NASA Exploration Production and Operations Long-Term Sustainability
Request for Information (RFI)

Synopsis

The National Aeronautics and Space Administration (NASA) invites industry to submit responses to this Request for Information (RFI) to assist NASA in maximizing the long term efficiency and sustainability of the Exploration Systems Development (ESD) programs, including the Space Launch System (SLS), Exploration Ground Systems (EGS) and Cross-Program Systems Integration (CSI) office by minimizing production, operations, and maintenance costs. NASA will use the information received from this RFI on a non-attribution basis for informing future acquisition(s) to address this challenge.

With the ESD programs now preparing for the first flight of the Artemis missions (Artemis I), and with the flight hardware for Artemis II and beyond in production, NASA is transitioning from design and development to long-term affordability and sustainability within a broader exploration framework. In this evolving environment, NASA is looking to transform the current traditional acquisition approaches to an overall acquisition strategy of a service provider for the integrated vehicle system in partnership with the Consolidated Operations, Management, Engineering and Test (COMET) service provider for the ground systems and launch operations in order to evolve into an integrated launch service available to NASA and other customers in both the public and private sectors.

Introduction

Background: NASA is seeking industry input to maximize the long-term efficiency of the ESD programs to ensure an affordable and sustainable SLS, EGS, and CSI including Orion/payload integration, which will be referred to as the Exploration Transportation System (ETS). Specifically, responses should focus on providing information on achieving an affordable ESD enterprise as it moves from development to production, operations, and maintenance as soon as practical. This will make resources available for other parts of the Artemis program to develop the capabilities necessary for sustainable missions leading to a permanent human presence on the moon and into deep space. The basic programmatic construct assumed is an industry-led integrated mission services approach across two contracts (Vehicle Production and Ground Operations). More information on NASA's Artemis Program can be found here.

Goals: The vision for the ETS is to establish it as a long-term (30 years or more) national capability that is a sustainable and affordable system for moving humans and large cargo payloads to cis-lunar and deep-space destinations for NASA and to these and other orbits for other government and non-government users. This model assumes the current government-owned and government-led system will be moved to industry. While NASA will retain at least government purpose rights to intellectual property of the system; industry will produce, operate and effectively "own" the system. Industry will also market and supply the system for other (non-NASA human spaceflight) users, including the science community (e.g. outer planet exploration), and where appropriate, other government and non-government entities. The vision assumes that NASA is the anchor tenant of the system by purchasing from the industry supplier one crewed flight per year for the next 10 or more years following contract formulation while providing appropriate supporting infrastructure and personnel for production and operations, even as the industry owner offers the service to non-NASA users.

The primary goals enabling this vision include 1) moving ESD programmatic implementation to a construct in which industry owns vehicle production and the flight hardware, and leads the ground operations services, 2) production, operations, and maintenance costs at a substantial savings of 50% or more off of the current industry baseline per flight cost with a flight rate of one crewed flight and potential for at least one cargo flight per year (costs are inclusive of Orion/payload and system integration but exclusive of the Orion hardware, payload hardware, government personnel and government facility costs), and 3) a programmatic construct that is a launch service (across 2 contracts) available for additional customers, including other government agencies, international partners and commercial entities. Factors to be considered in meeting these goals include contract structure and incentives, system management and system integration approaches, integration complexity (opportunities) in a cross-corporate construct, transition of in-house government work to industry, Intellectual Property (IP) and data rights, use and/or transition of production, processing and integration facilities, transition of flight hardware and long-lead items to industry ownership, use and/or transition of special test equipment and government furnished equipment, options for accountability for flights between various contract entities, NASA insight and oversight models, and associate contractor agreements, which includes access and sharing of information for the benefit of the activities in the contract.

Specifications: For reference in this discussion, we consider this to be a capability-based trans-lunar injection (C3 = -0.99) requirement of launching 42t in a single launch with performance enhancements (BOLE) to enable an increase in future capabilities. This capability will be referred to as the ETS, and the end-to-end delivery (from SLS hardware build, SLS/Orion/payload ground processing and integration, and launch to the end-of-service at payload separation) will be executed across two contracts with vehicle production and maintenance and ground operations and maintenance. The launch rate and flight manifest for this system can be seen in Appendix A and is expected to sustain at the rate of one crewed launch per year, with options for cargo capability. ETS services start at system element production, and end-of-service is defined as the mission designated payload / Orion separation location.

Requested Response Topics

The global objective of this RFI is to solicit input from industry to maximize the long-term efficiency and sustainability for the ETS, including CSI, SLS, and EGS. With the ESD programs now preparing for the first flight of the Artemis missions (Artemis I), and with the flight hardware for Artemis II and beyond in production, NASA is transitioning from design and development to long-term affordability and sustainability within a broader exploration framework. Given the assumption made by NASA for flat or slightly increasing funding levels for human exploration, future production, operation, and maintenance costs for CSI, SLS and EGS are critical to identifying resources required for other deep space exploration capabilities.

NASA is seeking industry inputs on transitioning from the current government owned, integrated, and operated system to an industry provided ETS that is a launch service across two contracts. The current government reference model is to consolidate the current SLS contracts to a single corporate entity (which could be a single prime, a corporate partnership, or other business entity) to produce and operate the 42+t TLI capability. This consolidated contract will be referred to as the Exploration Production and Operations Contract (EPOC), and will be responsible for the ETS hardware production, operations, maintenance, evolution, and system integration up through TLI. In addition, EPOC will work in unison with the Kennedy Space Center (KSC) COMET service contract which includes ground operation, integration, and launch; until end-of-service/TLI. The EPOC contract is envisioned to be a contract in which NASA will purchase launch services and payload delivery, but not take ownership of the flight hardware. The separate KSC COMET contract to support this activity will also not be taking delivery of the hardware, and it will play an equally important role in the overall launch service, but it is not the main point of query of this RFI. The interfaces, domains, and roles and responsibilities between EPOC and the KSC contract are in the process of being defined, and the relationship between the two contacts is critical to the success of the ETS. NASA is seeking industry inputs regarding roles and responsibility, contract structure, incentives for corporate cooperation, and/or unique business arrangements between these two contracts that could lead to a cost-effective ETS while ensuring mission success. The goal is to have the consolidated contract (EPOC) in place by December 2023 to support the beginning and/or transition of flight hardware sets for Artemis V and beyond.

