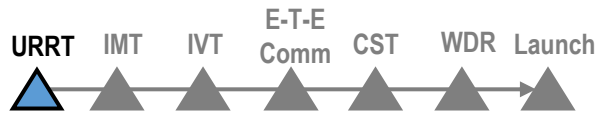
PAD OPS AND LAUNCH COUNTDOWN

ARTEMIS I LAUNCH WINDOW OPENS

RECOVERY OPS COMPLETED

Umbilical Release & Retract Test (URRT): COMPLETED

January 2022

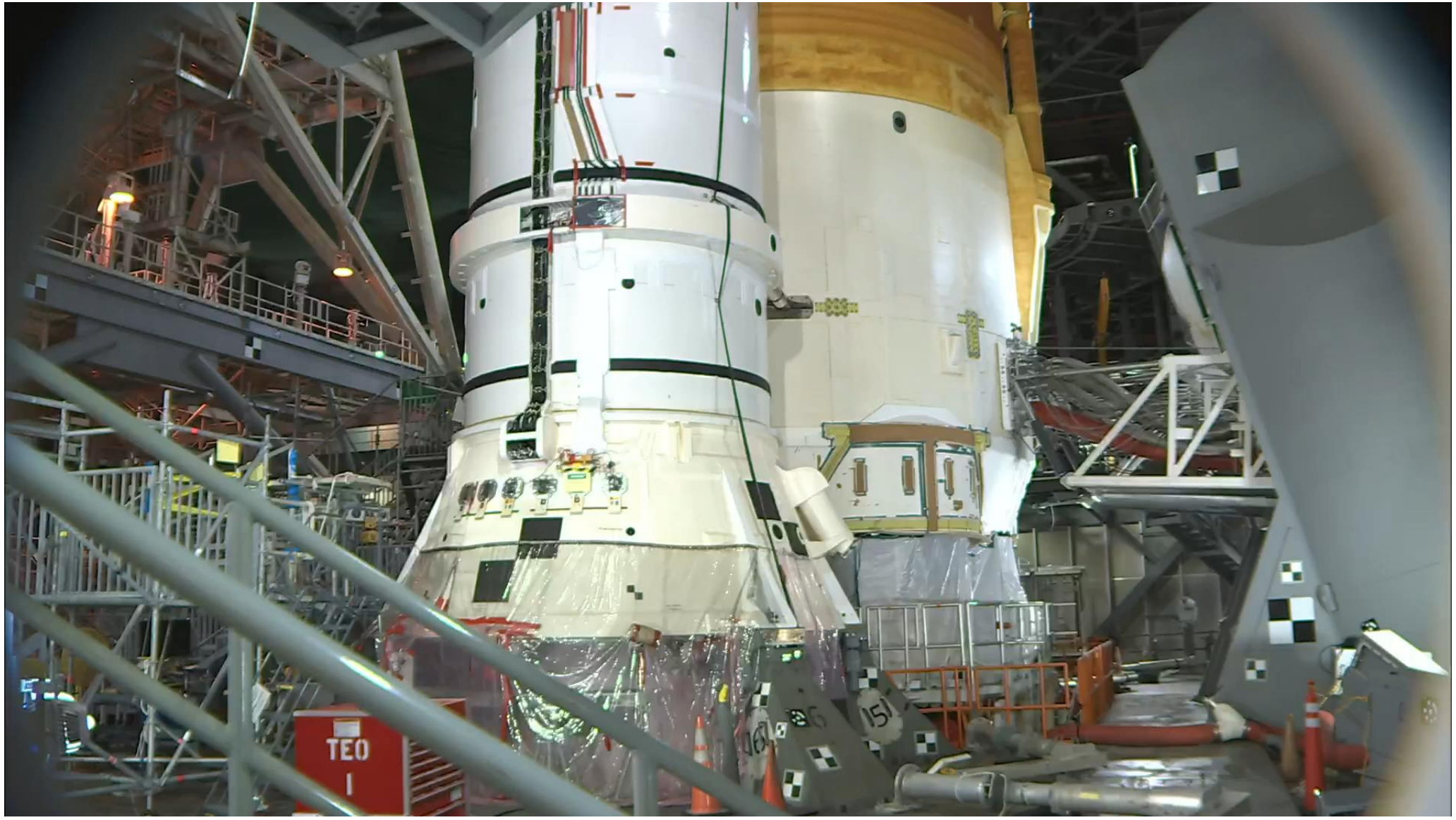


Task Description:

- URRT will demonstrate Crit-1 T-0 nominal umbilical release and arm retraction as an integrated flight/ground system
- Confirm nominal T-0 umbilical performances, release and retract loads
- Confirm End-to-End system timing and lift-off clearance

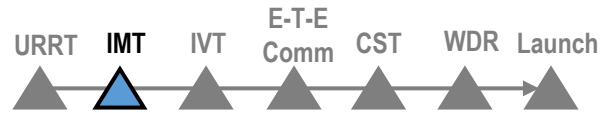
Umbilical Release & Retract Test (URRT): **COMPLETED**

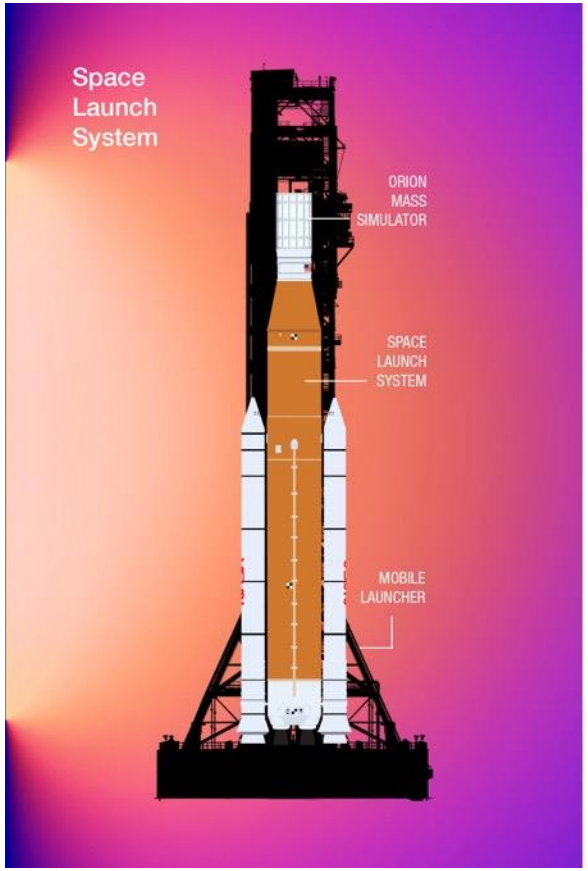
January 2022



Integrated Modal Test (IMT): COMPLETED

January 2022



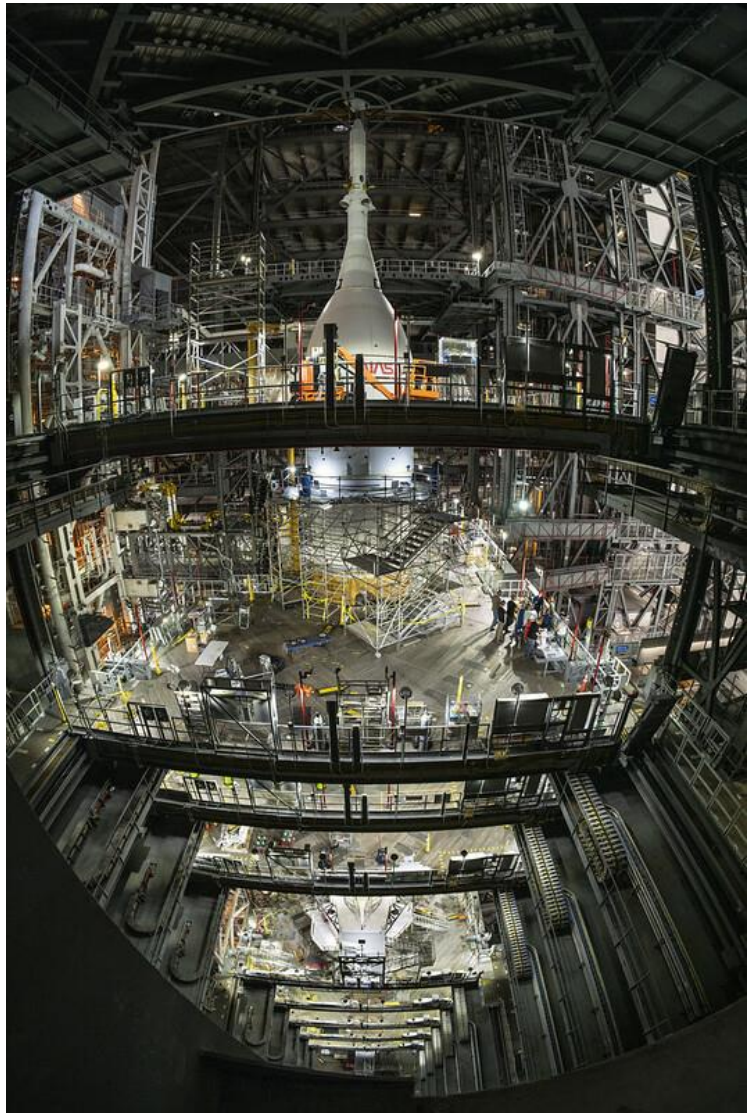


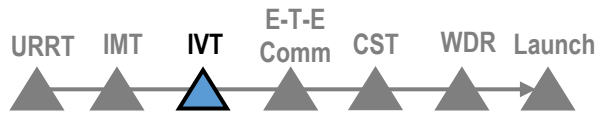
Task Description:

- Final integrated system test of the structural test campaign to support validation of structural dynamic math models and to confirm adequate GN&C and structural margins for Artemis I flight
- Leading to the IMT, ESD used a building block approach, which included significant static and modal testing at the element level (flight elements and Mobile Launcher)
  - Building block tests included static tests at MSFC with STAs, Orion STA testing in Denver, ML-only modal test at KSC, CS free-free modal test at SSC, booster pull test at KSC

Integrated Vehicle Interface Verification Test (IVT): COMPLETED

January 2022



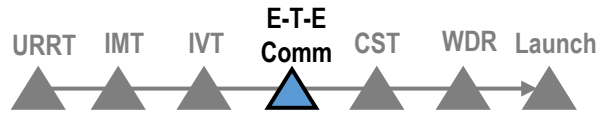


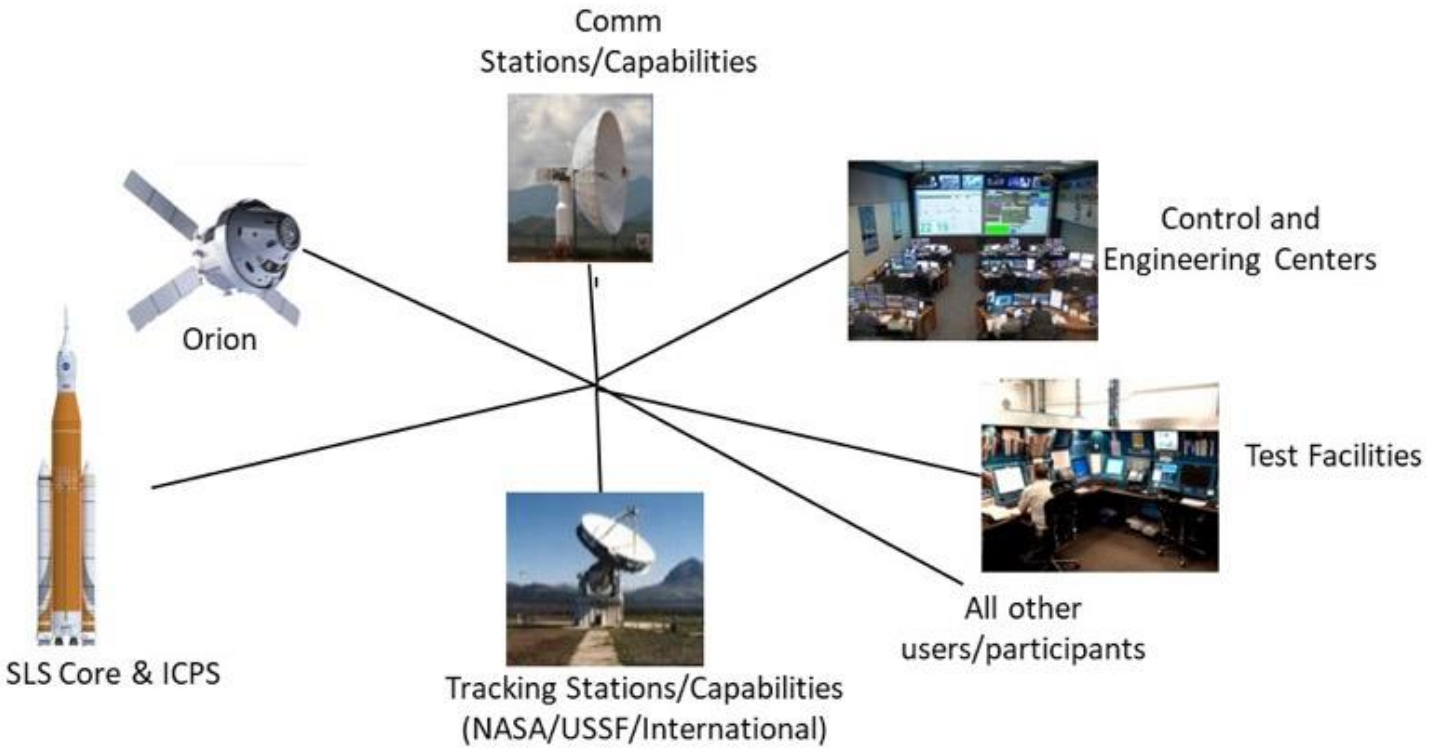
Task Description:

- Performed post-mate of the SLS and Orion vehicles, IVT is a verification of the functionality, interoperability, and workmanship (continuity/polarity) of interfaces across elements and systems
- IVT ensured successful mating of flight to flight and flight to ground interfaces and confirms the systems are ready to proceed with ground operations after successful mate of the integrated flight articles for the first time
- IVT also checked out the Launch Control Center (LCC) command & telemetry interface with full SLS/Orion vehicle indicating first-time power-up on ML

End-to-End Communications Test (E-T-E Comm Test): COMPLETED

January 2022

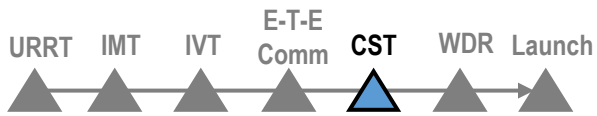




Task Description:

- Integrated communications test of SLS and Orion critical communication systems employed during countdown/day of launch, performed in the VAB using antenna hat couplers
- Demonstrated Orion/SLS/ICPS communications compatibility with required facilities and centers using the SCaN Near Earth Network, Space Network, and Deep Space Network as well as Space Force ground sites

Countdown Sequence Test (CST): COMPLETED Pt. 1



Task Description:

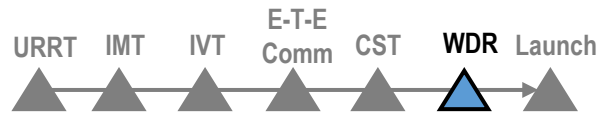
- End-to-end test of launch countdown interfaces and procedures by conducting a simulated launch countdown in the VAB prior to integrated vehicle rollout to the launch pad; tests the integrated vehicle responses to the launch countdown commanding/testing sequence
- Test included participation from all required off-site day-of-launch support locations and Orion critical communication systems (e.g., mission, ground, SCaN assets) used during countdown/day of launch
- Provided launch team training and opportunity to identify issues before WDR at Pad
- Completion of another CST run planned before WDR

