National Aeronautics and
Space Administration

DEEP SPACE
EXPLORATION SYSTEMS

NASA Advisory Council

Marshall Smith
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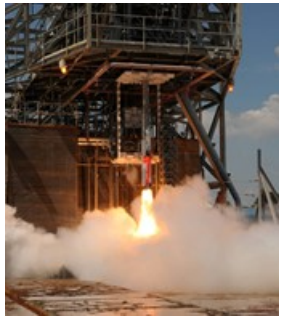
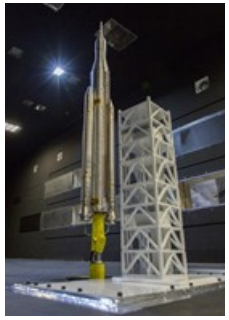
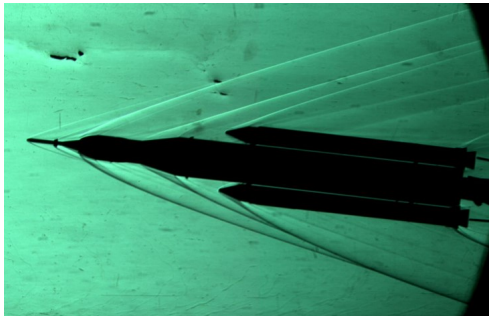
Exploration Systems Development

cross-program systems integration







CSI Technical Performance – Recent Major Accomplishments (March – June)

- Baselined MDB Annex 1 Cross Program Operational Groundrules & Constraints (March)
- Performed first mission focused testing of numerous key communications and network connections used for launch and flight, met all objectives (March)
- Approved EM-1 Mission Definition Baseline (MDB) revision D (lighting constraints, general priorities, Orion secondary payloads, etc.) (April)
- Completed initial assessment of Secondary Payloads Radio Frequency spectrum interference analysis (April)
- Completed development of Exploration Systems Development (ESD) Requirement Key Verification Requirement (KVR) Reporting Tools (April)
- Coordinated release of ESD and all Programs Validation reports for EM-1 (April)
- Implemented new Interim Cryogenic Propulsion Stage (ICPS) data processing architecture solution with KSC partially processing for MSFC and JSC (April)
- Conducted five tabletop reviews to begin baselining the Cross Program Integrated Hazard Assessments (CPIHA) (May – June)
- Conducted EM-1 Mission Integration Review (June)
- Baselined 1065 Operations Maintenance Requirements and Specifications (OMRS) records with 1241 left (June)
- Baselined 91 Launch Commit Criteria (LCC) with 368 left. 43 LCCs are currently out for review. (June)

CSI Technical Performance – Near Term Forward Work (July – September)

- Complete review and approval of Cross Program Quality Planning Requirements Document (July)
- Conduct Independent Crew Egress Exercise Neutral Buoyancy Lab session and Open Water Testing with United States Coast Guard (July)
- Assessment of NPR 8705 evidence as preparation for Human Rating Integration Task Team internal 'checkpoint' review (July)
- Coordinate content of Revision A of Mishap Preparedness and Contingency Plan to include an EM-1 specific Annex (July and beyond)
- Continue EM-1 Flight Rule development (July and beyond)
- Conduct CPIHA tabletops with 3 planned through the end of 2017 to complete review of all CPIHAs (July and beyond)
- Update process for Compact Unique Identifier (CUI) change control management (August)
- Assess options for measuring core to booster attach deflections for Wet Dress Rehearsal (August)
- Release change request for ESD Concept of Operations to include Block 1B Functional and Operational Capabilities (FOCs) (Sept)
- Develop Human Explorations and Operations (HEO) level requirements Concept of Operations, utilization plans and habitation standards drafts for Deep Space Gateway (Sept)

CPIT Top Technical Issues – July 2017

- **GSDO Ground to Flight Applications Software (GFAST)**
  - Development dependent on Compact Unique Identifier (CUI) definitions and Flight/Ground system descriptions
  - Programs have agreed to deliveries.
  - CUI change management strategy in work.
  - Working Groups established for Flight/Ground interface detailed functional descriptions.