For NASA to change acquisition methods, considerations of proprietary design and intellectual property should be discussed in the response. Further considerations also include a discussion of an effective corporate business plan and how the sustainability of a new acquisition process will or will not affect your corporate revenue position. Additionally, consideration of impacts to industrial base as anticipated by the RFI responder would be appreciated.

Specific to the consolidation of the SLS contracts to the single EPOC contract, please comment on:

1) Ownership of the flight hardware and contract features that incentivize the corporate entity to market and provide the EPOC system to non-NASA users.
2) Approaches and mechanisms for making this National capability readily available to non-NASA users.
3) In consideration of a commercial acquisition approach, provide perspective on industry innovation and the flexibility to achieve an affordable end state. Describe how the government can incentivize performance and the meeting of launch and mission milestones. Elaborate on what milestones would be appropriate to incentivize the goals of affordability and mission performance, and approaches for transitioning from the current multi-contract state to EPOC. Include specifics regarding small business utilization and opportunities.
4) The expected lead time for a complete flight set to launch or arrive on-dock at KSC.
5) The appropriate time/Artemis mission to transition to an integrated EPOC contract. Assess if the transition can be accomplished as soon as practicable before Artemis V, or if a longer transition via a phased approach is recommended. Identify associated risks and potential mitigations with the recommendation
6) Discuss your ability to support block upgrades, incorporation of design modifications and other unique system and sustainability improvements in the context of EPOC.
7) Recommendations for the integration, interfaces, domains, roles and responsibilities, and incentives to ensure mission success and affordability objectives between EPOC and the KSC COMET contract. Include recommendations for building successful interfaces between various contractors and recommendations regarding government mission assurance roles including flight certification.
8) Approaches for transitioning in-house government activities and tasks to EPOC.
9) Please provide recommendations for a data rights strategy to balance IP and data rights interests between government and industry partners to ensure a cost-effective lifecycle during the execution of the ETS.

10) Key factors, considerations, and assumptions for how industry will market this capability to additional customers to maximize the cargo capability of existing flights and/or increase the flight rate.

For any approaches proposed, please provide recommendations on phasing, timing, and transition approaches relative to Artemis missions (i.e. relative to Artemis II, Artemis III, IV, etc.). A rough order of magnitude cost estimate and estimation methodology for the proposed effort should be provided including any supporting rationale and basis-of-estimate. Provide the scope of effort for each the estimates and the basis of potential savings. For the final ETS configuration, the scope should include flight element hardware costs and physical and analytical integration costs. Costs of government personnel and facilities (except in those covered by Government Technical Agreements or Space Act Agreements) should not be included in any estimates but assumptions of their use should be described. Please include in your assessment potential schedule, performance, safety and cost risks that might develop under your approach and anticipated mitigation measures you would expect to take.

Please include in your RFI responses a brief summary of your company's experience utilizing the recommended approaches and lessons learned from previous NASA and non-NASA contracts. Address strategies and techniques for managing the industry workforce to deliver the Artemis missions on the expected annual cadence. Describe any government requirements, contract terms and conditions, contract clauses (including special clauses), processes, and/or deliverables which drive inefficiencies or additional costs that your company recommends removing to reduce cost, spur innovation, and enable mission success moving forward.

This RFI is not soliciting information on alternatives to major hardware elements (e.g. stages) or alternate architectures other than those already planned by the government. If it becomes necessary to explore alternative approaches and/or architectures; NASA will seek those solutions under a different RFI.

Assumptions for consideration within Response Topics

- In support of this activity, NASA will transition the majority of current in-house government tasks within SLS and some in CSI to the integrated EPOC entity. NASA will make available to industry the models and tools (as appropriate) used to support these tasks, and will work with industry in the transition of these activities These include (but are not limited to):

    - SE&I
    - Flight Software
    - GN&C
    - Trajectories
    - Technical discipline analyses
    - Safety Analysis and Failure Mode and Effects Analysis-Critical Items List

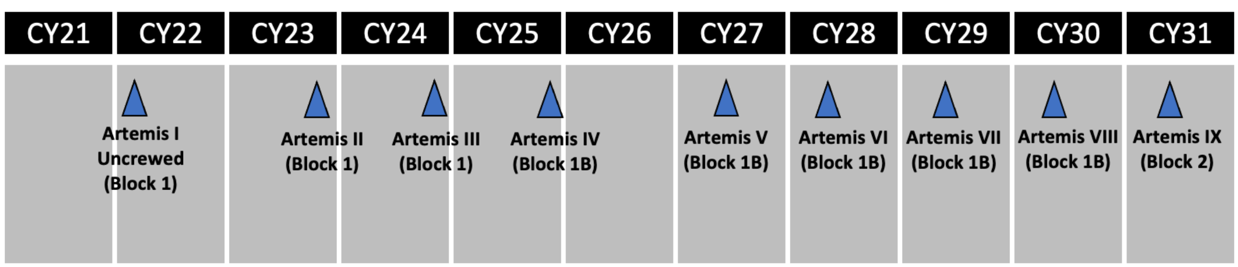
  A more detailed list of in-house governments tasks and software can be seen in Appendices C and D.

- NASA will make available to the EPOC entity the majority of government-owned facilities used in the production, operations and maintenance of the EPOC system. NASA will make available the facilities used to support these tasks, and will partner with industry on upgrades, modifications, etc. on an as-appropriate basis. It is expected that the current government-owned facilities will remain as such, and that some facilities will be designated Industrial Operating Zones or could become government-owned/contractor operated. These might include (but are not limited to):

- Select facilities at Marshall Space Flight Center (MSFC)
- Portions of the Michoud Assembly Facility (MAF)
- Booster Fabrication Facility (BFF)
- Stennis Space Center (SSC) Testing
- Sections of the Vehicle Assembly Building (VAB)

A more detailed list of facilities can be seen in Appendix E

- NASA will also either transition of or make available to EPOC the Special Test Equipment (STE), Government Furnished Equipment (GFE), and the logistics/transportation equipment used to support the current SLS system. These include (but are not limited to):
  - Pegasus Barge
  - Production equipment at MAF
  - MSFC's System Integration Laboratory
- The NASA initial concept is to continue providing indemnification in the same manner as it is currently operating today. However, the Government would welcome any comments from industry on how to make this process more efficient and effective.



Flight Dates are not final and may change

Figure 1 - Planned launch SLS launch schedule and manifest

Response Instructions

Responses to this RFI must be transmitted in PDF format to MSFC-EPOC@mail.nasa.gov no later than 2:00 PM Central Time (CT) on the 27th of Jan 2022. Responses should not exceed 20 pages total with 11-point font, and should not include sensitive, proprietary, or otherwise confidential data. Appendices, if included, should not exceed 20 pages total with 11-point font, and should clearly and conspicuously mark any information that is sensitive, proprietary, or otherwise confidential.