Artemis I Update: Engine Controller

January 2022

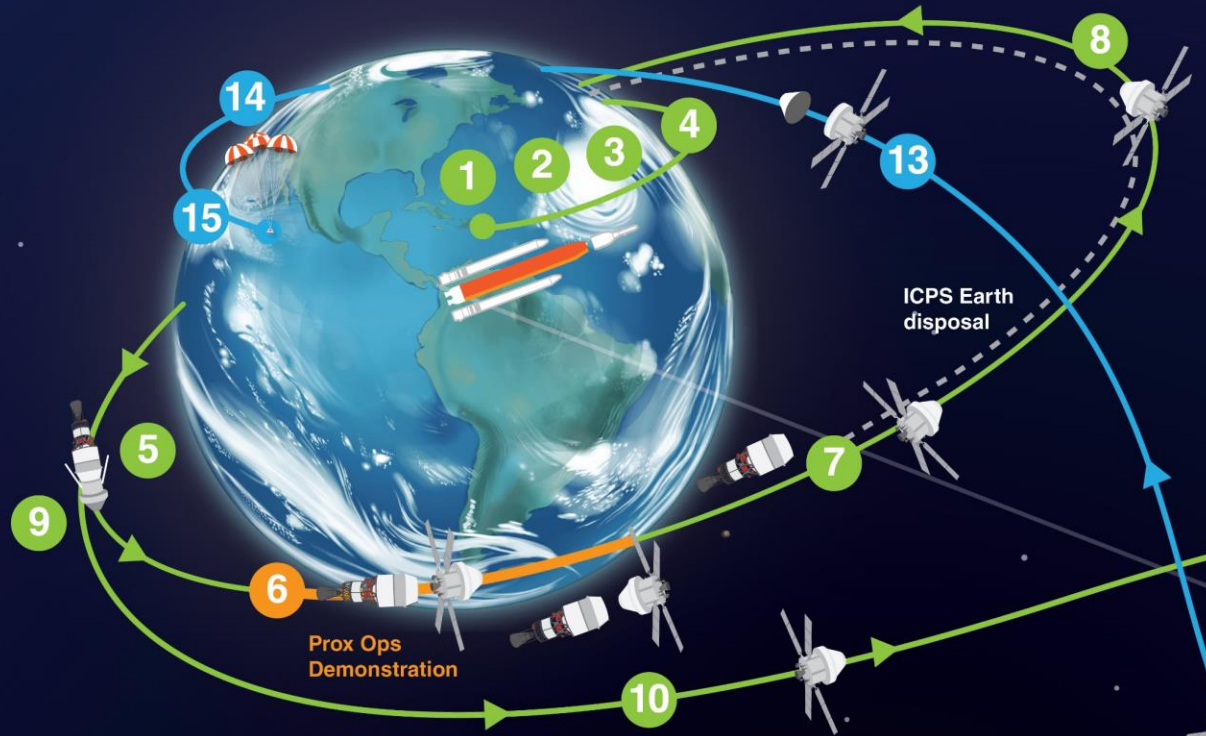
Wet Dress Rehearsal (WDR)

January 2022



Task Description:

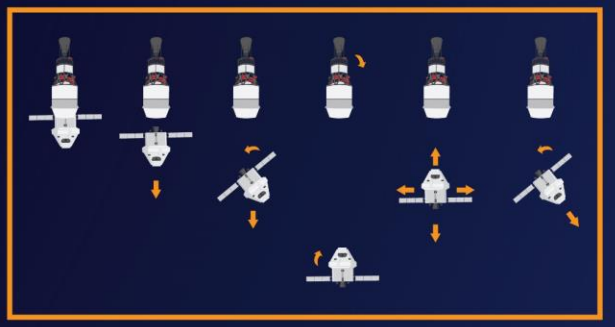
- Pad 39B cryo loading (core stage and ICPS), countdown, recycle, and scrub test (nominal/off-nominal) including detanking with integrated flight vehicle on Mobile Launcher at Pad; demonstrates end-to-end verification of vehicle and ground subsystems and components throughout all phases of the cryogenic operations
- Demonstrates nominal T-10 min hold, Ground Launch Sequencer/Automated Launch Sequencer (GLS/ALS) handover (30 sec) and countdown stop just inside T-10 secs (prior to RS-25 start)
- Provides training to launch team, range, weather, DOLILU, engineering support interfaces



ARTEMIS II

First Crewed Test Flight to the Moon Since Apollo

1. **LAUNCH**
   Astronauts lift off from pad 39B at Kennedy Space Center.
2. **JETTISON ROCKET BOOSTERS, FAIRINGS, AND LAUNCH ABORT SYSTEM**
3. **CORE STAGE MAIN ENGINE CUT OFF**
   With separation.
4. **PERIGEE RAISE MANEUVER**
5. **APOGEE RAISE BURN TO HIGH EARTH ORBIT**
   Begin 24 hour checkout of spacecraft.
6. **PROX OPS DEMONSTRATION**
   Orion proximity operations demonstration and manual handling qualities assessment for up to 2 hours.
7. **INTERIM CRYOGENIC PROPULSION STAGE (ICPS) DISPOSAL BURN**
8. **HIGH EARTH ORBIT CHECKOUT**
   Life support, exercise, and habitation equipment evaluations.
9. **TRANS-LUNAR INJECTION (TLI) BY ORION'S MAIN ENGINE**
   Lunar free return trajectory initiated with European service module.
10. **OUTBOUND TRANSIT TO MOON**
    4 days outbound transit along free return trajectory.
11. **LUNAR FLYBY**
    4,000 nmi (mean) lunar farside altitude.
12. **TRANS-EARTH RETURN**
    Return Trajectory Correction (RTC) burns as necessary to aim for Earth's atmosphere; travel time approximately 4 days.
13. **CREW MODULE SEPARATION FROM SERVICE MODULE**
14. **ENTRY INTERFACE (EI)**
    Enter Earth's atmosphere.
15. **SPLASHDOWN**
    Ship recovers astronauts and capsule.