- **Interim Cryo-Propulsion Stage (ICPS) Umbilical Loads**
  - Initial ICPS integrated loads >200% over hardware design loads.
  - No remaining analytical hardware loads issues.
  - First dynamic test complete with some hardware damaged on ground side.
  - Hardware redesigned and retract testing continuing.

CPIT Top Technical Issues – July 2017

- **Orion Pad Stay Time**
  - SLS and Orion derived differing requirements for pad stay with exposure to winds.
  - Joint Integration Control Board (JICB) approved Orion alternate fatigue spectrum with 68 day pad stay. Orion perform fatigue/fracture analysis.
  - Return to JICB, elevate to Exploration Systems Development (ESD) Control Board (ECB) for visibility.

- **Communication Uplink for EM-2 Exploration Upper Stage (EUS)**
  - Current plan does not include communication system.
  - Team is finalizing conclusions and recommendations for presentation to JICB.

- **Crew Time on Back (CTOB)**
  - Request to limit time on back to 2:45.
  - Developing cross program risk, refining CTOB timeline, reviewing Crew comfort enhancements.

CPIT Top Technical Issues – July 2017

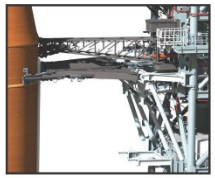
- **EUS Reaction Control System (RCS) thruster sizes for Proximity Operations and Docking**
  - Potential need for smaller thrusters on EUS for fine attitude hold for Orion docking to co-manifested payload.
  - Simulations show that EUS has capability to hold attitude with margin.
  - Crew handling simulations ongoing; which will help validate attitude error allocation to EUS.

- **Ground Systems Telemetry Processing Limitation**
  - Current Launch Control System architecture cannot process the expected amount of data from the vehicle and ground support equipment.
  - Upgrading servers in Firing Rooms 1, 2 and 3.
  - Updating software to increase throughput and use change filtering.

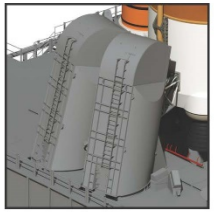
Collet for Umbilical Release

- **Common collet design is used across multiple umbilical arms to hold flight and ground plates together**