NASA intends to hold a virtual Industry RFI Forum via WEBEX on 10 Nov 2021 at 11:00 AM CT to amplify key components of this RFI and address questions. To receive a link/connection information for this forum, NASA requests that industry submit the registration information at Appendix F, as well as any questions that they would like addressed during the event to MSFC-EPOC@mail.nasa.gov no later than 2:00 PM CT on 02 Nov 2021. In addition, following the Industry RFI Forum, industry groups are encouraged to contact NASA via email at MSFC-EPOC@mail.nasa.gov to request a small group session to make inquiries and provide feedback regarding the EPOC requirement. Each industry group that requests a small group session will be scheduled for a virtual meeting lasting no more than one hour. NASA has the sole discretion to extend the small group meeting or allow industry groups a follow-on session. NASA will respond in writing to all questions and inputs received during the RFI process, virtual Industry RFI Forum, and virtual small group sessions. Throughout the RFI process, NASA encourages open two-way communication with industry especially concerning opportunities for partnering regarding NASA resources and workforce allocation and utilization.

NASA will use information obtained as a result of this RFI as part of its ongoing market research and on a non-attribution basis as part of future planning. The information received in this RFI is intended to inform future Agency decision making. To that end, NASA requests that the submission include only non-proprietary information. Submission of information marked as sensitive, proprietary, or otherwise confidential significantly reduces the usefulness of a submission for the intended purpose of informing Agency planning and acquisition. However, if a submitter determines that it is necessary to include sensitive, proprietary, or otherwise confidential information to properly describe their submission, then this information must be provided as a separate appendix that is clearly and conspicuously marked as such. Upon receipt of a response which includes sensitive, proprietary, or otherwise confidential information that would reduce the submission's utility to the Agency, NASA may contact the responder and request reconsideration of the marking of such data. NASA may not be able to consider information marked as sensitive, proprietary, or otherwise confidential. Failure to so mark may result in the disclosure of the unmarked information under the Freedom of Information Act or otherwise. NASA is not liable for the disclosure or use of unmarked information and may use or disclose such information for any purpose.

This RFI is not a commitment by the government nor will the government pay for information solicited. A determination by the government to procure this requirement based upon responses to this notice or other market research is solely within the discretion of the government. As stipulated in FAR 15.201, Exchanges with Industry Before Receipt of Proposals, paragraph (e), responses to this notice are not considered offers and cannot be accepted by the government to form a binding contract. This RFI is subject to FAR 52.215-3, Request for Information of Solicitation for Planning Purposes. Respondents will not be notified of the results of the evaluation of responses to this RFI. Oral communications are not acceptable in response to this notice. Any responses to this RFI that are subject to export-controlled items should be properly marked as such.

NASA Clause 1852.215-84, Ombudsman, is applicable. The Center Ombudsman for this acquisition can be found at https://prod.nais.nasa.gov/pub/pub_library/Omb.html.

If an amendment to this RFI or solicitation is released, it will by synopsized on SAM.gov. It is the potential respondents' responsibility to monitor this website for the release of any amendments to this RFI or future potential solicitation documents related to this synopsis. Potential respondents will be responsible for downloading their own copy of this RFI, or if released, any future solicitation documents.

Appendix A: Background on Human Spaceflight Planning

There is a broad national consensus that extending a permanent human presence into deep space (including cislunar space, the Mars vicinity including the moons of Mars, and eventually the surface of Mars) is an appropriate long term goal for the United States. This consensus is reflected in NASA's balanced portfolio of investments in the International Space Station (ISS), commercial crew and cargo services, space science, technology, deep space habitation, and Exploration Systems Development. Achieving the goal of extending a permanent human presence to Mars requires both a cadence of progress and continuity of purpose over many years as well as strategic flexibility to take advantage of new capabilities, innovative business models, new discoveries, new technologies, and other emerging opportunities as they present themselves. NASA assumes that this goal will need to be achieved without a significant increase over current funding levels. NASA also recognizes that a series of measurable and observable progress must be present in this multi-decadal activity.

The Exploration Campaign has five strategic goals:

1. Transition U.S. human spaceflight activities in low-Earth orbit to commercial operations that support NASA and the needs of an emerging private sector market.
2. Lead the emplacement of capabilities that support lunar surface operations and facilitate missions beyond cislunar space.
3. Foster scientific discovery and characterization of lunar resources through a series of robotic missions.
4. Return U.S. astronauts to the surface of the Moon for a sustained campaign of exploration and use.
5. Demonstrate the capabilities required for human missions to Mars and other destinations.

As key technological and scientific challenges are addressed aboard ISS, NASA will move with increasing confidence into cislunar space around the Moon with the Orion crew vehicle, the SLS rocket and the Gateway lunar outpost. NASA will return humans to the surface of the Moon on the Artemis III mission leading to sustainable lunar exploration in the mid- to late 2020s. Missions to cislunar space and the lunar surface will build operational confidence for conducting long-term work and supporting life away from Earth before embarking on the first multi-year human mission to Mars in the 2030s.

NASA's approach to pioneering is designed around a set of key strategic principles that will increase our successes and rewards over the coming decades. These key principles for a sustainable, affordable space program provide overarching guidance to help ensure NASA's investments efficiently and effectively achieve the nation's goals. These principles are integrated throughout NASA's Moon to Mars strategy and are exemplified in current plans, activities, and mission development. These principles are:

- **FISCAL REALISM:** Implementable in the *near-term with the buying power of current budgets* and in the longer term with budgets commensurate with economic growth*;*

- **SCIENTIFIC EXPLORATION***: Exploration enables science and science enables exploration;* leveraging scientific expertise for human exploration of the solar system.

- **TECHNOLOGY PULL AND PUSH:** Application of high Technology Readiness Level (TRL) technologies for near term missions, while focusing sustained investments on *technologies and capabilities* to address the challenges of future missions;

- **GRADUAL BUILD UP OF CAPABILITY:** *Near-term mission opportunities* with a defined cadence of compelling and integrated human and robotic missions, providing for an incremental buildup of capabilities for more complex missions over time;

- **ECONOMIC OPPORTUNITY:** Opportunities for *U.S. commercial business* to further enhance their experience and business base;

- **ARCHITECTURE OPENNESS AND RESILENCE:** Resilient architecture featuring multi-use, evolvable space infrastructure, minimizing unique developments, with each mission leaving something behind to support subsequent missions;

- **GLOBAL COLLABORATION AND LEADERSHIP:** Substantial *new international and commercial partnerships,* leveraging current International Space Station partnerships and building new cooperative ventures for exploration; and

- **CONTINUITY OF HUMAN SPACEFLIGHT***: Uninterrupted expansion of human presence into the solar system* by establishing a regular cadence of crewed missions to cislunar space during ISS lifetime.