PROXIMITY OPERATIONS DEMONSTRATION SEQUENCE

10/7/2021

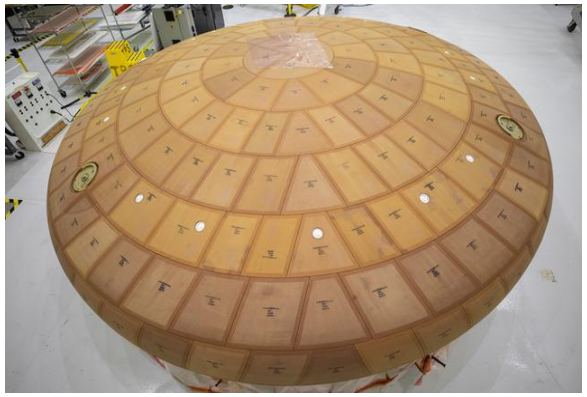
Artemis II: Unique Development Supporting Crew Capabilities

January 2022

Artemis II Accomplishments

January 2022

CM ECLSS Bay Components Installed



Heatshield Thermal Test Complete

CMA/ESM Mate

CM Prop & ECLSS Tanks Installed and Welded

Artemis II Slide Hatch in Acceptance Testing

Artemis II LAS 0 Degree Ogive in Protoqual Testing

Artemis II LAS Hatch Completing Production

Forward Bay Cover Tile & FRSI Bonding Complete

Rev D, Updated as of 1/6/2022

MAJOR MILESTONES FOR ARTEMIS II


PARACHUTES QUALIFIED FOR FLIGHT


*CREW EGRESS TRAINING AT NBL


ORION PRESSURE VESSEL ELEMENTS MACHINED


*HAND CONTROLLER EVAL


*DOCKING HATCH EVAL


ORION WATER IMPACT TESTING


*CREW EMERGENCY EGRESS TESTS


*CREW AT SEA TEST


*CREW MODULE UPRIGHT SYSTEM TEST


ORION ENVIRONMENTAL TESTS


HEAT SHIELD BLOCK INSTALL COMPLETE


SLS BOOSTER MOTOR SEGMENTS CAST


RS-25 ENGINES PROCESSED


SLS CORE STAGE PROOFING AND WELDING


*HUMAN-IN-THE-LOOP TESTS


*DIVER RECOVERY TRAINING


ORION MISSION CONTROL SIMULATIONS


*VACUUM PRESSURE CREW TEST


PRESSURE VESSEL COMPLETE


PRESSURE VESSEL ARRIVES AT KSC


*DISPLAY AND CONTROL EVAL


ASSEMBLY, INTEGRATION, AND TESTING AT KSC


JETTISON MOTOR QUALIFIED


ATTITUDE CONTROL MOTOR QUALIFIED


SLS RL10 ENGINE COMPLETION


CREW MODULE TRAINING ARTICLE TRANSPORTED TO LETF


*EES MOCKUP EVALUATION


*PAD EMERGENCY EGRESS SYSTEM 60% DESIGN REVIEW


*EMERGENCY EGRESS SYSTEM BASKET PROTOTYPE


LH2 SPHERE


*MOBILE LAUNCHER 1 60% DESIGN REVIEW


ENVIRONMENTAL CONTROL SYSTEM CHILLERS INSTALLED


ENVIRONMENTAL CONTROL SYSTEM INFRASTRUCTURE INSTALLED


EUROPEAN SERVICE MODULE ASSEMBLY AT AIRBUS


HEAT SHIELD INSTALL ON CREW MODULE


EUROPEAN SERVICE MODULE SHIPS TO KSC


CREW MODULE ADAPTER/ EUROPEAN SERVICE MODULE MATE


CORE STAGE 2 FORWARD JOIN

CORE STAGE 2 AFT JOIN