Orion Service Module Umbilical

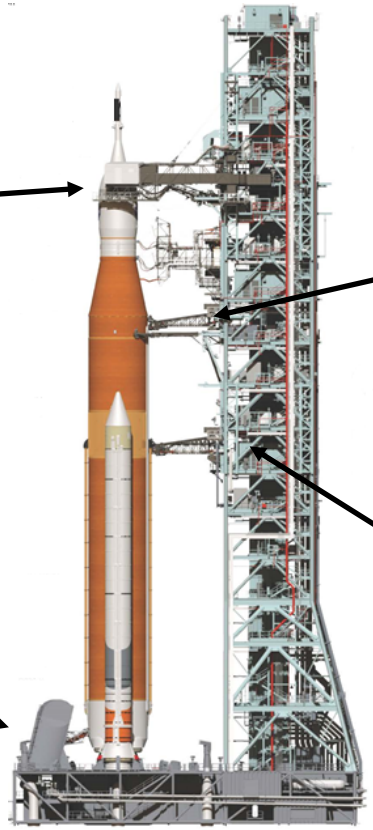


Core Stage Forward Skirt Umbilical

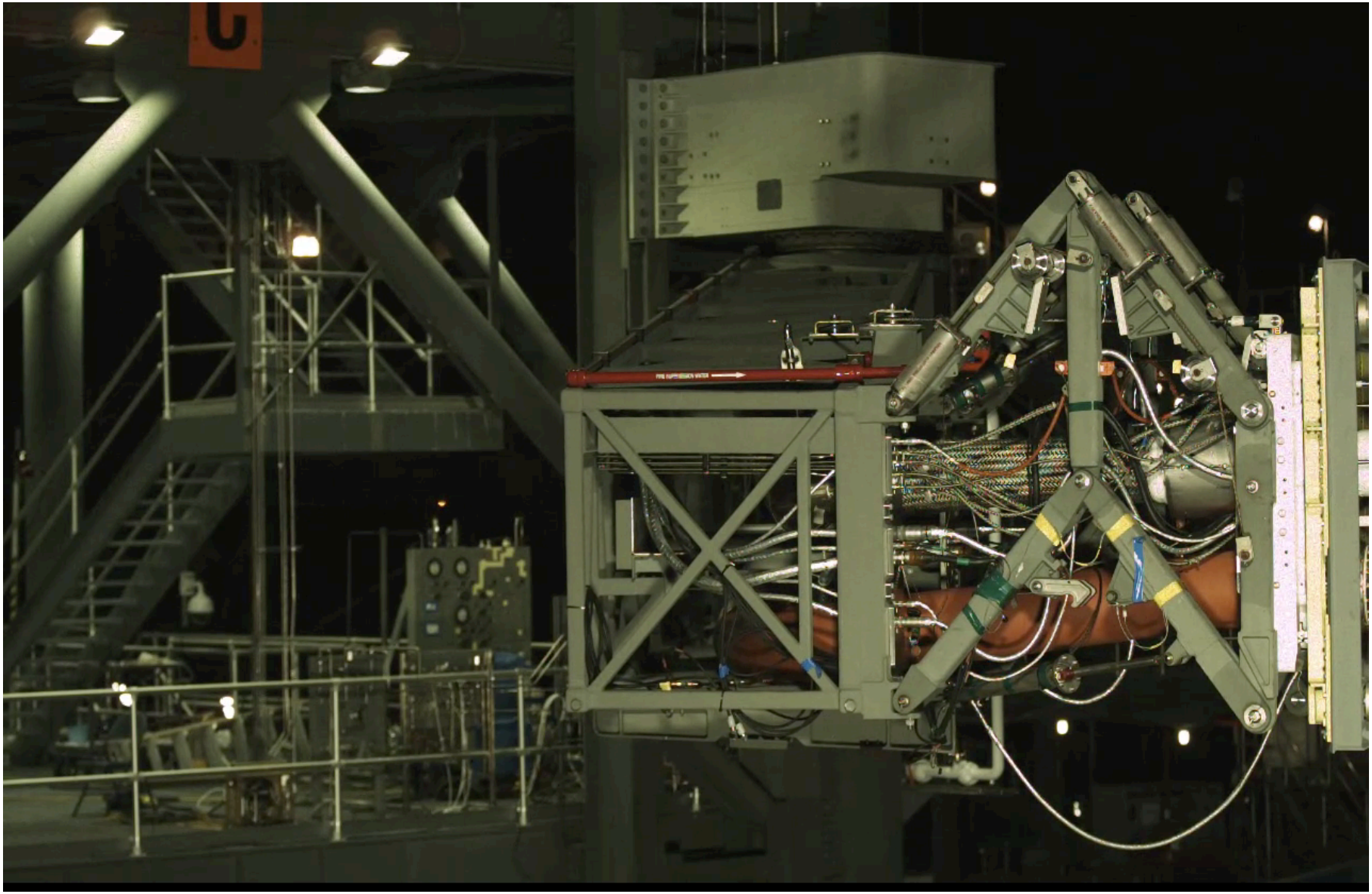


Tail Service Mast Umbilicals

Core Stage Inter-tank Umbilical



Collet for Umbilical Release

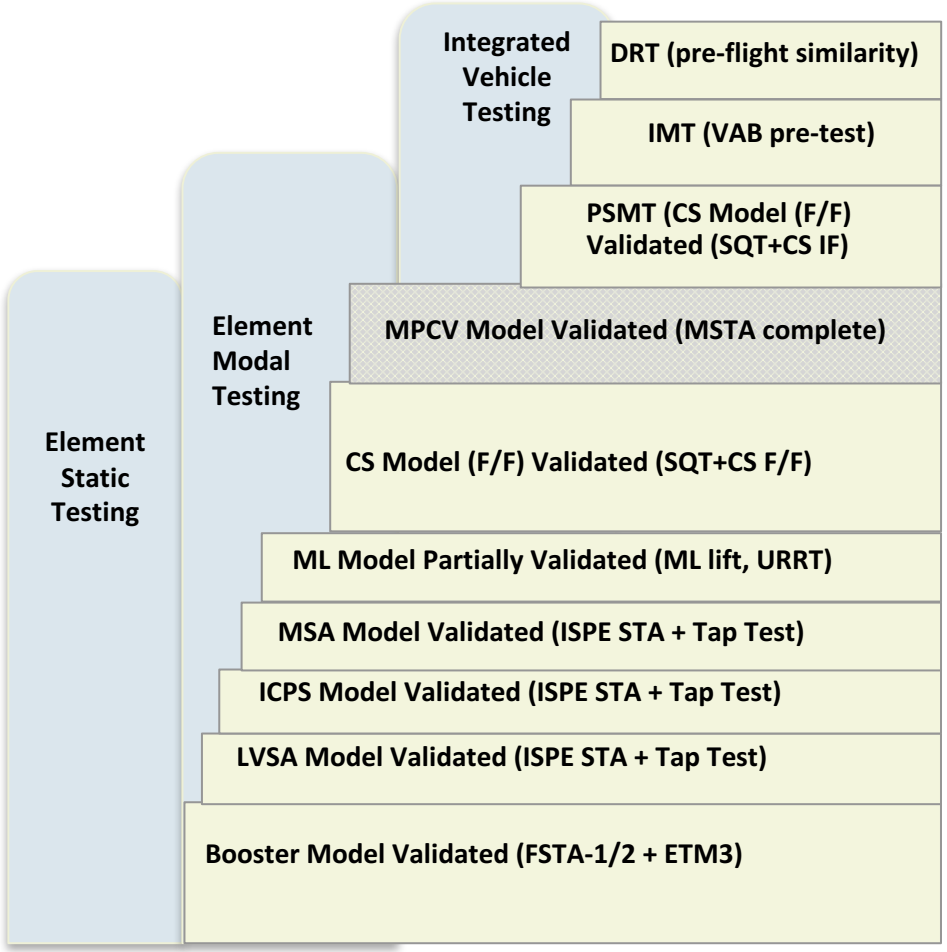


Collet for Umbilical Release

- **The collet has had multiple failures in development including:**
  - Binding
  - Rear Linkage pin and rear linkage arm damage
  - Collet receptacle cup release during secondary release
- **Various modifications have been made to the collet design including:**
  - Changed finger geometry
  - Added stiffer spring
  - Added lubrication to pin and fingers
  - Replaced rear linkage pin with stronger material
  - Modified rear linkage arm. Added bump stop, eliminated neckdown at pin
- **Revised collet design worked well in development testing**
- **Issue closed**

Mobile Launcher (ML) modal testing

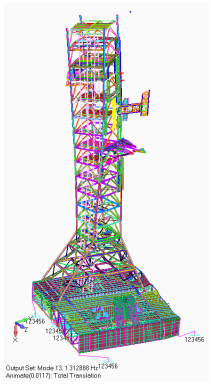
- Test-validated structural dynamics models are used in building block approach to assemble integrated flight models
- Element static and modal tests are used to update individual element models
- Integrated testing at KSC includes the Partial Stack Modal Test (PSMT), the Integrated Modal Test (IMT), and the Dynamic Rollout Test (DRT)
- These integrated tests use the ML as a "test stand" providing boundary conditions which must be understood to characterize the system



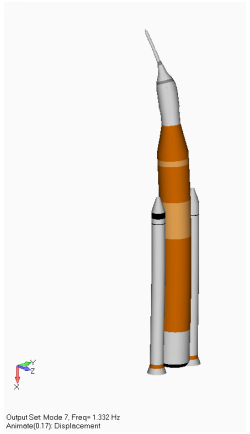
DRT- Dynamic Rollout Test
PSMT- Partial Stack Modal Test
IMT- Integrated (Vehicle) Modal Test