Appendix B: Overview of NASA's Artemis Program

Artemis encapsulates NASA's human lunar return efforts.

Early Artemis missions will focus on landing the first woman and next man on the Moon, while later surface missions will focus on creating a sustainable presence to enhance our scientific discovery as well as prepare us for missions to Mars. With Artemis, NASA will use innovative technologies in collaboration with commercial and international partners to explore more of the lunar surface than ever before.

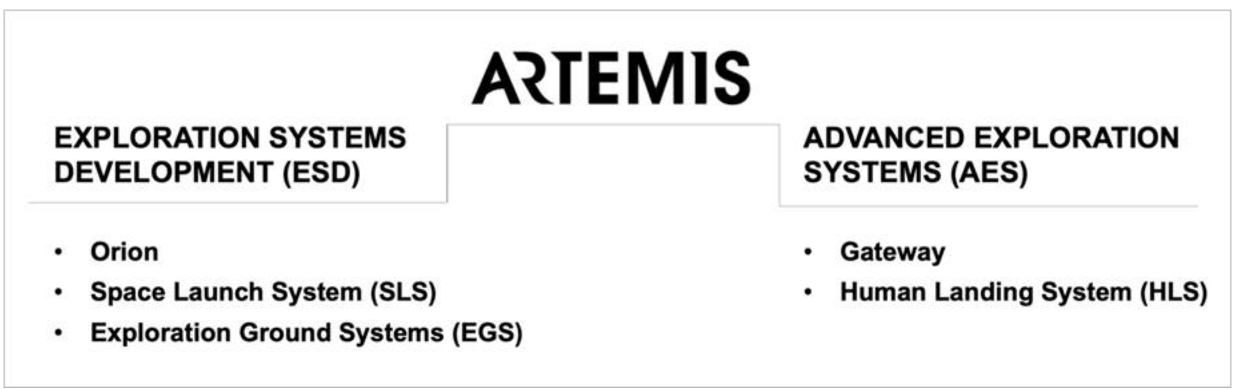
An investment in Artemis is an investment in America's future.

Exploration Systems Development (ESD)

ESD advances America's space exploration endeavors through the incremental development of powerful, sophisticated capabilities required for human spaceflight beyond low-Earth orbit. ESD is responsible for integration of its portfolio, currently encompassing the Space Launch System, Orion, and the Exploration Ground Systems.

Advanced Exploration Systems (AES)

AES pioneers new approaches for rapidly developing prototype systems, demonstrating key capabilities, and validating operational concepts for future human missions beyond low-Earth orbit. AES activities are uniquely related to crew safety and mission operations in deep space, and are strongly coupled to future vehicle development, including Gateway and the human landing system.



Orion - ESD - Johnson Space Center, Houston, TX

The Orion spacecraft, built by NASA and prime contractor Lockheed Martin, is currently the only spacecraft capable of crewed deep space flight and high-speed reentry from the vicinity of the Moon. The spacecraft is made up of three components, the crew module, the European service module, and the launch abort system.

Space Launch System - ESD - Marshall Spaceflight Center, Huntsville, AL

NASA's Space Launch System (SLS) is a super heavy-lift launch vehicle that provides the foundation for human exploration beyond Earth's orbit. SLS is the only rocket that can send Orion, astronauts, and cargo to the Moon on a single mission. Offering more payload mass, volume capability, and energy, SLS is designed to be flexible and evolvable and will open new possibilities for payloads.

Exploration Ground Systems - ESD - Kennedy Space Center, Cape Canaveral, FL

The mission of Exploration Ground Systems (EGS) is to integrate, process and launch the world's most powerful rocket, the Space Launch System (SLS), and the world's only deep space crew vehicle, Orion, in support of NASA's exploration objectives while simultaneously supporting operations and maintenance of unique KSC systems necessary for the sustainability of Artemis. The program's prime contractor is Jacobs Technology Inc.

EGS provides the advanced ground systems to safely connect a spacecraft with a rocket, move the launch vehicle to the launch pad and successfully launch to deep space, as well as safely recover Orion from the Pacific Ocean when it returns to earth. EGS has completed modifications of unique government assets, such as the 52-story Vehicle Assembly Building (VAB), Launch Control Center, Crawler-Transporter, and Launch Pad 39B.

Appendix C: ESD Systems Engineering and Integration

ESD Systems Engineering and Integration

NASA is investigating strategies, constructs, and key tenets to maximize the long-term efficiency and sustainability of the Exploration Systems Development
(ESD) programs through an affordable and sustainable Space Launch System (SLS), Exploration Ground Systems (EGS), Orion, and Cross-Program Systems Integration (CSI). The bulk of the tasks listed in this appendix are expected to be transferred to the EPOC contract with the exception of inherently governmental work (for example flight certification).

ESD Cross-Program Systems Integrations (CSI)

ESD CSI leads multi-mission SE&I efforts that includes the following.

- Con Ops, Design Reference Missions, Architecture Configuration
- Verification & Validation
- Ascent and in-space trajectories
- Loads and Environments; System level analyses
- Integrated Avionics & Software
- Interface development and control
- Ground operations requirements
- Flight operations requirements

The Enterprise integration approach has been designed to target accountability to the lowest practical level, proactive mission-level vision, oversight, cost-effectiveness, and effective checks & balances. There are 40 teams producing over 200 integrated products and that where developed from benchmarking of integration functions against past programs, independent assessments by NESC, and HEO Program Status Assessment (PSA) confirm that necessary work is identified. Figure 1 shows the CSI SE&I structure with who currently performs the functions identified in the chart.