SLS INTERIM CRYOGENIC PROPULSION STAGE (ICPS) COMPLETION

SLS ORION STAGE ADAPTER COMPLETION

SLS LAUNCH VEHICLE STAGE ADAPTER COMPLETION

EGS CRYO SYSTEM V&V COMPLETE

CREW MODULE COMPLETE

CREW AND SERVICE MODULE MATE

*MOBILE LAUNCHER 1 CREWED MODS COMPLETE

CORE STAGE 2 FINAL ASSEMBLY AND INTEGRATION

BOOSTERS ARRIVE AT KSC

EGS BOOSTER OFFLINE PROCESSING START

CORE STAGE 2 SHIPMENT TO KSC

VAB ECS UPGRADES COMPLETE

*PAD UPGRADES COMPLETE

*MOBILE LAUNCHER 1 MULTI-ELEMENT V&V COMPLETE

EGS OPERATIONAL READINESS CHECKPOINT

ORION HANDOVER TO EGS

EGS ORION OFFLINE PROCESSING START

CREW AND SERVICE MODULE POWER ON

BOOSTER STACKING COMPLETE

SLS CORE STAGE, ICPS, & ADAPTERS INTEGRATION AT KSC

ORION MASS SIMULATOR MATE

ROLL TO PAD FOR TANKING TEST

ARTEMIS II TANKING TEST

ROLL TO VAB FOLLOWING TANKING TEST

ORION CSM MATE

CONDUCT FINAL INTEGRATED TESTING

ROLL TO PAD FOR LAUNCH

ARTEMIS II LAUNCH

Unique aspect of Artemis II (* unique for crew config.)

For Artemis II:

- No core stage hot-fire at SSC or post hot-fire refurbishment required at KSC
- No modal test required
- Bleed line re-sizing and Pre-Valve clutch R&R are not anticipated

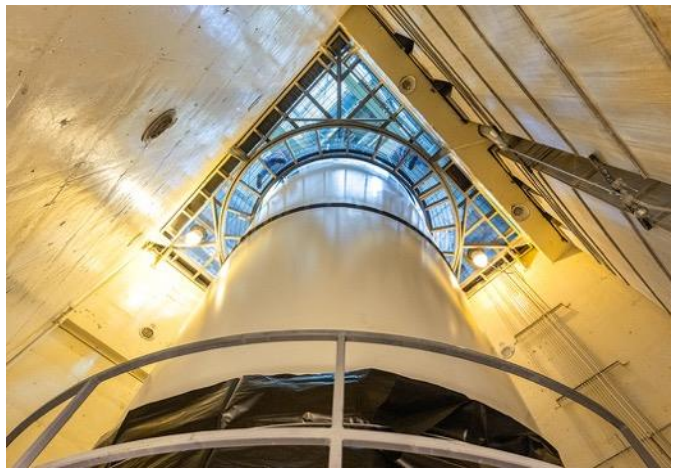
The Path for Missions Beyond Artemis I and II

Artemis III and Beyond: Progress Across the Nation

January 2022

- NASA and Boeing crews have successfully placed the forward skirt for the Artemis III SLS rocket into the Vertical Assembly Center robotic weld tool for its next phase of production at Michoud Assembly Facility in New Orleans, Louisiana.

- The Artemis IV Orion heat shield skin is undergoing heat and pressure testing at Lockheed Martin facilities in Sunnyvale, CA.



- Casting and assembly of solid rocket booster for the Artemis IV mission is underway at Northrop Grumman's factory in Promontory, Utah.

The Launch of the Artemis I Mission is Around the Corner.

We Are Going!