Mobile Launcher (ML) modal testing

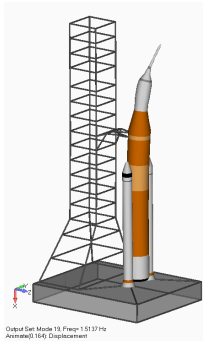
- Once coupled with the ML the vehicle bending mode no longer exists as a single mode but becomes entangled with the characteristics of the ML, resulting in the 5 integrated modes shown below
- Test recommended by the Joint Loads Task Team (JLTT) and also by an NESC independent review team
- ML only modal test was approved at JPCB on 4/13/17

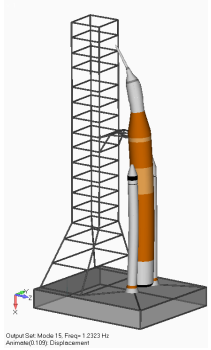


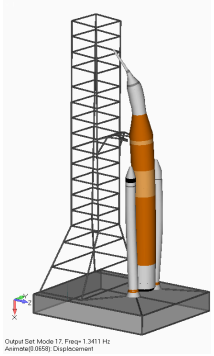
ML Only

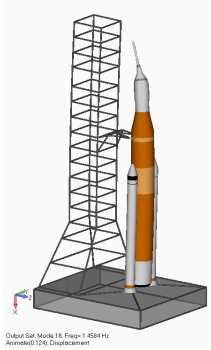


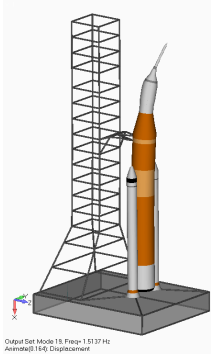
Vehicle Only - Cantilevered











Resulting 5 integrated system test modes

- Testing expected to occur in January 2018 at the end of ML/VAB Multi Element Verification and Validation (MEVV) testing
- Issue closed

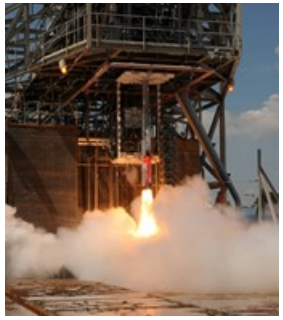
Major ESD/CSI Independent Assessments In Progress

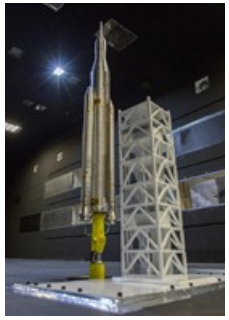
- **Independent modeling and simulation of separation events**
  - Ascent trajectory analysis shows good comparison with program. Design Analysis Cycle (DAC)-3R Reports provided for Liftoff clearance; Solid Rocket Booster (SRB) separation clearance; Service Module (SM) Panel Jettison clearance. Results and recommendations provided; Working Block 1B and Verification Analysis Cycle (VAC)-1R updates.
  - Initiating Ascent Abort-2 (AA-2) ascent analysis.
- **Peer Review of Enterprise Modal Testing**
  - Correlation effort - Task provides ongoing peer review of ESD modal test planning, analysis, and execution, including model correlation, flight loads readiness, and development flight instrumentation (DFI), for EM-1 and EM-2
- **Independent Verification of Ascent Abort Loads**
  - Task complete, report provided and analysis tool delivered. Continued use of tool developed by the study is planned.
- **Independent Verification of Pre Launch Loads**
  - Independent verification of SLS methodology and loads predictions for pre-launch, liftoff, and ascent gust.
  - Recent aero database comparisons with SLS push stacking and launch analyses to 8/18
- **Evaluation of Orbital Debris Engineering Model (ORDEM) 3.0 Micrometeoroids and Orbital Debris (MMOD) environment**
  - Using data from available on-orbit assets. NESC Review Board scheduled for 6/29 for final report.