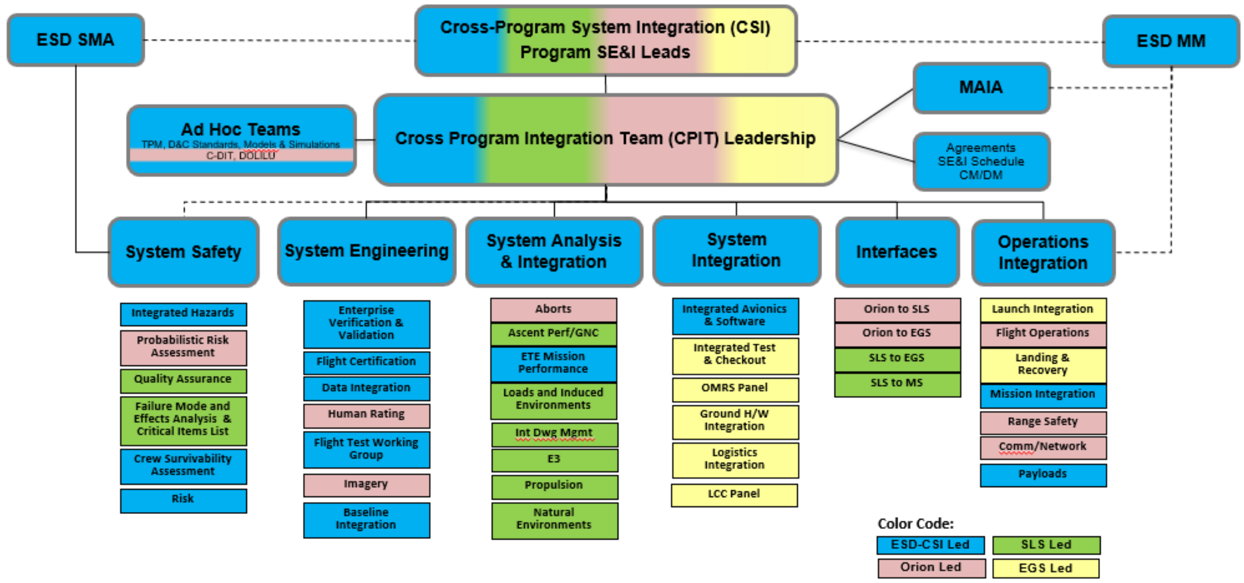


Figure 2 – Existing Key Cross-Program System Integration functions.

Figure 2 above represents the current Cross-Program System Integration functions. This chart is presented only for reference and is not intended to be the roadmap for a future organization structure. The Government is looking for industry to bring innovative solutions for these functions that drive collaboration and maximize efficiencies.

CSI Functions

System Safety

Definition: ESD manages the cross program integrated hazard analysis process and products. The Cross Program Integrated Hazard Analysis (CPIHA) is a coordinated effort by all programs to analyze the hardware interfaces, system interactions, and interdependencies to identify the Cross Program Integrated Hazards (CPIHs), causes, effects, controls and verifications.

- Develops the S&MA related analytical and planning products needed for cross-program integration including:
  - ESD Safety and Mission Assurance Plan
  - ESD Mishap Preparedness and Contingency Plan (MPCP)
  - Exploration Systems Development Artemis I Planetary Protection Plan
  - Cross-Program Orbital Debris Assessment Report (ODAR)
- Integrated Hazards – Manage the development of the cross-program integrated hazard analysis
- PRA – Manage the development of the cross-program integrated PRA
- Quality Assurance – Manage cross-program QA processes
- FMEA/CIL – Manage coordination and resolution of cross-program failure modes and effects
- Crew Survival Analysis Team – Manage crew survival analysis to support Human Rating
- Risk – Manage enterprise risks, including integration of program risks

System Engineering

Definition: Provides the baseline integration for the enterprise including technical, test & verification, flight certification and human rating processes

- Manages the overall technical baseline for the integrated system including:
    - Systems Engineering Management Plan
    - Human Exploration Requirements
    - HEO Exploration Design Concept of Operations
- Enterprise Verification & Validation (V&V) – Establish plan to verify and validate the ESD requirement set
- Flight Certification – Develop CoFR approach and plans for CoFR products
- Data Integration – Build tools to manage data integration across the Enterprise
- Human Rating – Manage approach for meeting the Agency human rating requirements
- Flight Test Working Group – Perform integration for the development of ESD level flight test objectives
- Imagery – Provide integrated imagery objectives and requirements for ground processing, launch and flight
- Baseline Integration – Evaluate changes and identify impacts to other elements or integrated system

System Analysis & Integration

Definition: Provides design requirements and predicts system performance and environments by analyses and tests

- Aborts – Develop and implement strategies for mission abort from the pad, through ascent and through TLI
- Ascent Performance/Guidance, Navigation, & Control (GNC) – Develop ascent trajectories, characterize vehicle performance and GNC subsystem performance
    - 3 DOF and 6 DOF Ascent Trajectories
- End-to-End (ETE) Mission Performance – Generate integrated mission analysis, reference trajectories, and performance margins for ESD missions
- Loads – Develop integrated loads and induced environments including:
    - Cross-Program Integrated Vehicle Loads
    - Cross-Program Debris Assessment
    - Cross-Program Vehicle Design Environments Integrated Vehicle Loads
    - Cross-Program Vehicle Design Environments External Thermal, Shared Compartment Thermal, Acoustic, and Vibro-acoustics and Shock
- Integrated Drawing Management – Define and control the physical configuration for the integrated system
- Electromagnetic Environmental Effects (E3) – Define E3 requirements and assess integrated system
- Natural Environments – Define natural environments

System Integration

Definition: Assembles and tests the integrated system to ensure that it's ready to fly

- Integrated Avionics and Software – Perform avionics and software integration across the Enterprise
- Integrated Test and Checkout (ITCO) – Develop integrated test and checkout objectives for use at KSC prior to launch including:
    - Cross-Program Launch Site Integrated Test and Checkout Plan
    - Launch Site Integrated Test Objective Reports
    - Cross-Program Communication System End-to-End (CS ETE) Test Plan
    - Cross-Program Integrated Vehicle Modal Test Plan
- Operations Maintenance Requirements and Specifications (OMRS) Panel – Manage OMRS development for integrated vehicle assembly and testing
- Ground H/W Integration – Develop cross-program plans and coordinate ground hardware integration activities
- Logistics Integration – Develop integrated logistics strategy for ESD
- Launch Commit Criteria (LCC) Panel – Manage LCC development for system and environmental constraints to launch

Interfaces

Definition: Ensures that all inter-program interface products are developed on schedule and that the content meets the needs of the interfacing programs and key stakeholders