Backup

ESD Commonly Used Acronyms and Abbreviations

Acronym	Definition
AA	Ascent Abort
AI&T	Assembly, Integration, and Testing
APU	Auxiliary Power Unit
ASEU	Aft Skirt Electrical Umbilical
ATLO	Assembly, Test, and Launch Operations
ATP	Authority to Proceed
BFS	Backup Flight System
C&DH	Command and Data Handling
CAA	Crew Access Arm
CM	Crew Module
CMA	Crew Module Adapter
CMASS	Crew Module Ammonia Servicing Subsystem
C/O	Check Out
CR	Change Request
CS	Core Stage
CSI	Cross-Program Systems Integration
CSM	Crew and Service Module
CSS	Consumable Storage System
CT	Crawler Transporter
DCR	Design Certification Review
DFAT	Direct Field Acoustics Test
DVO	Detailed Verification Objectives
ECD	Estimated Completion Date
ECLSS	Environmental Control and Life Support System
ECS	Environmental Control System
ECU	Engine Controller Unit
EES	Emergency Egress System
EGS	Exploration Ground Systems
EGSE	Electrical Ground Support Equipment
EMI/EMC	Electromagnetic Interference and Electromagnetic Compatibility
ES	Engine Section
ESA	European Space Agency
ESD	Exploration Systems Development
ETE	End to End
FAST	Final Assembly and System Test
EUS	Exploration Upper Stage
FCAS	Flight Controller Application Software
FCV	Flow Control Valve
FDIR	Fault Detection Isolation& Recovery
FIL	Fillet Panel
FM	Flight Model
FMA	Final Mission Analysis
FRAC	Flight Readiness Analysis Cycle
FRR	Flight Readiness Review
FS	Forward Skirt
FSS	Flight Safety System
FSW	Flight Software
FWD	Forward
GFAS	Ground/Flight Application Software
GFAST	Ground/Flight Application Software Team
GHe	Gaseous Helium
GLS	Ground Launch Sequencer
GN2	Gaseous Nitrogen
GNC	Guidance, Navigation, and Control
GO2	Gaseous Oxygen
GR&A	Ground Rules and Assumptions
GRAS	Green Run Application Software
GRC	Glenn Research Center
GSE	Ground Support Equipment
HB	High Bay
HOTH	Houston Orion Test Hardware
HW	Hardware
ICPS	Interim Cryogenic Propulsion Stage
ICPSU	Interim Cryogenic Propulsion Stage Umbilical
IPO	Initial Power On
IT	Intertank
ITCO	Integrated Test and Checkout
ITL	Integrated Test Laboratory
JICB	Joint Integrated Control Board
JM	Jettison Motor
KCCS	Kennedy Complex Control System
KSC	Kennedy Space Center
LAS	Launch Abort System
LCC	Launch Commit Criteria
LETF	Launch Equipment Test Facility
LH2	Liquid Hydrogen
LN2	Liquid Nitrogen
LO2	Liquid Oxygen
LOX	Liquid Oxygen
LVSA	Launch Vehicle Stage Adapter
MAF	Michoud Assembly Facility
ME	Multi-Element
ML	Mobile Launcher
MPPF	Multi-Payload Processing Facility
MPS	Main Propulsion System
MSFC	Marshall Space Flight Center
NDE	Nondestructive Evaluation
O&C	Operations and Checkout
O/D	On Dock
OGV	Ogive Panel
OMRS	Operations and Maintenance Requirements and Specifications
OMS-E	Orbital Maneuvering System Engine
OSA	Orion Stage Adapter
OTP	Orion Transportation Pallet
PBS	Plum Brook Station
PCDU	Power Control Distribution Unit
PDU	Power Distribution Unit
PLI	Propellant Liner Insulation
PM	Program Manager
PPE	Power and Propulsion Element
PRA	Probabilistic Risk Assessment
QD	Quick Disconnect
QM	Qualification Motor
RCS	Reaction Control System
SAR	System Acceptance Review
SCCS	Spaceport Command and Control System
SCAPE	Self-Contained Atmospheric Protection Ensemble
SE&I	Systems Engineering and Integration
SIL	System Integration Lab
SITF	Software Integration Testing Facility
SLS	Space Launch System
SM	Service Module
SSC	Stennis Space Center
SSPF	Space Station Processing Facility
STA	Structural Test Article
SW	Software
TCU	Thermal Control Unit
TLM	Telemetry
TPS	Thermal Protection System
TRR	Test Readiness Review
TSMU	Tail Service Mast Umbilical
TVC	Thrust Vector Control
ULA	United Launch Alliance
V&V	Verification and Validation
VAB	Vehicle Assembly Building
VAC	Vertical Assembly Center
WDR	Wet Dress Rehearsal
XCS	Extensible Columns