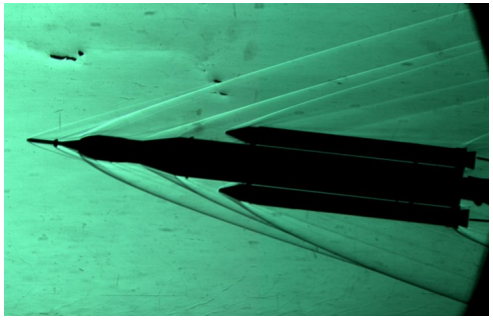
Major ESD/CSI Independent Assessments In Progress

- **MMOD Pressure Vessel Failure Criteria**
  - Hypervelocity Impact Testing on Composite Overwrap Pressure Vessels (COPVs) to validate models. Small tank testing complete. International Space Station (ISS) high pressure gas tank testing in work. No rupture of tanks observed in any tests.
- **Cross-Program Verification and Validation (V&V) Mapping. Performing interface requirements and compliance gap assessment. Provided briefing to ESD June 20.**
- **ESD developing a Cross-Program Independent Assessment Summary Matrix. Establishing ESD library of independent studies; Reviewing extent of independent use and review of system models defined in SLS-RPT-105, Cross Program Design Model Log.**
- **The Flight Safety Office (FSO) evaluated the Launch Verification Matrix (LVM) (used for independent verification of DoD and other commercial launch providers' certification of launch vehicles) versus NASA S&MA processes.**
  - Assessment completed: LVM and NASA overall requirement/V&V processes are very similar from S&MA coverage perspective, no significant gaps identified.
- **The FSO is assessing the 186 *"Significant Incidents and Close Calls in Human Spaceflight"* (plus 3 candidates) for relevance/applicability to ESD.**
  - Phase 1 Assessment (67 directly applicable events) complete.
    - Overall, good validation of current ESD plans/Hazard Reports (HRs), a few noted forward work items discovered to watch.
  - Phase 2 Assessment in work.

Backup-Cross-Program Systems Integration







Cross Program Interdependencies

Management and Status

- **Cross Program System Integration (CSI) team continues to manage Interdependencies, working across ESD to ensure Program needs are being met**
- **Major deliveries last quarter include:**
  - SLS, MPCV, and GSDO Software and Emulator updates
  - Continued hardware deliveries for facility readiness and test programs
  - Model and data exchanges including detailed drawing and schematic access, Computer Aided Design (CAD) models, Finite Element Models (FEMs), dynamic models, procedures and test data associated with Verification Analysis, Mission Integration and Testing
  - EM-2 related analyses for continued design refinement and change incorporation
- **Significant upcoming deliveries include:**
  - Additional SLS, MPCV and GSDO Software and Emulator updates for System Integration Lab (SIL)/Integrated Test Lab (ITL) testing
  - Continued hardware deliveries for facility readiness and test programs, including delivery of the MPCV Stage Adapter (MSA) Structural Test Article (STA) from SLS to Orion
  - Data needs to continue Verification and Work Authorization Document (WAD) Development activities as well as EM-2 Design Analysis

Since 2012, 1018 (formerly 994) interdependencies have been identified by the team, with 225 (formerly 234) currently active

Interdependencies Category Definitions
Candidate – An item that has been identified as an interdependency by one program, but formal agreement with the providing program has not been achieved.
Partnered (In Work) – An item has been agreed by the providing program to provide scope on the requested need date, but has yet to be received by the requesting program.
Baselined - An item has been approved in the baselined Bilateral Software and Hardware Exchange Agreements, Lists and Schedules (BSHEALS) or Bilateral Data Exchange Agreements, Lists and Schedules (BDEALS) documents
Under Review (Delivered) – An item/delivery that has been received and is presently under review prior to formal acceptance.
Elevated – An item that has been elevated to the Cross Program Integration Team (CPIT) Leadership, as no resolution has been reached at the Integration Taks Team (ITT)/working group level, or need date has passed.
Closed – An item has been received, reviewed, and closed.

CPIT SE&I Schedule
Product/Revision Completion Progress