- Orion to SLS
    - Orion Multi-Purpose Crew Vehicle (MPCV) Program-To-Space Launch System (SLS) Program Interface Requirements Document (IRD)
    - Project Orion Interface Control Documents Orion Multi-Purpose Crew Vehicle (MPCV) Program-to-Space Launch System (SLS) Program
        - Hardware
        - Command and Data Handling (C&DH)
- Orion to EGS
    - Orion Multi-Purpose Crew Vehicle (MPCV) Program To Ground Systems Development and Operations (GSDO) Program Interface Requirements Document (IRD)
    - Project Orion Interface Control Documents Multi-Purpose Crew Vehicle (MPCV) to Ground Systems Development and Operations Program (GSDO) Volume 1: Hardware
    - Project Orion Interface Control Document Orion to Exploration Ground Systems (EGS) Interface Control Document (ICD) for EM-1/EM-2
        - Orion to EGS Software Interface
        - Radio Frequency (RF)
- SLS to GSDO
    - Space Launch System Program (SLSP) to GSDOP Interface Control Document (ICD)
        - Functional Interface Definition and SLSP Integrated Vehicle-to-GSDOP Detailed Design

        - SLS Booster. Core Stage, ISPE and C&DH to-GSDOP Detailed Design (06-10 for Block 1B)
- Mission Systems to SLS interfaces
    - Space Launch System Program (SLSP) SLS-to-Mission Systems Interface Control Document (ICD)

Operations Integration

Definition: Develops and defines integrated systems and plans required to operate the system through mission completion.

- Mission Integration – Develop the mission requirements technical baseline, define plans and processes for mission definition and execution
- Launch Integration – Develop launch countdown operations and launch planning
- Flight Operations – Develop flight techniques, processes, plans, and flight rules for flight planning and operations
- Landing and Recovery – Develop requirements and operations for landing and recovery, coordinate with DOD
- Range Safety – Manage Range Safety efforts across the Enterprise
- Comm/Network – Develop overall communication, tracking, & network strategy and architecture including: Cross Program Spectrum Management Plan

SLS Systems Engineering & Integration

The SLS Systems Engineering & Integration (SE&I) Office is responsible for execution of the operational planning and integration of the SLS vehicle and systems engineering to also include the development of flight software, execution of software and hardware system level tests, test readiness, vehicle configuration, vehicle verification, and flight readiness certification. The SE&I Office, working collaboratively with the OCE and SMA, integrate with ESD, Orion, EGS, Prime Contractors, and secondary payload providers from integrating and certifying the generational development of the SLS (i.e., Block 1 un-crewed/crewed, Block 1B crewed, and Block 2 Crewed) to flight readiness certification. The following paragraphs will provide a functional description for the SLS SE&I functional areas of: Cross-Program Integration, Payload Integration and Vehicle Evolution, Configuration and Data Management, Launch Integration and Mission Ops, Integrated Avionics & Software, Integrated Flight Certification, System Engineering and Verification, System Analysis and Integration, and Flight Safety System Integration.

SLS SE&I Functions

Cross Program Integration

Definition: The Cross Program Integration Team serves as a primary focal point for communicating, developing, and managing the interdependencies (Data and Hardware agreements) that are required to be exchanged between the Programs. Serving as the liaison between other SLS SEIO teams and CSI personnel to assure the cross-program communication is carried out in an effective manner. Primary areas of support are listed below:

- CPIT Leadership
- CP Interdependencies
- Liaison to CSI

Payload Integration & Vehicle Evolution

Definition: The Payload Integration and Vehicle Evolution office is responsible for the development, management, and implementation of all requirements, processes and activities associated with integrating payloads into a specific mission on the Space Launch System. In addition, they lead the development and assessment of future capabilities at the direction of the Program. Primary areas of support are listed below:

- Payload Utilization & Implementation
    - PLITT Support
    - Payload Integration Plan (PIP)
    - Payload Agreements
    - Interface Contract Documents / Safety Requirements
    - PL Management
- Vehicle Evolution
    - Performance roadmap
    - Performance Analysis
    - Element allocation

Configuration and Data Management

Definition: The Configuration and Data Management Office is responsible for the development and execution of requirements, policies and procedures for the effective management of the technical baseline of the SLS Program as well as cross program delegated products. Primary areas of responsibilities are listed below:

- Technical Baseline Configuration Management
- Model and Data Management

Launch Integration and Mission Ops

Definition: The Launch Integration and Mission Operations Team is responsible for the development and execution of SLS requirements and processes for Launch integration and Mission Operations support. This includes managing the support infrastructure systems development and management for the real time supports of integrated test and launch operations. Primary areas of responsibilities are listed below:

- KSC RMO
- Vehicle Assembly & Integration Planning
- Vehicle Assembly & Integration Test & Checkout
- Launch and Flight Operations
- Integrated Logistics Analysis and Support

Integrated Avionics & Software

Definition: The Integrated Avionic & Software Team is responsible for numerous areas within the SLS Program as well as the Cross Program Team. They are responsible for the development and execution of SLS requirements for vehicle software, the actual flight and cross program simulation software infrastructure, design and maintenance of the System Labs that enable software development and enterprise system level certifications and managing the interface requirements for the cross program delegated functions. Primary areas of responsibilities are listed below:

- Avionics, Power and SW Technical Integration

- FSW Development and Certification
- Integrated Testing and Facilities
- Cross Program Interfaces and Verifications (SLS-MS; SLS to CTN)
- Electrical Implementation Engineering (RF Analysis, Link Margin, etc.)

Integrated Flight Certification

Definition: The Integrated Flight Certification Team is responsible for the development and execution of SLS requirements and processes for supporting the integrated Certification of Flight Readiness (CoFR) process. This includes the integration of the SLS Element processes to support the overall ESD process which is intended to assure that the hardware and systems are ready to support a risk informed launch campaign. Primary areas of responsibilities are listed below:

- ESD Flight Cert
- SLS CoFR Planning and Implementation
- Lead SLS System Acceptance Reviews
- Program representative for hardware acceptance reviews

System Engineering and Verification

Definition: The Systems Engineering and Verification Team is responsible for the development and management of SLS design requirements and processes for supporting the certification of the SLS vehicle. This includes the planning and execution of the program level reviews that lead to the successful design certification at the Element and Program level, including the Cross Program delegated functions. Primary areas of responsibilities are listed below:

- Element Integration that includes internal interface management and verification
- Engineering Tools Management
- Program V&V Planning and Implementation
- Design Certification

System Analysis and Integration

Definition: The Systems Analysis and Integration Team is responsible for developing and managing a wide variety of analysis products for the SLS Program and the Cross Program Enterprise. This includes the development and integration integrated trajectories, loads and environments for the Enterprise. Primary areas of responsibilities are listed below:

- Engineering Analysis
    - Induced Environments
    - Loads & Dynamics
    - Propulsion
    - Vehicle Management
    - Production
- System Assembly & Integration Requirements

Flight Safety System Integration

Definition: The Flight Safety System Integration Team is responsible for the overall development and certification of the SLS flight safety system. This include serving as the interface to the EGS ground systems architecture as well as the interface for implementing the requirements and processes managed by the 45th Space Wing who is responsible for protecting the public from adverse effects of launch vehicles. Primary areas of responsibilities are listed below:

- Define & Verify FSS Requirements
- Vehicle FSS Analysis
- FSS Architecture
- CPI Range Safety ITT Rep for SLS
- AFSS/Range of the Future
- Human Exploration Range Safety Panel Member

Appendix D: System ground and flight software

The SLS Flight Software (FSW) provides centralized autonomous nominal and off-nominal operation of the integrated SLS vehicle from start of Autonomous Launch Sequence (ALS) through Core Stage Disposal. Consisting of 50,000 logical source lines of code, the software executes on the 3 SLS Core Vehicle Flight Computers providing support for vehicle integration, testing, and pre-launch operations.

The FSW is based on a triplex voting avionics architecture and performs the major functions of:

- Autonomous mission management following hand-off from Exploration Ground Systems
- Execution of Guidance, Navigation, and Control algorithms
- Management of vehicle sub-systems, including Boosters, Main Propulsion System, Electrical Power System, Core Stage Engines, Core Stage Thrust-Vector Control System, Rate Gyro Assemblies, Redundant Inertial Navigation Unit, Command and Telemetry Computer
- Management of the Flight Computer Operational Group, including synchronization, reliable data exchange, and output voting
- Vehicle Fault Management, Cautions, Warnings, and Abort Recommendations
- Command and Data Handling, including Telemetry
- Management of and communication via bus interfaces to EGS, MPCV, and ICPS
- Calculation of Mission Elapsed Time, Absolute Time, and Navigation Time.

ESD data integration is managed using the Artemis Data Integration Tool Suite. Data integration provides a method of relating and exchanging data from a variety of applications, data repositories, and services that are distributed among multiple centers, networks, providers and owners. Comprising of approximately 70,000 lines of code, the system consists of structured data with bidirectional linking for durable relationships. The system houses over 200,000 data records for HEOMD programs and manages interfaces to external systems to provide access to millions of program specific data including:

- ESD Data Integration Strategy
- High Availability & Operations
- Integrated Avionics Software assessment environment
- Cross-Program Interdependencies
- Design Math Model Metadata
- Failure modes and effects analysis
- Hazard analyses
- Government mandatory inspection points
- Launch commit criteria
- Operations and maintenance requirements and specifications
- Problem reporting; non-conformances
- Enterprise data viewer/browser
- Success Criteria, Statements of Readiness, Records of Completion
- SE&I Data Viewer (Functions, Requirements, Verifications)
- HEO Requirements
- ESD and SLS Functional Decomposition
- Launch Site Assembly and Integration Baseline
- Operational Controls Agreements Database
- Enterprise custom reports
- Enterprise search
- A catalog of as-delivered schematic PDFs for search / browse

- A web-based environment to communicate and coordinate around changes to the baseline

Cross program integration laboratories, housed with emulator and simulators, are used to support the ESD software development, integration, and operator training. These integration laboratories provide the capability to support the software development and integration activities throughout the software life cycle.

Emulators and Simulators

- SLS High-Fidelity Advanced Digital Emulator (SHADE)
    - Emulation of SLS avionics and interfaces
    - Contains models of the flight computers, CTC, Core Stage Avionics, Flight Dynamics, Booster, RS25 Engine, MPS, Power, and TVC
- Software Only CEV Risk Reduction, Analysis, and Test Engineering Simulator (SOCCRATES)
    - Emulation of Orion Avionics Interfaces
- ICPS Emulator
- GSDO Advanced Hardware LCS Emulator (GAHLE)
    - Emulation of EGS SCCS LCS Hardware
    - Supports all vehicle umbilical data gateways, displays, application software, and user consoles
- CAIDA Advanced Telemetry Tool (CATT)
    - Used to modify telemetry between emulators and the SCCS Gateways at the CAIDA. It can also be used in place of an emulator to drive data patterns for channelization and performance testing.
- Exploration Upper Stage Emulator *(To be developed)*

Various versions of the SHADE and SOCCRATES emulators were developed to meet the needs of the development and software integration activities at the respective locations to support specific needs of the EGS software, FSW software, and MPCV software communities.

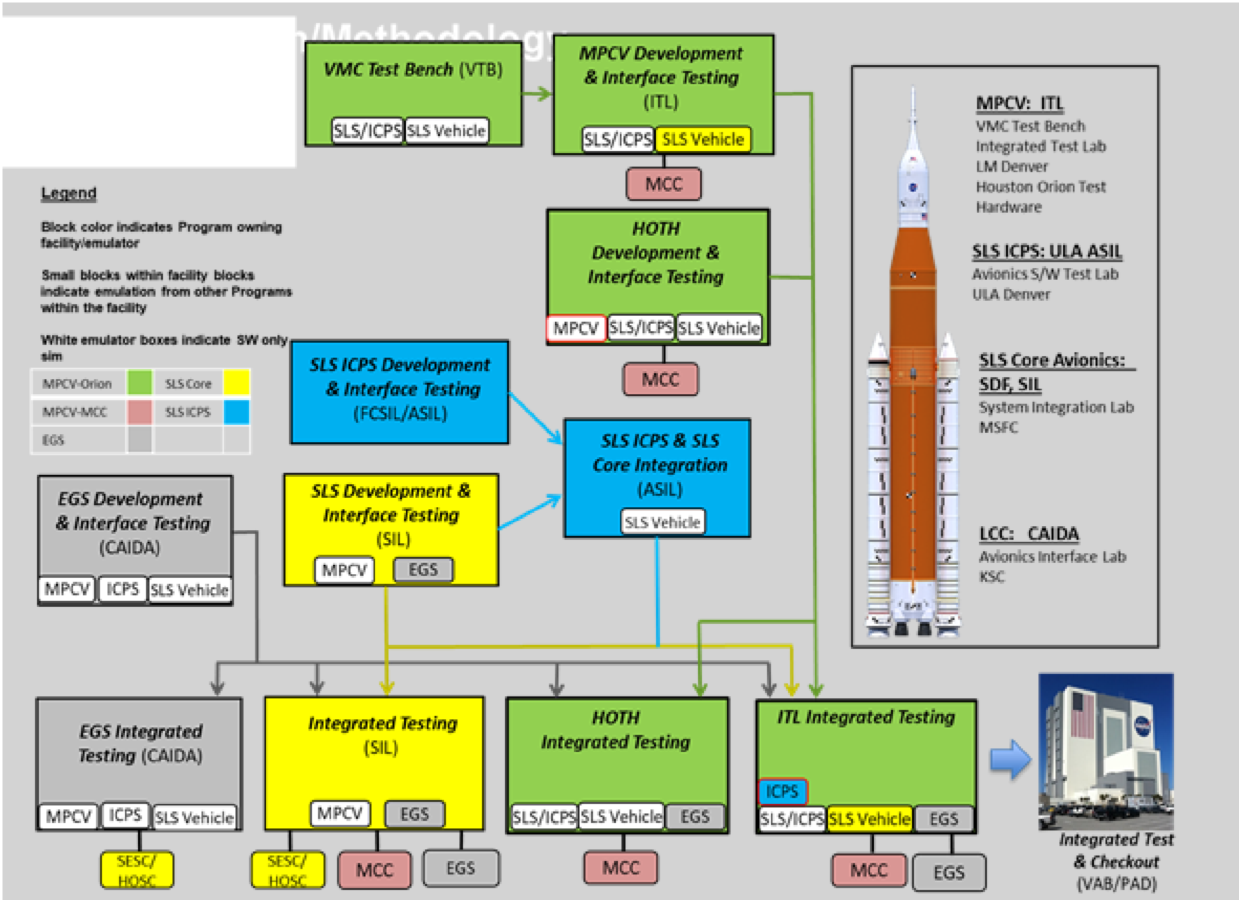


Figure 3 - Depiction of the ESD flight software and interfaces between elements for Block 1 configuration. EPOC would be expected to maintain SLS flight software and provide emulators to EGS and MPCV.

Appendix E: Facilities

Majority of government-owned facilities used in the production, operations and maintenance of the EPOC system. NASA will make available the facilities used to support these tasks, and will partner with industry on upgrades, modifications, etc. on an as-appropriate basis. It is expected that the current government-owned facilities will remain as such, and that some facilities will be designated Industrial Operating Zones or could become government-owned/contractor operated. These might include (but are not limited to):

Booster Fabrication Facility (BFF) - 45-acre site at KSC used to refurbish, manufacture, and assemble the aft skirt assembly and forward assembly for the SLS boosters. Includes the Multi-Purpose Logistic Facility used to receive, inspect and store shipped flight hardware.

Vertical Assembly Building (VAB) - Large (456 ft H max) vertical rocket integration facility. Floor load capacity of 12 million lbs, cranes located throughout building. Handling and storage of hazardous/ nonhazardous commodities. (HB-1 is still in Shuttle platform config, HB-3 is used for stacking, HB-4 is a staging area.)

Payload Hazardous Servicing Facility (PHSF) - The Payload Hazardous Servicing Facility (PHSF) was built in 1986. It is a Level 4, class 100,000 clean room that can be used as a Payload Processing Facility (PPF) and/or a Hazardous Processing Facility (HPF). Managed by Launch Services Program, desired usage would have to be coordinated with LSP.

Michoud Assembly Facility (MAF) – 832 acre production complex located in New Orleans. MAF is one of the largest manufacturing plants in the world with 43 environmentally controlled acres (174,000 m2) under one roof. Includes two Vertical Assembly Buildings. Current site of the majority of core stage manufacturing and assembly and planned location for EUS manufacture and assembly.

Systems Integration Lab (SIL) - The Systems Integration Lab (SIL) supports end-to-end integrated avionics and software integration, check-out, verification, and validation. It demonstrates real-time flight control of a launch vehicle, such as SLS, during ascent. This lab at NASA's Marshall Space Flight Center in Huntsville, Alabama, not only includes the flight computers and avionics identical to the core stage avionics but also includes emulators for the rocket's boosters and engines, the Launch Control Center and Orion.

Systems Integrated Test Facility (SITF) - The Software Integration and Test Facility (SITF) at MSFC on Redstone Arsenal integrates and tests software specifically for the SLS Core/Upper Stage avionics system.

Software Development Facility (SDF) - This Capability Maturity Model (CMM) Level 3 certified facility at MSFC performs a complete range of flight software activities from requirements development and analysis, software processes and planning, design and development, to systems integration and development testing. Products developed at the SDF are installed and tested at MSFC's SITF.

Huntsville Operations Support Center (HOSC) – At MSFC on Redstone Arsenal, the HOSC is capable of distributing secure mission voice, video and data anywhere in the world. Includes Engineering Support

Center (SESC). Certification runs for contingencies are performed by engineers responsible for the major elements of the SLS.

SLS Engineering Support Center (SESC) - Engineering Support Center (SESC). Certification runs for contingencies are performed by engineers responsible for the major elements of the SLS. Located in the HOSC, the SESC leverages remote architecture built for the ISS Payload Operations Center to allow engineers to focus on the engines, boosters, and stages of the SLS during testing and launch.

Advanced Manufacturing and Weld Facility – Located in MSFC's Building 4755 on Redstone Arsenal, this friction stir welding facility uses advanced robotic tooling to weld barrel or dome segments up to 33 feet in diameter.

MSFC Flowrate and Structural Test Stands –Located at MSFC on Redstone Arsenal, designed to push, pull and apply pressure loads to SLS cryogenic tanks. Cutting-edge technology is also adaptable for future large-scale rockets and systems. Testing and data can be safely monitored from a control room via fiber optic cables.

Stennis Space Center – Multiple propulsion testing facilities for components, engines and stages located near Bay St. Louis, Mississippi. Facilities include the B-2 test stand used for the SLS core stage green run. Formerly used for Saturn V and Space Shuttle testing, this stand is equipped with a 195-ton (US), main derrick, lifting crane, with a 20-ton jib crane and is capable of static-firing test articles up to 33 ft in diameter.

Appendix F: Virtual Industry RFI Forum Information

The forum will take place on 10 Nov, 2021, 11:00 CT

Submit registration request / questions to: MSFC-EPOC@mail.nasa.gov

Deadline for registration request / questions: 2 PM CT, 02 Nov, 2021

Please provide the following information to request attendance at the Virtual Industry RFI Forum:

EPOC Virtual Industry RFI Forum Registration Request

Name:

Company:

Company Location:

Email Address: