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SPACE LAUNCH SYSTEM PROGRAM (SLSP) LOGISTICS SUPPORT ANALYSIS (LSA) REPORT

VERSION AND HISTORY PAGE

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Released	1	Initial Release of SLS DRD 1406OP-012 for SLS PDR, MSFC 4511 Concurrence on file	04/26/13

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1.1 Scope

The scope of this LSA Report is to provide the results of the Logistics Support Analysis (LSA) activities leading to the SLS Preliminary Design Review (PDR). Current activities include the Front End Analyses (Use Study, Comparative Analyses, Supportability Design Factors), Maintenance Concept development, Off-nominal Timeline Analysis, Supportability Assessment, LSA Record database, SLS Support System Alternatives determination, Launch Availability (LA) and System Readiness (SR) assessments, supportability Technical Performance Metrics (TPMs) assessments, supportability risks and mitigations, LSAR Database development, LSAR Team meetings, and Technical Interchange Meetings (TIMs). The LSA efforts for the Project Elements were tailored to focus on the flight development program and also selected to provide the foundation for data collection to support conducting supportability Trade-off assessments post PDR.

Interfaces with the R&M plans and requirements are key aspects of the LSA approach. As stated in the SLS-PLAN-013, SLS Program Safety and Mission Assurance (S&MA) Plan, the objective of the SLS supportability program is to assure that the SLS meets operational and supportability objectives at minimum life cycle cost. The various supportability activities and analyses are highly dependent upon close interaction with reliability and maintainability activities and data. It is important to the success of the supportability program that a close working relationship be established early among S&MA, Operability, Logistics, and Engineering groups to assure effective interaction and timely exchange of information.

1.2 Purpose

The purpose of the LSA Report is to document the in-process LSA tasks for the SLS PDR. One of the critical activities for successful LSA approach is tailoring of the tasks based on the acquisition phase and the extent of design influence that can be achieved for a typical major system development program. With the SLS acquisition approach, the level of design influence varies for each major Element (Project Element). Therefore, each Project Element will be responsible for tailoring of their respective LSA tasks, with guidance from SLS Vehicle.

1.3 Change Authority/Responsibility

The NASA Office of Primary Responsibility (OPR) for this document is EO40.

Proposed changes to this document shall be submitted by an SLS Program Change Request (CR) to the Chief Engineer's Control Board and Program Control Board for disposition. All such requests shall adhere to the SLS-PLAN-008, SLS Program Configuration Management Plan.

2.0 DOCUMENTS

2.1 Applicable Documents

The following documents include specifications, models, standards, guidelines, handbooks, and other special publications. The documents listed in this paragraph are applicable to the extent specified herein. Unless otherwise stipulated, the most recently approved version of a listed document shall be used. In those situations where the most recently approved version is not to be used, the pertinent version is specified in this list.

NPD 7500.1 Revision C	8/17/2012	Program and Project Life-Cycle Logistics Policy
SLS-PLAN-008 Revision A	8/17/2012	Space Launch System Program (SLSP) Configuration Management Plan
SLS-PLAN-013	7/12/2012	Space Launch System Program (SLSP) Safety and Mission Assurance (S&MA) Plan
SLS-PLAN-022	12/8/2011	Space Launch System Program (SLSP) Insight/Oversight Plan
SLS-PLAN-047 Revision A	9/13/2012	Space Launch System Program (SLSP) Technical Metrics Plan
SLS-RQMT-014 Revision A	7/12/2012	Space Launch System Program (SLSP) Safety and Mission Assurance (S&MA) Requirements
SLS-RQMT-161 **<TBR-001>**	Not Released	Space Launch System Program (SLSP) Human Systems Integration Requirements (HSIR)

2.2 Reference Documents

The following documents contain supplemental information to guide the user in the application of this document.

DD1149	Department of Defense Form 1149 Requisition and Invoice/Shipping Document
DD250	Department of Defense Form 250 Material Inspection and Receiving Report
ESD 10012	Exploration Systems Development (ESD) Concept of Operations
GEIA-STD-0007-A	Logistics Product Data
GSDO-PLN-1070 Not Released	Exploration Systems Logistics Integration Plan (ESLIP)

MIL-STD-1388-1A	Military Standard: Logistics Support Analysis
MIL-STD-1388-2B	Military Standard Department of Defense (Dodd) Requirements for a Logistics Analysis Support Record
NASA/SP-2007-6105	NASA Systems Engineering Handbook
NASA-STD-0005	NASA Configuration Management Standard
NASA-STD-8719.12	Safety Standard for Explosives, Propellants, and Pyrotechnics
NPD 8730.2C	NASA Parts Policy
NPD 8730.5	NASA Quality Assurance Program Policy
NPR 4200.1	NASA Equipment and Management Procedural Requirements
NPR 5900.1	NASA Spare Parts Acquisition with Change 2
SLS-PLAN-001	Space Launch System Program Plan
SLS-PLAN-003	Space Launch System Program (SLSP) Systems Engineering Management Plan (SEMP)
SLS-PLAN-004	Space Launch Systems Program Data Management Plan
SLS-PLAN-020	Space Launch System Program (SLSP) Concept of Operations
SLS-PLAN-036 **<TBR-002>**	Space Launch System Program (SLSP) Certificate of Flight Readiness (Cover) Implementation Plan
SLS-RPT-087 **<TBR-003>**	Space Launch System Program (SLSP) Integrated Mission and Fault Management (M&FM) Design Analyses and Performance Assessment
SLS-SPEC-030-01 **<TBR-004>**	Space Launch System Program (SLSP) Support Equipment Specification, Volume I: Support Equipment Planning
SLS-SPEC-030-02 **<TBR-005>**	Space Launch System Program (SLSP) Support Equipment Specification, Volume II: GSE Design and Construction Requirements
SLS-SPEC-030-03 **<TBR-006>**	Space Launch System Program (SLSP) Support Equipment Specification, Volume III: Derived Requirements
SLS-SPEC-030-05 **<TBR-007>**	Space Launch System Program (SLSP) Support Equipment Specification, Volume V: Heritage Ground Support Equipment (GSE) Certification Process Plan
SLS-SPEC-032	Space Launch System Program (SLSP) System Specification
SLS-SPEC-043 **<TBR-008>**	Space Launch System Program (SLSP) Vehicle Operations and Maintenance Requirements Specification (VOMR)

3.0 EXECUTIVE SUMMARY

The Integrated Logistics Support Team and the LSAR Team (sub-team to the ILS Team) are responsible for performing Logistics Support Analyses for the design of the SLSP Vehicle to ensure compliance with the supportability objectives and Integrated Logistics Support requirements defined in the SLSP ILSP. The LSA includes Front-end Analysis, evaluation of system alternatives and trade studies, identification of Maintenance Significant Items (MSIs), LSAR database development, and supportability requirements assessments. These activities are supported by bi-weekly LSAR Team meetings and semi-annual Technical Interchange Meetings (TIMs).

3.1 ILS Roles and Responsibilities

The development and integration of the ILS elements data, parts, equipment, and services required for launch at KSC, is essential to optimal launch support contingency operations. Especially since the Project Element data is being developed for a development "two flight" program. The roles and responsibilities between the SLSP and the GSDO for KSC launch operations are represented in the Figure 3.1-1.

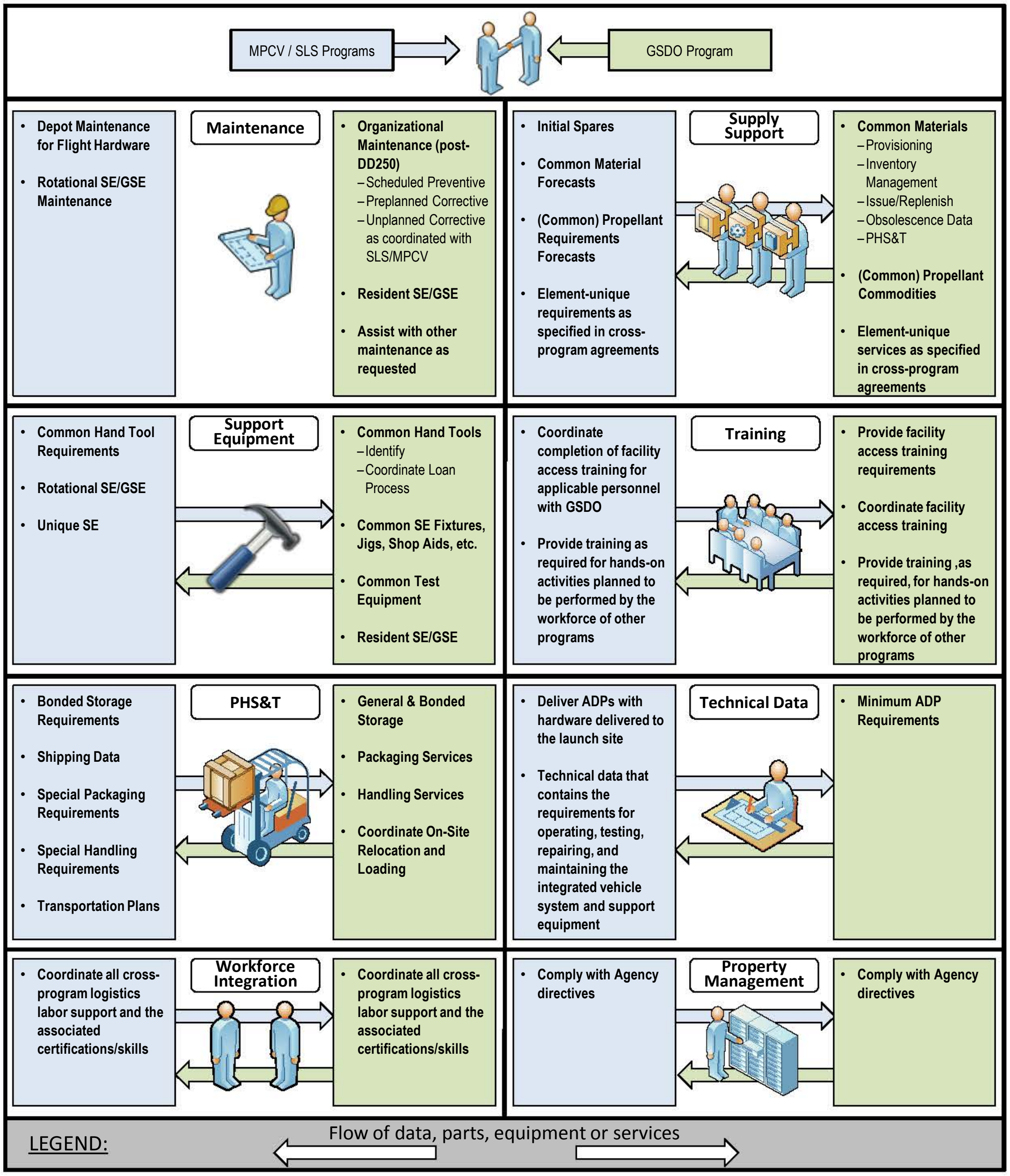


Figure 3.1-1 Integrated Logistics Support Programs Roles and Responsibilities

The LSAR Team is working to establish the data requirements to support this R&R diagram with the specific Logistics Support Documentation to be provided to KSC with the approach that SLSP Documentation will be tailored to support Block 1 activities. Current plans are to provide this data through the PowerLogJ software and select reports will be delivered to KSC for off-nominal activities. Section 8.0 details the specifics related to the LSAR Team and the approach to data documentation and delivery.

These LSA activities will identify opportunities to enhance SLS supportability and reduce costs. Figure 3.1-2 provides the process flow for implementation of supportability engineering analyses activities and to ensure supportability concerns are being considered during SLS design.

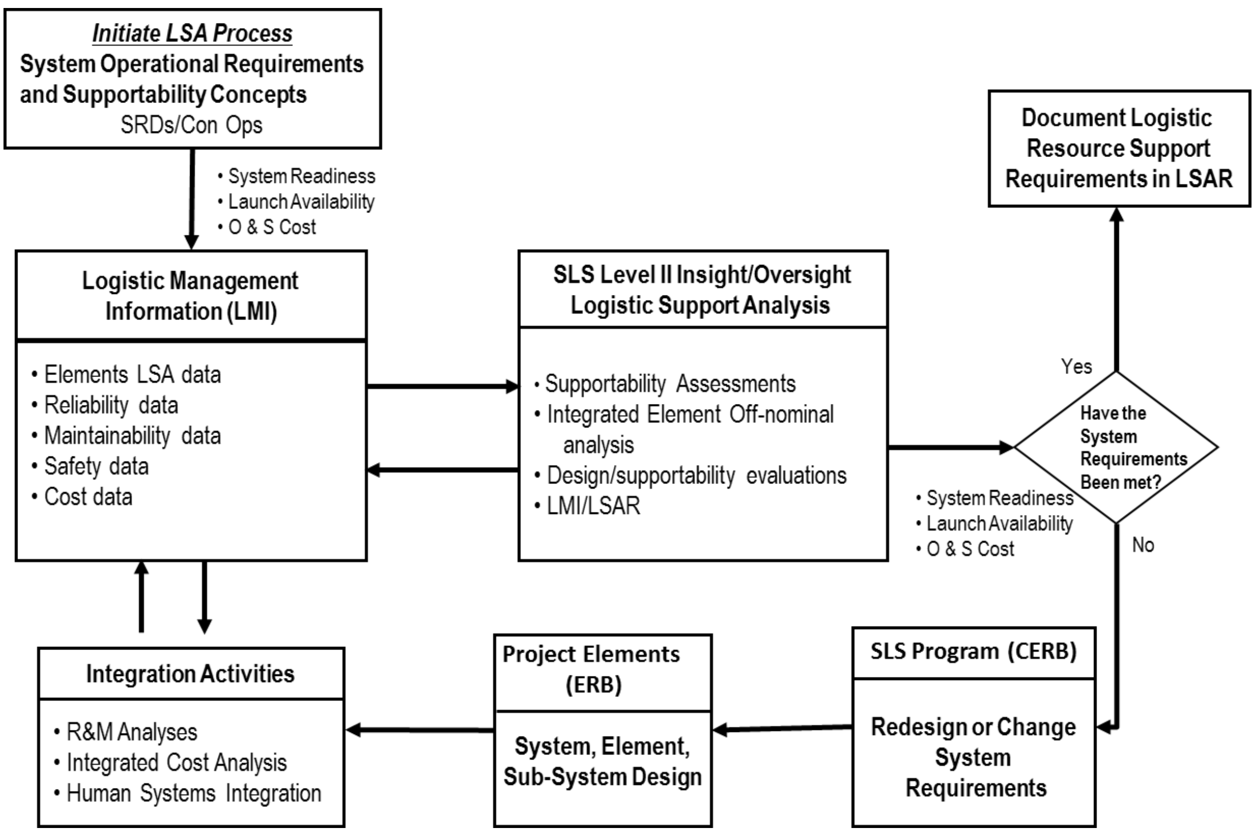


Figure 3.1-2 Supportability and Logistics Engineering Implementation Process

3.2 LSA PDR Activities and Assessments

There are several activities to be accomplished for a detailed and complete LSA program to support Block 1 and the operational 30 year program. SLSP ILS Team is responsible for conducting an integrated analysis to define the support system and provide that analysis to GSDOP for facilitation of the cross program integration. This report provides the integrated LSA activities for the SLSP for PDR. The Project Elements are responsible for conducting their own studies and documenting concepts in their ILSPs. Below is a listing of activities performed and documented in this Report.

- Conduct Front End Analyses (Use Study and comparative systems).
- Develop the maintenance concept, support concepts and support system alternatives.
- Identify qualitative cost drivers.
- Conduct alternative support system trade-off studies.
- Develop, analyze and maintain Maintenance Significant Items components list.
- Identify supportability risks and risk reduction approaches.
- Conduct supportability assessment.
- Establish and maintain logistics support analysis record (LSAR) and logistics control numbering system.
- Develop and maintain the Level II Integrated Logistics Support Plan (ILSP) (SLS-PLAN-025) and the Supportability Operations Assessment Report (SOAR) (SLS-RPT-168).
- Establish ILS and LSAR teams as required to support the ILS Activities.

This list will be re-examined at each major milestone to determine the products/activities to be accomplished. Many of these activities, initiated during this design phase, will carry forward to SLSP Critical Design Review (CDR) phase. Other tasks listed in the ILSP will be initiated post PDR and conducted during the CDR phase. The Integrated Master Schedule of the activities is currently in planning and a draft schedule is attached in Appendix C.

Below is a synopsis of each task listed above with the referenced section for the details.

Conduct Front End Analyses (Use Study and comparative systems). (Section 4.1, 4.2) The purpose of the Front-end Analysis is to analyze mission scenarios, conduct comparisons, and define supportability factors for design influence. A Use Study on supportability requirements (TPMs) and Baseline Comparative System (BCS) Assessment on similar vehicles were the two LSA tasks selected for this analysis. The Use study was performed to identify supportability objectives, goals and parameters to be used for evaluations, assessments and trade off analyses. The BCS assessment was utilized to identify potential supportability and readiness drivers and identify potential support alternatives. Assessments of the SLSP System requirements were performed to evaluate SLSP and project element TPMs. Results of this analysis were used to develop the maintenance concept and alternatives for SLSP.

Develop the SLS Program maintenance concept, support concepts and support system alternatives. (Section 4.3) The maintenance concept is a planning guide for influencing system design and to establish the framework for development of the maintenance plan. Flight and ground hardware design engineers will ensure that systems are maintainable and supportable using a maintenance concept that includes launch site operational logistics support infrastructure, manufacturer facilities, and interim original equipment manufacturer (OEM) capabilities.

Identify SLSP qualitative cost drivers. (Section 4.4) Determine the cost drivers for SLSP. The SLS life cycle cost analyses (LCCA) are bottoms-up engineering analyses performed by the SLS system for determining total ownership cost (TOC). The SLS Elements are responsible for identifying costs associated with their Element. The SLSP ILS team is responsible for integrating the SLS Elements' costs and providing an LCCA input that identifies the P&O costs in support of the PP&C/XP03 office which is the OPR for the SLSP LCCA Report, SLS-RPT-096 per agreement with the PP&C office and SLS Chief Engineer.

Conduct SLS alternative support system trade-off studies. (Section 4.5) Evaluation of Alternatives and Trade Studies is used to determine preferred support alternative(s) and their associated risks for the SLSP system. Assessments of Launch Availability (LA), System Readiness (SR) were conducted along with specific "what ifs" to assess identified risks. This can be accomplished by conducting trade-off analyses of all alternatives and identifying which one provides the best balance for cost, schedule, performance, readiness, and supportability. Integration of these analyses with the R&M modeling and analyses and the Maintainability modeling and analyses described in the SLS-RQMT-014, Space Launch System Program (SLSP) Safety and Mission Assurance (S&MA) Requirements is critical to increased fidelity and accuracy when conducting the trade-off studies.

Develop, analyze and maintain Maintenance Significant Items (MSIs) components list. (Section 4.6) Identification of MSIs was conducted by the Project Elements using similar set of criteria and evaluation techniques. The MSI candidate list will continue to be assessed against mission requirements, as the Maintenance Engineering Analysis (MEA) defines timelines and design matures to develop LRU candidates and determine final LRUs for CDR.

Identify supportability risks and risk reduction approaches. (Section 4.7) The purpose of this effort is to determine the preferred support system alternative(s) and their associated risks for the SLSP system. This will determine, through trade-off analyses the potential risk that may not meet the support, design, and operation requirements for schedule, performance, readiness, and supportability, and to evaluate the new system support alternatives with regard to the proposed design, operation, and support concepts.

Conduct Project Elements supportability assessment. (Section 5.0) SLSP Supportability requirements assessments are to determine the maturity of analysis of design with respect to supportability for the SLSP PDR. SLSP ILS Team worked with Project Elements to determine if ILS elements have been assessed for compliance and appropriate risks identified.

Establish and maintain logistics support analysis record (LSAR) and logistics control numbering system. (Section 6.0) The LSA process is conducted on an iterative basis through all phases of the system/equipment life cycle to satisfy the support analysis objectives. LSA documentation, including LSAR data, is generated as a result of the analysis tasks specified in the LSA Tasks. LSAR documentation is generated in all phases of the system/equipment life cycle and is used as input to follow-on analyses and as an aid in developing logistics products. The LSAR data shall serve as the ILS technical database applicable to all SLSP and Project Elements. The specific data entry media, storage, and maintenance procedures are left to the Project Elements.

Develop and maintain the Level II ILSP and SOAR. (Section 7.0) The SLSP ILSP delineates how logistics and supportability engineering and management concepts will be applied to the Space Launch System Program (SLSP). The ILSP identifies and plan the integrated logistics support required to achieve the program operational goals. These goals include improving readiness, assuring availability, and lowering total cost of ownership by minimizing the logistics footprint required for operational sustainment. This plan addresses how the elements of Integrated Logistics Support will be integrated with disciplines set forth in other SLS program documents. The ILSP addresses supportability engineering analyses to be performed during SLS design and development and physical logistics support for the operational phase of the SLSP. The ILSP is to be baselined for PDR and has been submitted as a category 2 document. The SOAR assesses the baselined design for operability and supportability, and each individual design change to the baseline. Each assessment will be against a set of operational criteria based on the deleted operability and supportability requirements, vehicle operations, and maintenance requirements.

Establish ILS and LSAR teams as required to support the ILS Activities. (Section 8.0)
The ILS Team hosts monthly meetings to resolve supportability issues, LSAR database team meet bi-weekly to discuss Logistics Support Documentation and coordinate bi-annually TIMs to discuss the extensive Logistics Support Analyses being performed to ensure compliance with the supportability objectives and Integrated Logistics Support requirements.

Key results:

- **Maintenance/support concept**
  - There are two physical locations at which maintenance will be performed for SLS: Kennedy Space Center (KSC) and the manufacturing site.
  - Maintenance allocations by location are determined by access (external and internal), weight of LRUs, hazardous processing, availability of tools and test equipment. Maintenance actions are distinguished by whether de-stacking is required to perform a maintenance function on a given item.
  - Project Elements have varied approaches but fit within the SLSP maintenance concept. These variations will be assessed in the next design phase to determine the support alternative that meets the Block 1A flight test and ultimately the operational support system requirements.
  - No pad access can have impacts on LA and number of rollbacks between launch attempts.
- **SLS alternative support system trade-off assessments**
  - When assuming a 3-8-7 shift schedule, the Block 1, Block 1A (Solid), and Block 2 (Solid) can achieve an LA of 96.7% or greater. The LA of the Block 1A (Liquid), Block 1B, and Block 2 (Liquid) have an LA of 96.3%, 96.3%, and 96.2% respectively. With the assumption of a 3-8-7 shifting over 80% of the failures can be repaired within the 30 calendar days, but the MDT threshold of 85% at 20 calendar days is still not met by any of the cases.
  - LDT assessment had Case 1-4 look at the worst case scenarios for having a logistic delay associated with every off-nominal event that occurs. Case 5 looks at a mixture of logistic delays occurring. The result of this analysis shows a decrease in LA from 97.3% to 94.9% and shows that the logistics delay has an impact on the vehicle.
  - The only Element that has an issue with battery life right now is Boosters. The batteries used by Boosters, which are installed prior to IVT, have a life of 109 days, which will be violated before launch. Since the Booster silver zinc batteries

cannot be recharged this likely means that Boosters will need to have another set of batteries at KSC to be installed in the vehicle sometime prior to the FTS test and roll-out.

– The results shown in Table 4.5.8.2-1 show that that the Booster procedure delay has no impact on SR. This is due to the minimal number of Booster failures that occur during the processing of the vehicle as compared to Core Stage or Engine failures.

- **Supportability issues and candidate risks.**

– Block upgrades could affect the positioning and number of: *PAD Access (Consistent Elevations), Vehicle Assembly Building (VAB) platforms, Umbilical Locations, Services (i.e., RP for advanced boosters), and Support Equipment required.* **(Candidate Risk 11626)**

– Current planning by Ground Systems Development and Operations Program (GSDOP) is for no pad access; this leads to the possibility for rollback and possible launch delays. Lack of vehicle access on the launch pad for repair will impact LV: *R-15 Launch, Availability Requirement, Maintenance Downtime, and System Readiness.* There is currently a trade study being conducted to look at this risk further (SLS-TRADE-019). **(Candidate Risk 11629)**

– Given the limited development test baseline and the associated development of processing procedures, there is a possibility processing procedures will not be in place to meet first launch date at KSC. (**Candidate Risk 11632)**

Supportability issues:

– Given the fixed budget for Project Element hardware production, there is a potential of not having sufficient spares. **Issue - Yellow (May require hardware development and potential for LLTIs)**

– Given the SLS Block 1 launch processing manifest (4-5 years with little to no activities), there is a potential of not having sufficiently trained and experienced personnel**. Issue - Yellow (May require personnel with advanced skills not readily available)**

– Given the limited / reduced maintenance concept approach, there is a potential of not having sufficient tooling / GSE for maintenance activities. **Issue - Yellow (May require hardware development for GSE)**

- Given the limited / reduced maintenance concept approach, there is a potential for a time delay for maintenance activities (schedule may be in terms of days, not shifts). **Issue - Green (limited delay, but not significant Program costs)**
- Given the limited / reduced maintenance concept approach, there is a potential of not having instructions ready for corrective maintenance task in timely manner. **Issue - Green (limited delay, but not significant Program costs)**

4.0 SLSP LOGISTICS SUPPORT ANALYSIS

The primary goal of the Space Launch System (SLS) supportability efforts are to ensure that when the SLS system is operational, it is fully operable and maintainable in its intended environment. The supportability analysis efforts will help develop an effective and economical support infrastructure for the SLSP. The early focus of the supportability analyses will emphasize developing an approach for Block 1, along with establishing supportability requirements/metrics for reducing integrated program costs for the long-term flight program. As system design progresses, the supportability analyses will be to update support system concepts alternatives, conduct evaluation of alternatives, and estimate logistics support requirements. The analyses will be iterated as the design progresses to ensure that support concepts meet defined SLS technical performance measures (TPMs).

The initial effort for SLSP was to conduct front end analyses. The purpose of the Front-end Analysis is to analyze mission scenarios, conduct comparisons, and define supportability factors for design influence. A Use Study on supportability requirements (TPMs) and Baseline Comparative System (BCS) Assessment on similar vehicles were the two LSA tasks selected for this analysis. The Use study was performed to identify supportability objectives, goals and parameters to be used for evaluations, assessments and trade off analyses. The BCS assessment was utilized to identify potential supportability and readiness drivers and identify potential support alternatives. Assessments of the SLSP System requirements were performed to evaluate SLSP and project element TPMs. Results of this analysis were used to develop the maintenance concept and the support concepts.

4.1 USE STUDY

The purpose of the SLSP Use Study is to identify and document supportability goals and objectives related to the intended use of the SLSP. The Use Study is designed to provide a foundation for the identification of supportability parameters to be used for tradeoff analyses. In addition, use study information can be used to add or verify the System Requirements necessary to optimize system supportability. The documentation of the supportability parameters in this task will feed the Comparative Analysis, and Supportability Design Factors tasks. The Use Study is accomplished at the front end of any program or project. The SLSP Use Study is focused on two specific areas: design supportability factors and providing SLSP with the lessons learned needed to configure an efficient and cost-effective support system while making maximum use of current support infrastructure. The complete Use Study is provided in Appendix D.

4.1.1 Supportability Factors

This section focuses on what capabilities and infrastructure the SLSP currently has in place to support the program. Issues and possible improvements are addressed in order to focus on improvements that could be utilized during the life of the program to reduce costs and schedule.

4.1.1.1 Operating Requirements

The SLSP is facing a number of issues related to vehicle processing, infrastructure, and personnel, among others that are in place to support a new vehicle. The Block 1 vehicle will utilize heritage solid rocket boosters (SRBs), Orion Multi-Purpose Crew Vehicle (MPCV), and RS-25 engines while designing a new core stage (CS). Requirements addressing ground operations greatly limit what can be done to the vehicle at the launch site (Kennedy Space Center (KSC)) as well as limit NASA's ability to modify or upgrade the vehicle design.

This philosophy creates a significant risk for ensuring a supportable design. Without upfront requirements and design integration across elements, stages, and programs, vehicle design changes are inevitable and will cost more to operate the vehicle. A number of risks have been developed by the SLS Operations team at Marshall Space Flight Center (MSFC) to address a number of foreseen issues with ground operations and processing. A few examples are listed below:

- **Candidate Risk 11626** – Given the expected, but still undefined block changes, there is a possibility that significant launch support systems changes will be required. Block upgrades could affect the positioning and number of: *PAD Access (Consistent Elevations), Vehicle Assembly Building (VAB) platforms, Umbilical Locations, Services (i.e., RP for advanced boosters), and Support Equipment required.* Any of these modifications will cost the Program millions of dollars in the future if not properly planned for, or vehicle redesign is addressed early in the design, development, test and evaluation (DDT&E) phase of the Program.

- **Candidate Risk 11629** – Current planning by Ground Systems Development and Operations Program (GSDOP) is for no pad access; this leads to the possibility for rollback and possible launch delays. GSDOP planned pad interfaces consist of the Mobile Launcher (ML) Deck and a crew access arm at specified elevation. SLS Launch Vehicle (LV) nominal operations require access at the launch pad, vehicle redesign, or process mitigation. Lack of vehicle access on the launch pad for repair will impact LV: *R-15 Launch, Availability Requirement, Maintenance Downtime, and System Readiness.* As with the above, unplanned-for access and changes to existing infrastructure will cost the program millions. There is currently a trade study being conducted to look at this risk further (SLS-TRADE-019).

- **Candidate Risk 11632** – Given the limited development test baseline and the associated development of processing procedures, there is a possibility processing procedures will not be in place to meet first launch date at KSC. Procedures for the following will be affected: *Chill down, Propellant Loading, Venting, Purge and Inerting, Detanking techniques and timelines, Prelaunch sequencing of the Main Propulsion System (MPS), Hazardous Gas detection techniques, Turnaround times from a scrub, and Demonstrate allowable hold times for launch count down.*

Along with risks that have been identified, there are other areas of concern that can affect the vehicle's cost, schedules, and NASA's ability to properly operate and process the vehicle on the ground.

Without proper integration efforts from SLSP to the Elements, the stages and individual components may be designed without proper transportation environments addressed. If the individual element's environmental constraints do not fall within expected constraints, specialized ground support equipment (GSE) for temperature and humidity control, purging, pressurization, and monitoring will need to be developed that will lead to increased costs to the Elements and Program.

Due to the use of heritage hardware and infrastructure, the design of SLSP is limited by the existing infrastructure at KSC. Below are some examples of constraints on SLSP by the existing infrastructure at KSC and Figures 4.1.1.1-1 and 4.1.1.1-2.

- High Bay (HB) crane hook height limits integrated height of the vehicle with the primary concern being the encapsulated payload.
  - 462.5 ft. hook height restricts maximum integration height to include: vehicle stack on ML, encapsulated payload integrations, CS transfer to HB, and total integrated height (see VAB Door Restrictions).
- VAB door height limits the integrated height of the vehicle.
  - The VAB door height is 456 ft. from ground level. Exact dimension is 455 ft. 10 3/8 in. per door manual.
  - Integration of the vehicle onto ML cannot exceed the door height.
- VAB door width limits the integrated width of the vehicle.
  - VAB door width is 71 ft. (per door manual). Current SLSP diameter only leaves for a clearance of 4.9 ft. on either side of the vehicle.
- VAB diaphragm height limits the stage height.

The vehicle size restraints for the VAB are listed below with illustrations:

- The SLS integrated vehicle height will be no greater than 390 feet. This constraint results from the vehicle being integrated inside the VAB and on the ML. The Block 2 cargo vehicle is the driving case for SLS. The VAB door restricts the SLS integrated vehicle height as the vehicle must pass through the door on rollout to the pad.

- The SLS vehicle element height will be no greater than 235 feet. This is a constraint for the element height resulting from the VAB diaphragm to crane hook height. The diaphragm is the opening into the VAB high bay. The SLS stage must be lifted into the high bay through the VAB diaphragm. GSE lifting devices must be accounted for as part of the lifting length.
- The SLS vehicle width will be no greater than 61 feet. The greatest width of the integrated vehicle is the core stage diameter plus attached boosters. The VAB door restricts the total width of the SLS vehicle in order for the integrated vehicle to pass through the door on rollout.

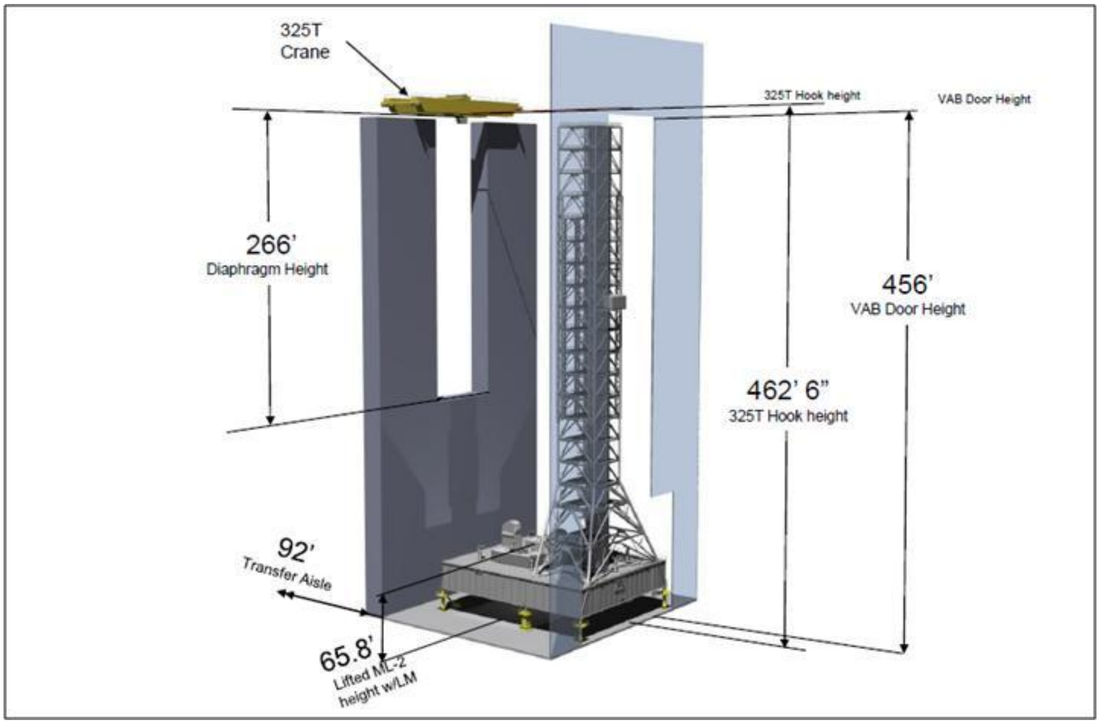


Figure 4.1.1.1-1 VAB Height Constraints

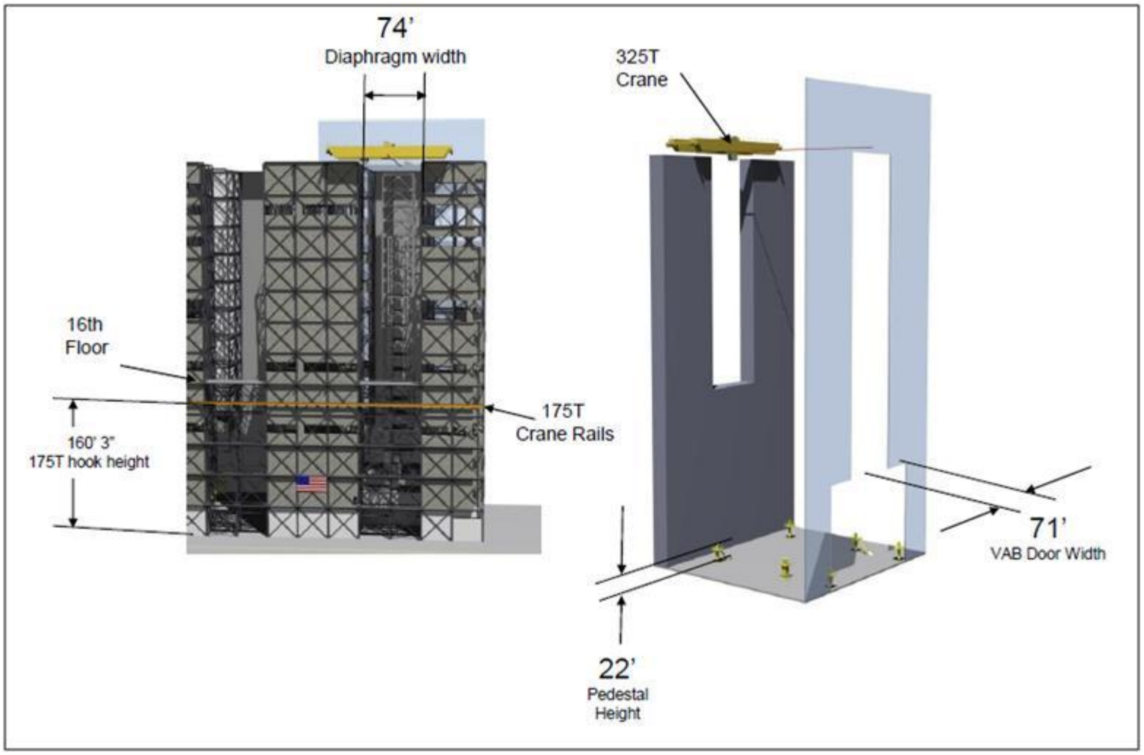


Figure 4.1.1.1-2 VAB Width Constraints

Once SLSP is out of DDT&E and has the required infrastructure in place to support the design, design changes or modifications to the existing infrastructure will cost exponentially more than if it had been addressed during DDT&E.

4.1.1.2 Maintenance Factors

In the concept and early design phases of the SLS launch vehicle, many maintenance considerations have been addressed. Design influence as well as process improvements are in work to create a more supportable vehicle and support infrastructure through design-in supportability (DIS) and supporting the design.

Operations and maintenance (O&M) requirements will be documented in a ground operations specification and used to identify and levy SLS technical requirements on the launch site. These requirements will not duplicate design, construction, assembly, and installation requirements defined by released engineering (drawings and specifications). The requirements will allow KSC to plan and schedule processing activities and ensure the necessary facilities and equipment is in place when needed. Coordination of the O&M requirements during the design phase will allow for a reduction in inspections and servicing. Also the coordination will allow optimized planning to reduce the operation timeline at KSC and optimize the use of the ground infrastructure.

Pad access at KSC was one of the first design considerations addressed to reduce the amount of activities at the launch pad. The O&M requirements were identified early to analyze for several recommendations. The recommendation to increase the number of access arms due to planned pad operations created the optimal support, while several planned pad operations were moved to the VAB to reduce infrastructure complexity.

Along with the optimization of the physical design, facilities and personnel also need to be addressed. The current element planning is for the delivery of elements when needed storage facilities are no longer required outside the VAB; the exception to this is the SRB element. Spare components will be production spares reducing the logistics storage facilities required and personnel to maintain such facilities. Vehicle integration and maintenance operations will utilize Element “contact teams” reducing the number of permanent employees required at the launch site. All of these are in the early planning of the SLSP and exceptions will be individually addressed.

Several previous systems developed and/or utilized by NASA provide many lessons learned to improving future launch vehicles. The systems used for this activity will be the STS and Ares I. The following will provide identification of design characteristics that drove maintenance cost. Items such as accessibility, testability, and personnel required will be addressed.

Accessibility - Accessibility is a major design consideration that influences the maintenance cost of any vehicle. The STS orbiter was “designed” as a reusable vehicle and was refurbished at KSC after each flight. Personnel access into the aft compartment, where the propulsion system is located, was not designed for access and required climbing around components with the risk of damaging the vehicle. The installation of a full protective kit was required around valves and propulsion system lines, drag on lighting was secured by zip-ties creating a risk for FOD, wires from lighting created a personnel tripping hazard, and lack of space created a risk of personnel damage to flight articles. Figure 4.1.1.2-1 shows the orbiter aft compartment, illustrating the difficulties associated with obtaining access within the orbiter.

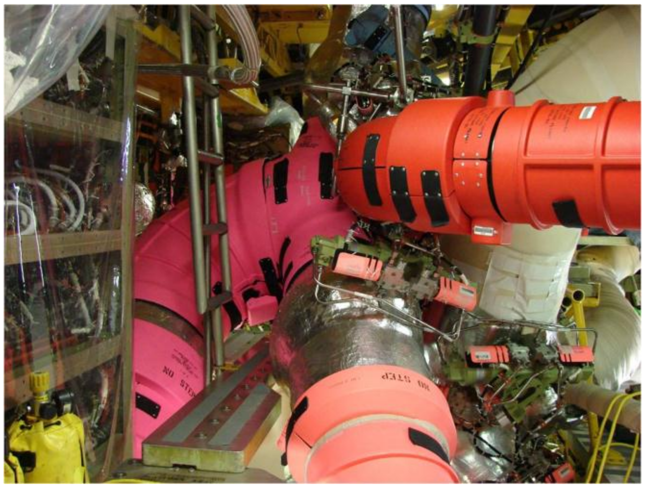


Figure 4.1.1.2-1 Orbiter Aft Compartment

During the development of Ares I, accessibility was addressed early in the design process by Supportability and Human Factors Engineers (HFE).

Personnel access within compartments of the Ares I, especially the US, was specifically designed to allow for personnel access for maintenance activities. The GSE design for the US IS compartment was designed to be modular in order to reduce the estimated time to establish access to given components for maintenance activities. Figure 4.1.1.2-2 shows the conceptual design for the modular access kit.

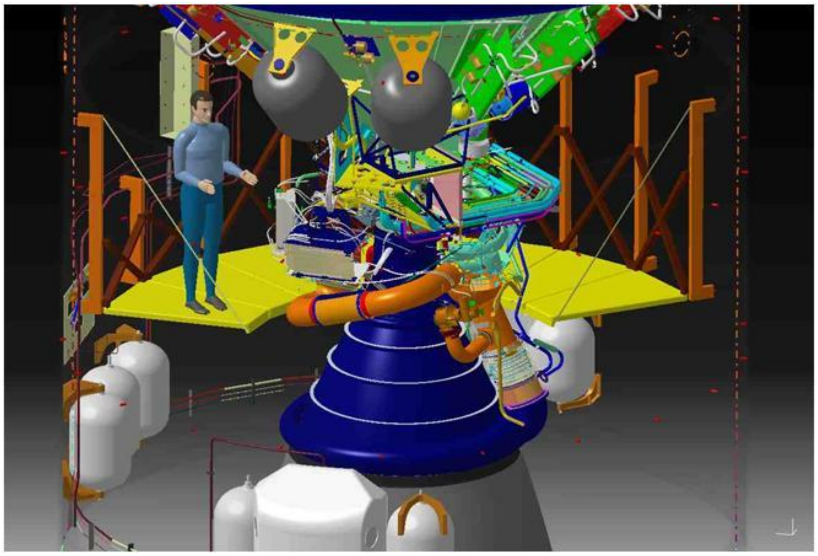


Figure 4.1.1.2-2 US IS IA GSE

Testability - Testability is a characteristic of a system pertaining to the level of ability to evaluate the system's performance for actual, expected, and/or desired behaviors versus unpredicted and/or unwanted behaviors, which is not entirely dependent on the system design (i.e., external resources and capabilities to test the system are also factors for testability). Testability is also a measure of the ability to detect system faults and to isolate them at the lowest replaceable component(s).

As technology advancements continue to increase the capability and complexity of systems, the use of automated applications or tools to perform fault detection, isolation, and recovery (FDIR) substantially reduces the need for highly trained maintenance personnel and decrease maintenance costs by reducing the erroneous replacement of non-faulty equipment, in addition to reducing the amount of time needed to restore lost or degraded functionality. The FDIR systems include both internal diagnostic systems, referred to as built-in test (BIT) or built-in test equipment (BITE), and external diagnostic systems, referred to as automatic test equipment (ATE), and test sets or off-line test equipment used as part of a reduced ground support system; all of which will minimize downtime and cost over the operational life cycle.

Manpower - Many other design issues and personnel requirements drive the maintenance cost for a system. The STS and Ares I provided many lessons learned and examples of specific drivers to avoid. On the STS Program, a paper system was used to accomplish tasks and log each step with signature approval from several organizations that had to be on hand while tasks were being completed. An electronic system with electronic signatures would simplify maintenance procedures and reduce personnel requirements. Cross-training of individuals would also allow for a reduction in the maintenance "army" required for any task. Design considerations also drive labor-intensive processes where lessons can be learned.

4.1.2 Summary of Lessons Learned from Previous or Similar Systems

This section contains facts, both quantitative and qualitative, about previous or similar systems. The focus in this section is to create the primary source for follow-on LSA. Throughout the development and design of launch vehicles, there are obstacles to properly support and operate the launch vehicle on the ground. Risks are developed and mitigated, requirements changed, and designs altered to help meet logistics and supportability requirements and desires. This section focuses on "lessons learned" from previous similar systems so as to avoid repeating similar mistakes on SLSP where they can be avoided.

4.1.2.1 Ares – Design Impacts

On the Ares Projects, there were many challenges to designing a supportable vehicle on the ground while still meeting the flight requirements. This section outlines examples that were encountered by the Ares team. Each one of these examples required extensive work with other

NASA centers, design teams, the Program and Project offices, review boards, and other NASA organizations to ensure work was done properly and the changes were documented adequately.

- Through the addition of a second IS door to the upper stage (US) of Ares I, the NASA team was able to reduce ground processing times at KSC, decrease operations costs, and increase safety while working interior to the US IS.
- The original IS access door was relocated in order to be properly aligned with the reaction control system (ReCS) servicing panel location, allowing for use of the double-decker arm on the pad – eliminating the need for two separate access arms, and enhancing vehicle access at the pad.
- Relocated the ReCS and roll control system (RoCS) servicing panels from the inner mold line (IML) to the outer mold line (OML) of the vehicle. This move eliminated internal access to the vehicle for ReCS and RoCS pressurant and propellant servicing while reducing the chance of a dangerous chemical leak inside the vehicle.
- Minimized the number of attach points in the IS for internal access (IA) GSE.
- Recommended the use of common battery chemistry.
- Routed the common bulkhead serving port to the ReCS service panel for accessibility.
- Relocated VAB platforms to adapt to changes in vehicle designs.
- Developed component access requirements for initial IA GSE concepts for the IS and IU.
- Provided input to the hydrazine loading trade – Preferred loading at the pad to reduce hazardous operations in the VAB.
- Worked with ReCS and RoCS service panel designers to ensure proper spacing of valves.
- Assisted in development of panels for avionics mounting to provide for easy replacement.
- Directed placement of avionics line replaceable units (LRUs) close to the door in the IU.
- Implemented LH_2 tank design change to accommodate LH_2 vent valve removal and replacement.
- Participated in the US port hole study to move the US and FS electrical mate to the OML of the US.
- Changed the GSE forward dome from a soft cover to a metal cover to serve as a rain shield.
- Identified the need for required “Remove Before Flight” GSE covers.

- Formulated the need for GSE tracking resulting in the development of the US Support Equipment Management System (SEMS).

There were also instances where operational improvements were recommended, but were not implemented. For example:

- Request for an additional access platform in the VAB between the IS and IU to repair thermal protection system (TPS).
- Proposed a new requirement that would state something similar to: The LH_2 tank shall be structurally stable for all ground processing events without requiring pressurization.
    - The requirement was included in the US Element Requirements Document (ERD), but not properly interpreted.
    - Increases risk for damage if pressure is lost and complicates replacement of the LH_2 vent valve.
- Developed risks with MPS and Structures & Thermal (S&T) on accessibility to the LH_2 and LO_2 tanks for sensor replacement.
    - Tied to LH_2 (Risk 2630) and LO_2 (Risk 2629) tank access risk mitigation.
    - Recommended removable mast for sensors in the LO_2 tank.
    - Utilized historical data from past launch vehicles to identify need for access and recommendations of design solutions for the vehicle and GSE.

4.1.2.2 Ares I-X

Ares I-X was a one-time flight test article with a limited support infrastructure and logistics processes. With that said, there were still many examples of operational limitations and lessons learned that were beneficial to Ares. Some of those are listed below.

- Supply chain responsibilities were not clear between contracts.
    - Example for first stage hardware: Frothpack, RTV-455.
- Not all flight hardware procurements were compliant with NASA directives.
    - Flight hardware falls under more stringent procurement/quality requirements.
        - NPD 4100.1B, – Supply Support and Material Management Policy
        - NPR 5900.1, NASA Spare Parts Acquisition with Change 2,
        - NPD 8730.2C, NASA Parts Policy.

    - Waivers processed for US hardware.
- Real-time demands for flight material were constant.
    - Material quantities uncertain.
        - "As Required" quantities used on drawings and parts lists.
        - Shortages caused delays during vehicle processing.
    - Supply support expectations for ground operations – minutes/hours, not weeks.
    - Element procurement representatives experienced conflicting resource requirements once vehicle was transferred to KSC.
    - Processes not setup to enable transfer of material.
        - Contractual issues.
        - Property.
        - Material pedigree.
- Inventory management for material and GSE were time consuming and resource intensive.
    - Tracking material location required extensive manual effort.
    - Separate databases for inventory.
    - Researching availability of material available from each element was a manual process.
    - No indication of who was accountable for the parts and where they should be returned.
- Mystery shipments.
    - The following issues cause delivery delays and waste resources:
        - Incorrectly addressed packages.
        - Packages with missing/incorrect paperwork: DD1149/DD250.
        - Element contract not specified.
        - Owners not identified; Elements not specified.
        - Direct shipments from sub-vendors.

- Expedited shipments.
    - Commercial carriers do not have access to deliver to the processing location.
    - Must inform United Space Alliance (USA) transportation of shipment.
        - Tracking number.
        - Delivery date.
    - Delivery from warehouse is not instantaneous.
        - Receiving/Quality Receiving inspection must be performed.
        - Multiple shipments may arrive together – resources may be an issue.
        - Proper final delivery location and point of contact required.
- Confusion over receiving requirements for shipments.
    - Two types of quality inspections.
        - Government Acceptance Inspection – contractual requirement.
            - Assurance that contractual obligation has been satisfied.
            - Acceptance data package or Certificate of Compliance review involved.
            - Quality signs DD250 or validates invoice, closes out Purchase Request.
            - For each Ares I-X “Element” – a formal acceptance review was conducted.
        - Identification (ID) and damage quality inspection performed after shipping.
    - For Ares I-X, USA was only on contract for ID and damage quality receiving inspections.
    - Material procured by Elements and shipped directly to KSC required a quality acceptance inspection.
- Element requirements for Processing Operations Support were identified through the Launch Site Support Plan and captured in a joint Program Requirements Document (PRD).

    - Generating KSC Ops PRD consumed a lot of resources.
        - PRD system has to be used for range requirements because of Range requirements.
    - PRD system/process not user friendly.
    - Launch Site Support Plan (LSSP) and PRD requirements documented too late.
        - Example: Transportation operations were complete before PRD requirements were baselined.
- Recommend consolidated transportation plan referencing KSC internal paper for KSC moves.

4.1.2.3 Non-Design/Program Specific Lessons Learned

Launch vehicles often experience vast knowledge growth from cradle to grave of any system. This knowledge gained is most often in the form of lessons learned and often doesn't deal with design itself. Below are some non-design and facility based lessons learned.

- Integration between NASA centers is vital at an early stage.
- Have a strict NASA-wide DD250 and DD1149 process in place for the movement of goods.
- If at all possible, adhere to commonality for any piece, part, consumable, etc., possible.
- The Ares I Element subsystems were organized and allowed to operate as mini-projects which caused redundancy, wasted manpower, and thus wasted money.
- Future inventory systems will have to have the capability to distinguish material ownership between multiple contractors and multiple elements. Further, how inventory management will be performed during development should be outlined in an Integrated Logistics Support Plan (ILSP).
- The Level II supportability document needs to define key logistics infrastructure relationships, roles and responsibilities, and common logistics data/tools.
- A program labeling plan should be put in place from the beginning of any new program. This will encompass parts marking as well since it is a part of any labeling plan.
- Life cycle cost analyses should be performed as an integral part of the design process from the inception of the project.

- Initial LSA development should be provided in conjunction with the design effort. After initial development, an operations contractor should then be brought in to lend insight and past operational experience with similar systems to further develop the LSAs.
- Parts and materials standardization/commonality should be a design requirement.
- Embedded supportability engineers have a positive effect on improving design.

The Use Study in this section is a summary to the complete version of the Use Study. The remainder of the Use Study is in Appendix D.

4.2 BASELINE COMPARATIVE ANALYSIS (BCA)

The purpose of the BCA is to select or develop a Baseline Comparison System (BCS) representing characteristics of the new system/equipment for (1) projecting supportability related parameters, making judgments concerning the feasibility of the new system/equipment supportability parameters, and identifying targets for improvement, and (2) assist in determining the supportability, cost, and readiness drivers of the new system/equipment. The main purpose for PDR is to conduct data collection on these similar systems. The approach of this subtask is to identify systems and subsystems which may be useful for comparative purposes with new system/equipment alternatives. These systems were chosen for their functional similarity to the new system.

We were able to obtain information on three comparison systems to baseline, Ares I, Ariane 5 and the Atlas V. These were picked for their similarity to SLSP. Data was collected on the maintenance approach to develop similarities and to benchmark potential “good ideas” for the current SLS design. Below are excerpts from these reports that are applicable to the supportability of the SLS design. Complete comparative analysis is in Appendix E.

4.2.1 Ares I Comparison

For Ares I, there were several items developed prior to the Ares 1X flight. Items contained below include the Ares maintenance concept, latest Ares LRU and limited life components candidates list assessment, supportability requirements, and support system alternatives.

4.2.1.1 Ares I Maintenance Concept

The concept for Ares I was a two level maintenance concept with items identified with the potential for on-pad removal and replacement. The Ares I levels of maintenance were described in terms of “operations location.” These are Launch Site (which includes both the Vehicle Assembly Building (VAB) and Pad) maintenance, Manufacturing and Assembly Site (Michoud Assembly Facility (MAF), Stennis Space Center (SSC), and Kennedy Space Center (KSC)) maintenance, and Component Vendors/Off-Site Vendors maintenance.

Launch Site (VAB & Pad) Maintenance Summary

Launch Site maintenance will consist of maintenance actions performed in direct support of ground operations. National Aeronautics and Space Administration (NASA) Kennedy Space Center (KSC) and TOSC Contractor will perform the Launch Site maintenance requirements on the Ares I System. Launch Site maintenance requirements on the Ares I system will be performed by NASA, KSC, and support contractors’ maintenance personnel on a day-to-day basis in the support of launch site operations. The Launch Site maintenance personnel will keep the Ares I in a full mission-capable status while it is at the launch site. Launch Site maintenance will be limited to periodic checks of equipment performance, visual inspections, cleaning of equipment, some servicing, external adjustments, handling, and the removal and replacement (R&R) of Line Replaceable Units (LRUs). Fault isolation times and corrective maintenance actions are reduced through the limited, but effective, use of system built-in test features. Components that are removed at this level are forwarded to the Manufacturing and Assembly (MAF, SSC, and KSC) or Off-Site Vendors for repair. Recordkeeping and reports preparation are also performed at the launch site.

4.2.1.2 Ares I LRU candidates

LRU Determination

The LRU candidates list for Ares CDR comprised of 165 LRUs for the Ares Integrated Upper Stage and 80 for the Ares First Stage. The complete list is in Appendix E.

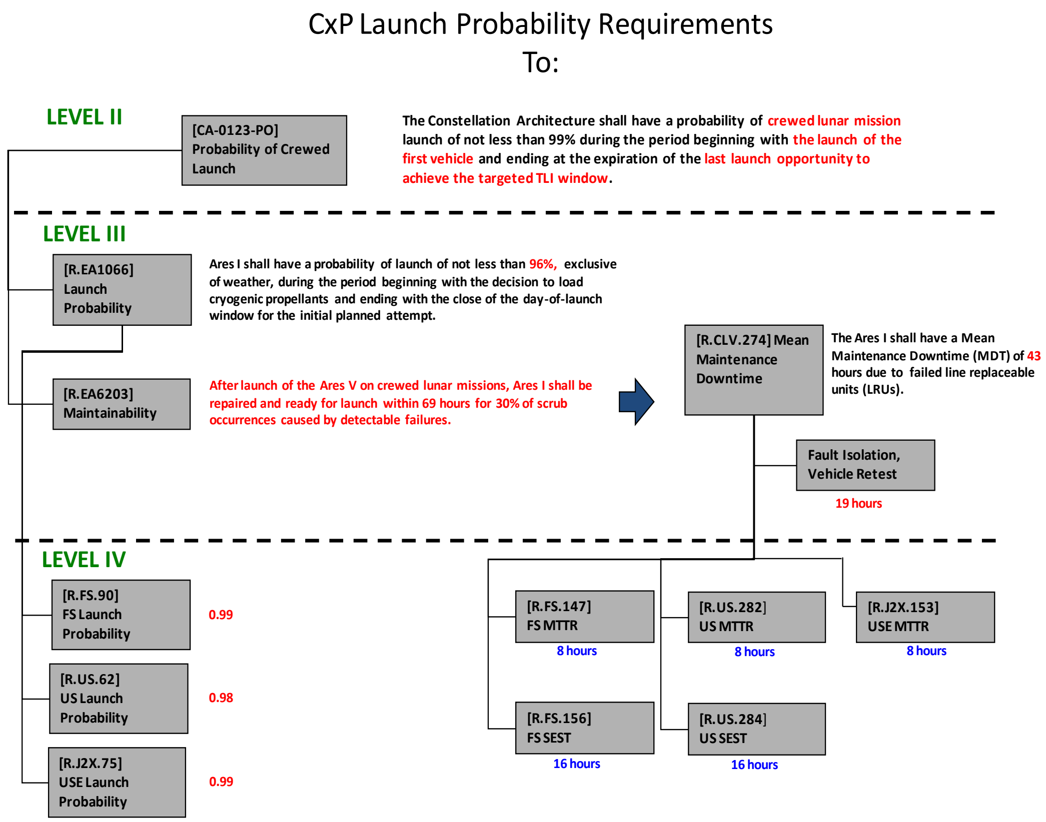
4.2.1.3 Ares I Limited Life Components

An initial data collection effort for the Ares I Program determined a list of Limited life components from the LRU list.

139 Inch ETL
309 Inch ETL
110 Inch ETL
NASA Standard Detonator (NSD)
NASA Standard Detonator (NSD)
279 Inch ETL
109 Inch ETL
Safe & Arm Device (S&A)
NASA Standard Detonator (NSD)
319 Inch Explosive Transfer Line (ETL)
375 Inch ETL
FTS Battery Unit (BU)

4.2.1.4 Ares I Supportability Requirements

Ares I specific supportability related factors are identified and applied with the objective of ensuring that the system will be designed and developed such that it will satisfactorily accomplish its intended mission(s). These were identified as supportability requirements to be assessed during design for the prime mission-related elements of the system and for those elements that are necessary for the support. Figure 4.2.1.4-1 depicts the allocation tree for the



Ares I requirements.

Figure 4.2.1.4-1 Ares I Derived Level 3-4 Maintainability Requirements and TPMs

Analyses of potential timelines for contingency activities are to consider both Ground Operations processing and the Vehicle maintenance down time activities to be completed in the times consistent with a more affordable system. These derived requirements are:

- Maintenance Downtime (MDT) = 40 hours (3 hour reserve)
- MTTR = 8 hours

- MaxTTR = 12 hours
- System Retest times = 8 hours
- SEST = 16 hours
- Isolation times = 4 hours
- Order Ship Times (OST) = 24 hours.

4.2.1.5 Ares I Support System Alternatives

Listed below were the support system alternative(s) identified for the Ares I system. SLSP is evaluating similar system support alternatives with regard to the proposed design, operation, and support concepts. The following are the current support system alternatives identified by Ares I are:

- Alternative 1
  - Two Levels of Maintenance
  - Optimize access for R&R of Mission critical LRUs
  - KSC (GOP) and launch site contractor is responsible for maintenance support (R&R of LRUs and Standard Repairs)
  - Ares I (OEMs) provide maintenance support as requested by EGLS contractor repairs at launch site
  - EGLS Contractor Ship Removed LRUs back to Depot
  - Mission Critical LRUs will be Stored at launch site
  - No US Stored at launch site
- Alternative 2
  - Two Levels of Maintenance
  - Minimize Maintenance at the Pad
  - Optimize access for R&R of LRUs in VAB
  - KSC (GOP) and launch site contractor provide all maintenance support
  - EGLS Ship Removed LRU back to Depot
  - No Storage facility for LRUs
  - Provisioning is Just-in-Time

4.2.2 Atlas and Ariane 5 Comparison Systems

Atlas and Ariane 5 support systems were also assessed. The following approaches for comparison were implemented by both of these programs. These approaches are being considered for the Support Alternatives for SLSP. Complete assessments for both are included in Appendix E.

- Ground Operations
  - There is no vehicle access at the pad for maintenance. The vehicle is rolled back to the BIL or BAF for Ariane V and Vehicle Integration Facility (VIF) for Atlas V for maintenance.
  - Most of the Ariane V and Atlas V boxes/components and LRUs are all accessible in the integrated stacked configuration. Access doors are located 360° around the vehicle. Both vehicles require 24 hours to rollback, repair, and roll-out if problems are detected prior to tanking. After tanking, the requirement is 48 hours to allow time for safing and de-tanking.
  - Vehicle engine and engine parts repairs/ maintenance are off-nominal
- Sparing
  - No spares are kept on hand. Spares and repair parts are taken from the next vehicle in line being processed or by having a replacement part shipped via air from the production line to the launch site.
  - Ariane 5 stores at least 2 set of batteries on hand since they cannot be easily transferred.
- Launch Operations
  - Minimum amount of seats during Launch countdown
  - Atlas has minimal fault detection and isolation system. They want to keep the system simple which also keeps the cost down.

4.2.2.1 Ariane 5

The Ariane Launch System is composed of the Launcher (Launch Vehicle) and the Launch Complex. The Ariane 5 launch vehicle is composed of a liquid core stage using composite tanks for the liquid oxygen and liquid hydrogen propellant. Two strap-on solid boosters are attached to the cryogenic propellant core stage. The Ariane 5 has operational heritage from the Ariane 4 and can deliver 21 metric tons (46,200 lbs.) to low earth orbit and has a five meter diameter payload fairing. The Ariane 5 delivers the 21 metric ton Automated Transfer Vehicle (ATV) to orbit in February 2008 which will rendezvous with the ISS. This mission requires a re-ignition of the EPS (upper stage engine) to place the ATV in a circular orbit.

Operational Requirements - To meet the goals of designing to operations and cost the launch vehicle and the launch complex were required to support the following requirements:

a) Capable of supporting 8 launches per year

b) Capable of supporting a one month inter-launch period
c) Launch Pad capable of surviving a serious accident at lift off
d) Capable of supporting two launch campaigns in parallel (using two mobile launch tables)
e) Probability to postpone a launch (1 day): $< 6.5 \text{ X } 10^{-2}$ (with the exception of weather)
f) Probability to postpone launch (> 1day): $< 1.8\text{X}10^{-2}$ (with the exception of weather)
g) Minimization of launcher preventive maintenance on the launch site
h) Minimization of operations during launch vehicle assembly, integration, and test (ship and shoot philosophy for core and upper stages)

The following findings and observations are grouped according to Ground Operations, Logistics, and Flight / Engineering Support Operations during launch.

Ground Operations - The Atmospheric Explorer (AE) implements a ship and shoot philosophy for the main cryogenic propellant and the ECS stages. Additionally, minimal testing is conducted at the launch site other than post shipment inspections. The solid rocket boosters are loaded with propellant and assembled offline at the launch facility.

Items of interest relative to Ariane 5 ground processing:

- No access is available at the launch pad except at the ground level
- Capability of offline stacking of SRB segments removing the activity from the critical processing flow
- Only 1 launch pad with as many of the launch pad systems underground to avoid loss if catastrophic event occurs
- SRB's are recovered approximately once every 10 launches for engineering assessment and the Ariane 5 is certified for flight with and without SRB recovery parachutes
- Launch Vehicle Commit Criteria is automated in Ground Software (green light philosophy)
- Testing of the software with hardware in the loop is accomplished in France at a Systems Integration Laboratory. Non-flight software is used in all the hardware testing and checkout, even the integrated stack test. The flight software is loaded 4 hours prior to launch and all non-essential software is removed. The avionics boxes are operated for 40 hours during testing for "burn-in".

Logistics - The approach taken by Ariane 5 was that no spares are kept on hand for contingency reasons. The sparing was accomplished by either borrowing parts from the next vehicle in line being processed or by having a replacement part shipped via air from the production line to the launch site in Kourou. AE has a contract with Air France to provide a shipment of the part and airline seats to critical engineering personnel within 24 hours from France to Kourou. The only exception was that two sets of batteries were kept on hand since they could not easily be transported via airlines. At a flight rate of at least four per year, the processing model allows for up to one spare vehicle at the launch site and for the production line to have a spare far enough in production to be flight ready. At flight rates less than four, spares may not be ready from the production line. Also, the production lines are sized to be able to sustain low disturbances in production due to sparing requirements.

In the event of a contingency, the decision to borrow parts versus have a new one shipped was based on how quickly the spare was needed. If time permitted a part was shipped from the production line to avoid interruption in the ground processing for launch phase. During the down time, several key activities would occur; 1) the required piece or equipment is removed, controlled, packed, and sent to Kourou by commercial airlines. The commercial flights to Kourou occur at once per day and the ordered spare would be on hand in 24 to 48 hours. 2) On the same day the suspect part is removed from the launch vehicle. If required, the suspect part would be sent via air to Europe for examination by the experts. 3) The team at the launch site in the meantime would investigate the failure, prepare contingency procedures and plan the recovery including approval authority and safety buy off. If required, design engineers were sent to Kourou within a days' notice to address the failure and help resolve any issues. To date Ariane has performed many of these contingency operations and have done so with no loss of time due to sparing with this philosophy.

The development philosophy was to lower launch pad vulnerability to the Vehicle during on pad stay time as well as the launch pad infrastructure damage in the event of a failure. The Ariane 5 team has what they called the flat Pad concept. The vehicle has no pad access for vehicle mechanical access or contingency resolutions other than flight software updates. All contingencies can be addressed in the launch integration building (BIL) or the final assembly building (BAF). All contingencies requiring maintenance while at the launch pad require a vehicle rollback. The replacement of a Vulcan engine took approximately 10 days and experts came in from Europe to help with the repair. The replacement of an upper stage took approximately 2 weeks and included a new upper stage shipped overseas in 48 hours. The avionics boxes located in the Vehicle Equipment Bay (VEB) are all accessible in the integrated stacked configuration and all boxes are within arm's reach from one of the many access doors. Eight (8) access doors are on the VEB in two levels and are located 360 degrees around the vehicle. In 30+ Ariane 5 launches 4 rollbacks have been performed.

The key availability requirements for the Ariane Vehicle are:

- 0.065 probability to postpone launch (1 day – excludes weather)
    - 93.5 % launch probability
- 0.018 probability to postpone launch (> 1 day – excludes weather)

- 98.2% launch probability

The time from roll-out to launch is 36 hours. Ariane has the philosophy to minimize the Vehicle preventative maintenance at the launch site as well as to minimize the operations during ground operations i.e. vehicle assembly, integration and test, and launch countdown. The Ariane rollback requirement is 24 hours, which includes preparation for rollback prior to tanking. Included in the rollback requirement is the detection, roll-back time, 6 hours for replacement, test, and rollout to the pad. In reality, an Ariane roll-back usually means 48 hours. In the event the tanking has been performed the requirement is 48 hours to include time for safing and de-tanking the vehicle.

A summary of the Ariane 5 Anomaly resolution process follows:

1. Once an anomaly has been detected during the countdown process a Quality team records the Non-compliance Report (NCR)
2. The Launch Vehicle ops team: 1) ensures the safety of the launch site and vehicle 2) investigates the anomaly to the extent possible via telemetry, 3) presents their findings and planning impacts to the lead Ariane 5 Technical Manager (Ariane Space Office of Defense Trade Controls (DTC)).
3. The Launch Vehicle technical authority (Sustaining Engineering community for the launch vehicle: 1) investigates/confirms the anomaly analysis, 2) coordinates all recovery/repair processes, 3) presents their findings and recovery/repair plans to the lead Ariane 5 Technical Manager (Ariane Space DTC).
4. The lead Ariane 5 Technical Manager (Ariane Space DTC): 1) verifies the problem and solution, 2) accepts the findings and recovery procedures, and 3) presents the analysis and recovery plan to the CEO of Ariane Space for final approval.

4.2.2.2 Atlas V

The Atlas V was evolved from the previous Atlas family of rockets. The Atlas V uses the Russian RD-180 engines on the Common Core Booster for the first stage and can use up to five Aero jet strap-on solid boosters when needed. The Common Core Booster uses liquid oxygen and RP-1 (kerosene) rocket fuel propellants. The upper stage is liquid oxygen – liquid hydrogen powered Centaur. The Atlas V is 58.3 m (191.2 ft.) tall and accommodates a 5 meter diameter fairing. The Atlas V can deliver to just over 20 metric tons (44,400 lb.) to LEO.

The Atlas 5 design team was driven at the highest level by the United States Air Force requirements defined in the Programs System Performance Requirements. One of the major operability requirements identified was the launch vehicle must meet a 90% probability to launch within 10 days. This requirement was driven down into the lower level specifications.

Other key operational metrics included managing a head count level at the launch facility to reduce recurring cost. This was accomplished through the timeline process defined above where actual headcount was applied to the defined task. Additionally, there was a drive to keep the design simple. An Atlas V launch requires about 200 people which also include engineering support at the design center.

The Atlas V team also implemented the concept of performing as little testing at the manufacture and maximizing the testing at the launch facility. This was implemented based on the idea that they did not want to duplicate testing at the two sites and realized they needed the capability at the launch site for the first few flights. Therefore the initial concept was to implement the testing at the launch facility and move it back to the manufacturer later. What they found was that there were little problems found during testing at the manufacturer and the majority of failures were transducer related and may be caused during shipment. The Atlas V program continues to perform a horizontal integrated test of the electrical components at the launch facility today and minimizes testing at the manufacturer. After the horizontal test is complete, the vehicle is stacked and other tests are performed.

The Atlas V team found few situations where access to the launch vehicle at the pad would have resulted in quicker resolution of an anomaly than rolling back to the assembly building. The key driver for resolving any issue found during the processing flow is the root cause analysis. They have found that the majority of anomalies require a root cause analysis before the anomaly can be closed for flight. Therefore if you are going to attempt to have any type of maintenance activity on the pad there must be a root cause analysis process that supports the required turn-around time.

Operational Requirements - Avionics are powered up for the first time at the launch site in the integrated stack test. Twenty-four hour rollback, repair, and roll-out if problem detected prior to tanking. After tanking, the requirement is 48 hours. The engine and engine parts can be changed near the launch site but this is not a nominal operation. Avionics boxes can be accessed without de-stacking but some require going inside the vehicle. Atlas uses diving board approach for getting inside vehicle. Operational access is different than developmental access.

No inventory of spares is kept at the launch site. The next vehicle in the production line can provide a spare if needed. Or a part from the production site can be shipped or flown in, just-in-time. There was no pre-operational provisioning of spares/repair parts. Spares and repair parts are taken from the next vehicle in line at the launch site. The reason for this philosophy is that the time required to obtain a spare is less than the time required to perform a root cause analysis.

Atlas has minimal fault detection and isolation system. They want to keep the system simple which also keeps the cost down. Each sensor had to “buy” its way onto the vehicle. The chief engineer had to understand and approve each sensor added to vehicle. Atlas 5 does "maintain clean" throughout process, i.e., no checks or samples at the pad. Atlas warns of provisioning too many requirements. Requirement reduction and simplification is recommended.

Maintenance

- **Organizational – launch Site**: All contingencies requiring maintenance while at the launch pad require a vehicle rollback to the VIF. Most of the components are accessible while in the VIF.

- **Depot**: All LRUs/Components needing repairs are shipped back to the vender.

There is no vehicle access at the pad for maintenance. The vehicle is rolled back to the VIF for maintenance. Most of the Atlas 5 boxes/components and LRUs are all accessible in the integrated stacked configuration. Most boxes can be reach by adding platforms, which are attached to the ground support Equipment not the vehicle. The vehicle has a number of access doors located 360 degrees around the vehicle.

4.3 SLS MAINTENANCE CONCEPT, SUPPORT CONCEPTS AND SUPPORT SYSTEM ALTERNATIVES.

The maintenance concept is a planning guide for influencing system design and to establish the framework for development of the maintenance plan. Flight and ground hardware design engineers will ensure that systems are maintainable and supportable using a maintenance concept that includes launch site operational logistics support infrastructure, manufacturer facilities, and interim original equipment manufacturer (OEM) capabilities. The SLSP maintenance concept consists of a two-level maintenance system, organizational and depot/OEM, utilizing LRUs for launch site organizational corrective maintenance as items that are removed and replaced. The Elements are responsible for their own maintenance concepts and will define the maintenance locations, functions, and terms such as: location capabilities, corrective/preventive tasks, MSIs and LRUs. The purpose of the maintenance concept is to:

- Develop a common "language" for supportability/maintenance planning.
- Establish SLS maintenance parameters for technical performance measures (TPMs).
- Identify evaluation and support systems improvements.
- Determine the foundation for supportability alternative trade-off analyses.
- Provide framework for optimization of maintenance allocations through LORA:
    - Non-economic analysis.
    - Economic analysis.

The Elements are responsible for incorporating the SLSP maintenance constraints as defined in the SLS-PLAN-047, Revision A and the SLS-RQMT-014, Revision A into their maintenance planning to ensure Element requirements are consistent with capabilities and resources at KSC. For Block 1, the maintenance concept and support alternatives are defined in Table 4.3-1. The maintenance solution should include results of trades and consideration of utilizing LRUs for launch site organizational corrective maintenance as items that are removed and replaced.

ILS ELEMENTS	Alternative	Alternative 2
Maintenance Concept		
SLS Levels of Maintenance	Two level	Two Level
Organizational level		
Responsible Organization	NASA (KSC) and TOSC Contractor Support	NASA (KSC) and TOSC Contractor Support
Core Stage	Specialty Support	None
Booster	Specialty Support	None
Engine	Specialty Support	None
SPIO	Specialty Support	None

ILS ELEMENTS	Alternative	Alternative 2
Depot Level	Project element responsibility	
Maintenance Policy		
Organizational Level	R&R at VAB	R&R at VAB and Pad
VAB	List of VAB LRUs	
Core Stage	TBS	TBS
Booster	TBS	TBS
Engine	TBS	TBS
SPIO	TBS	TBS
Pad	N/A	List of Pad LRUs
Supply Support		
Organizational level		
Elements	LRUs per LORA	JIT
Depot Level	Project element responsibility	
Facility		
Organizational Level		
Storage Facility	Yes	No
Project Elements	(TBS) sq. ft.	
Maintenance Facility		
Project Elements	(TBS) sq. ft.	(TBS) sq. ft.
Depot level	Project element responsibility	
Training and Training Support		
Organizational Level	Limited Training	Complete Training
Core Stage	LSAR Data Base	LSAR Data Base
Booster	LSAR Data Base	LSAR Data Base
Engine	LSAR Data Base	LSAR Data Base
SPIO	LSAR Data Base	LSAR Data Base
Depot Level	Project element responsibility	

Table 4.3-1 – Support system alternatives

As part of the supportability engineering approach for Block 1A, non-economic LORA, maintenance engineering analysis (MEA), MSI candidate analysis, and preventative/corrective actions identification, will aid in the determination of the detailed maintenance concept and support alternatives.

There are two physical locations at which maintenance will be performed for SLS: Kennedy Space Center (KSC) and the manufacturing site. Maintenance locations are determined by access (external and internal), weight of LRUs, hazardous processing, availability of tools and test equipment. Maintenance actions are distinguished by whether de-stacking is required to perform a maintenance function on a given item. There will be four configurations: 1) SLS stacked at the pad, 2) SLS stacked at the Vehicle Assembly Building (VAB), 3) element un-stacked at the VAB, and 4) element disassembled at manufacturer.

The SLSP will utilize a set of qualitative guidelines, based on the maintenance concept, to assess Element supportability design maturity for maintenance activities through Preliminary Design Review (PDR) and into Critical Design Review (CDR). These guidelines are intended to drive system design to decrease downtime due to maintenance, reduce complexity of maintenance actions, and reduce operations and maintenance (O&M) costs. Examples of qualitative requirements include LRU interchangeability, clearance for inspection and tool access, use of captive fasteners on LRUs, and use of standard tools for LRU removal and replacement.

Where practical and feasible to do so, implementing certain Fault Detection, Isolation, and Recovery (FDIR) capabilities in the design of MSIs and LRUs should be considered for the purpose of maximizing the affordability of troubleshooting and maintenance activities and the availability of the launch vehicle. This includes taking into account the pad accessibility of the MSI or LRU and determining if it is prudent to develop and utilize non-invasive/intangible (hands off) means of troubleshooting the failure (even to a level within the MSI or LRU), in order to acquire as much knowledge about the failure as possible. Having such insight would be beneficial before deciding to roll back the vehicle to the VAB for removal and replacement of the MSI or LRU (if deemed necessary), or before continuing with launch. Moreover, such diagnostic functions for MSIs and/or LRUs may also prove invaluable in test and checkout activities during vehicle integration and prior to launch.

4.4 SLS LIFE CYCLE COST ANALYSIS

The SLS life cycle cost analyses (LCCA) are bottoms-up engineering analyses performed by the SLS system for determining total ownership cost (TOC). The SLS Elements are responsible for identifying costs associated with their Element. The SLSP ILS team is responsible for integrating the SLS Elements' costs and providing an LCCA input that identifies the P&O costs in support of the PP&C/XP03 office which is the OPR for the SLSP LCCA Report, SLS-RPT-096 per agreement with the PP&C office and SLS Chief Engineer. The LCCA/TOC consists of three parts: design interface, validation of support methods, and validation of operations. The LCCA is used to support the design analysis cycles (DACs), trades, change requests, engineering change proposals, comparative assessments, sensitivity analyses, and milestone reviews through all life cycles and is not intended to be a budget tool. The LCCA results will determine cost-effective support infrastructure solutions and supportability enhancements for production and operations (P&O). The SLSP ILS team is responsible for integrating the SLS Elements costs and providing an LCCA that identifies the P&O costs.

The allocated funds for design, production, operations, and other vehicle assets will be assessed to determine cost differences driven by vehicle design. In conjunction technical trades will be performed to identify lower cost options. Other trades not driven by vehicle design will also be supported by LCCA.

Design interface will include integration of supportability into flight and ground hardware design using LCCA to assist in determining cost-effective support infrastructure solutions and supportability enhancements for P&O. Assessment of support and operations costs will include a broad range of areas to include ILS planning, personnel, equipment, and facilities that ensure the system is available and operational.

It is imperative to set the baseline for affordability and supportable flight hardware and ground support infrastructure during the Block 1 SLS Program life cycle. Incremental improvements for designing to cost through application of lessons learned and innovation will be applied to ensure affordable and cost-effective operations, both on the ground and in flight for Block 1A.

4.5 SLS SUPPORT SYSTEM TRADE-OFF ASSESSMENTS

Evaluation of Alternatives and Trade Studies is used to determine preferred support alternative(s) and their associated risks for the SLSP system. Assessments of Launch Availability (LA) and System Readiness (SR) were conducted along with specific "what ifs" to assess identified risks. This can be accomplished by conducting trade-off analyses of all alternatives and identifying which one provides the best balance for cost, schedule, performance, readiness, and supportability. In addition to related requirements, Technical Performance Measurements (TPMs) provide benchmarks as to the design for supportability. Integration of these analyses with the R&M modeling and analyses and the Maintainability modeling and analyses described in the SLS-RQMT-014, Space Launch System Program (SLSP) Safety and Mission Assurance (S&MA) Requirements is critical to increased fidelity and accuracy when conducting the trade-off studies.

4.5.1 Analysis Tool

The analysis tool used to perform the analysis documented within this report is the SLS Discrete Event Simulation (DES) Model, which is a DES tool that was developed using ExtendSim™, a commercially available software package developed by Imagine That Inc. The SLS DES Model simulates the processing flow of the SLS launch vehicle from the beginning of manufacturing through launch. Currently the model encompasses work performed at the Michoud Assembly Facility (MAF), Stennis Space Center (SCC), Vehicle Assembly Building (VAB), and Launch Pad. In the future, the model can be expanded to simulate other facilities at the Kennedy Space Center (KSC), Alliant Techsystems Incorporated - Thiokol (ATK), and other sites as required. Regardless of the facility, each process simulated takes into consideration whether the process is performed in series or parallel, the number of personnel and Ground Support Equipment (GSE) required, the shift schedule being assumed, whether any unplanned event may occur, and what is required to get back on the nominal path. The SLS DES Model is used to support trade studies to determine how changes in the design or processes affect the SLS SR and LA. The results of the analyses are flowed back to the designers so that changes can be made to the design or the ground processing to resolve potential issues.

4.5.2 Launch Availability and Maintenance Downtime Analysis

Level I sub-allocated to SLS an LA TPM that is intended to ensure a high likelihood of launching the SLS vehicles within a specified timeframe. Launch Availability is a function of both launch reliability (probability of launching on a given attempt) and MDT (ability to repair the launch vehicle in time to achieve additional launch attempts in the given timeframe). The LA TPM is defined in the SLS Program (SLSP) Technical Metrics Plan (TMP) Revision A as the probability of the SLS successfully launching within 30 calendar days of the start of countdown for the initial launch attempt, exclusive of weather. The threshold value for the LA TPM is 96.7%.

A secondary component of the LA analysis is the MDT analysis. The SLSP TMP Revision A, SLS-PLAN-047 describes the MDT as follows: The MDT TPM assesses the degree to which the SLS is repairable to support additional launch attempts in the event of a launch scrub due to a hardware/software failure. MDT is inclusive of all the time from the point a launch scrub is declared until the vehicle is ready to restart countdown for the following launch attempt, exclusive of weather delays. The threshold for MDT is 85% of all failures can be repaired in a maximum of 20 calendar days.

The LA analysis is focused on the timeframe from the start-of-countdown through launch and the probability of launching the vehicle within 30 calendar days. Launch Availability is independent of anything that may occur before the start-of-countdown. The MDT analysis is concerned with single point failures and what percentage of failures can be repaired within 20 calendar days. Scenarios where multiple failures occur, a second off-nominal failure occurring while working a previous off-nominal event, are not considered as part of the MDT because the TPM is focused on single point failures. The impact of multiple off-nominal failures is captured within the LA analysis.

4.5.3 System Readiness Analysis

The SLS SR TPM covers all the operations from the start of manufacturing through launch and encompasses two distinct operational phases; 1) Manufacturing – the phase in which various elements are manufactured and delivered to the Vehicle Assembly Building (VAB) at a successful rate to not delay the start of stacking, 2) Ground Operations – the phase in which the operations at the VAB and at the Launch Pad are performed to meet a specific launch date. For EM-1 (Block 1), the interval that the SR analysis is measured against is 160 calendar days. The 160 calendar days is derived from the GSDO facility Operational Readiness Date (ORD), June 19, 2017, and the need to be ready to launch the SLS vehicle by December 13, 2017. See Figure 4.5.3-1.

The SR TPM is defined in the SLSP TMP Revision A as the likelihood that the SLS vehicle can be processed in time to be ready for the start of countdown in order to meet a launch date set at mission manifest approval. The SR TPM encompasses all of the operations from the start of manufacturing through start-of-countdown and includes transportation, element checkout, vehicle integration, vehicle testing, closeout, pad operations, and off-nominal events.

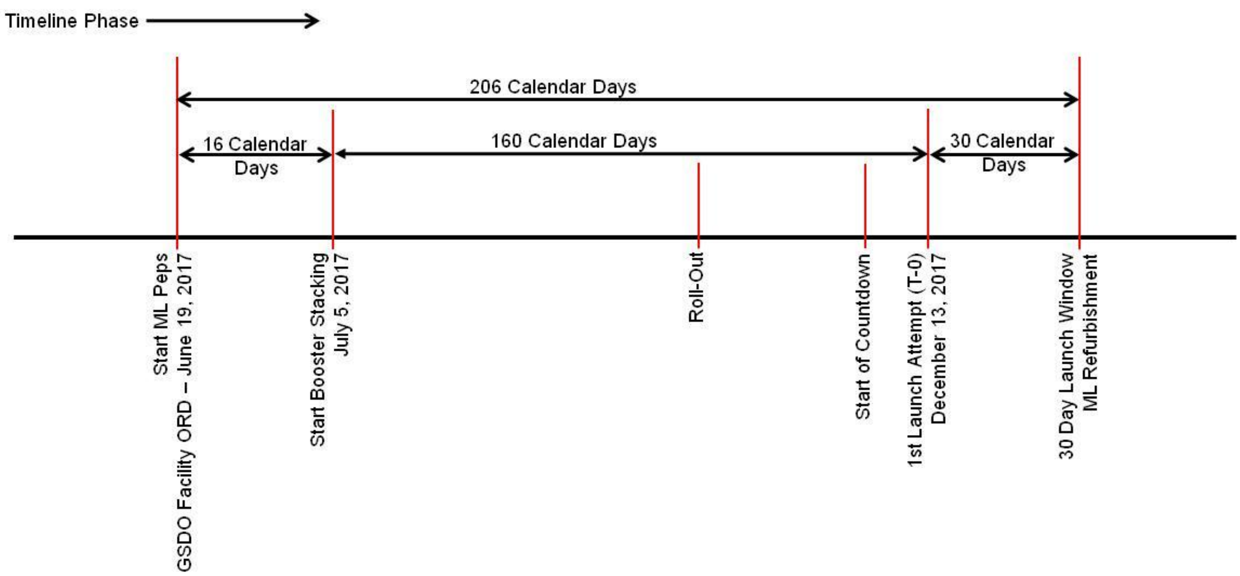


Figure 4.5.3-1 Launch-to-Launch Interval

4.5.4 Vehicle Stack and Pad Stay Time Analysis

The Vehicle Stack and Pad Stay Time Analysis looks at the current design of the Block 1 configuration to see if the Vehicle Stack Time or Pad Stay Time requirements are being violated based on the operations for processing the vehicle. The vehicle stack time is measured from the time that the Interim Cryogenic Propulsion Stage (ICPS) is stacked on the vehicle and concludes when the vehicle has been launched. The Vehicle Stack Time requirement states that the vehicle shall be capable of remaining in a stacked configuration for a minimum of 140 calendar days without being de-stacked.

The pad stay time measures the cumulative amount of time that the vehicle is exposed to the Launch Pad environments. If the vehicle has to be rolled back from the Launch Pad to the VAB for repairs, the actual time the vehicle is in the VAB is not considered part of the pad stay time. The Pad Stay Time requirement states that the vehicle shall be capable of being exposed to the launch pad environments for a minimum of 120 calendar days.

4.5.5 Battery Life Analysis

The Battery Life Analysis looks at the current design of the Block 1 configuration and the operations that are performed from the start of Integrated Vehicle Testing (IVT) through launch to see if the life of any of the Element batteries onboard the vehicle are violated based on when they are planned to be installed in the vehicle.

This analysis looks at three possible times that the Element batteries may be installed within the vehicle.

1) Prior to the start of IVT.

2) Prior to roll-out for the Wet Dress Rehearsal (WDR).

3) Prior to the Flight Termination System (FTS) Test and final rollout before the first launch attempt.

4.5.6 Logistic Delay Analysis

The Logistic Delay Analysis looks at the impact of four types of logistic delays on the Block 1 configuration LA. There are four logistics delays that are considered as part of this analysis and they are Procedure Delays, Ground Support Equipment (GSE) Delays, Personnel Delays, and Spare Delays.

The Procedure Delays assume that when an Element failure occurs that there will be some type of delay due to developing the required procedures. The assumptions are that the Element will develop actual procedures for Line Replaceable Units (LRUs) after the failure mode has been identified but all other items that may fail will not have procedures developed in advance.

The Personnel and GSE delays assume that the personnel and GSE required to performed an off-nominal task are not available at the Kennedy Space Center (KSC) and that the personnel and/or GSE will need to be shipped to KSC. The delay impact will be based upon how readily available the required personnel and/or GSE is.

The final logistic delay is a Spare Delay. The current SLS baseline is that there will be no spares located at KSC and if a spare is needed it will be sent from the Element manufacturing site. This philosophy can have a significant impact from the Core Stage standpoint for the provision of spares since, for Block 1, the next Core Stage will not be in production until after the first flight in 2017. The other Elements are based on heritage hardware, and therefore, spare components may exist resulting in a shorter delay.

4.5.7 Off-Nominal Analysis

Another important aspect of the SR and LA analysis is to evaluate the effects of off-nominal events. This is because unscheduled hardware/software and process failures, which lead to rework and delays, are historically probable in space flight operations. When a hardware/software failure occurs, it normally results in a halt to the nominal task work, a rectification of the failure, a recertification of the integrated system with incorporated changes, and a repeat of nominal operations.

There are three parts to the off-nominal analysis that are provided as inputs to the SLS DES Model. The first part is the probability that a failure occurred. For every task identified in the SLS Program Manufacturing and Assembly Operational Sequence Report, an off-nominal event can be associated with it by referring to an applicable Frequency Table which indicates the probability that a failure occurred. The Frequency Table does not indicate what off-nominal event occurred but simply that a failure occurred.

The second part of the off-nominal analysis is the Classification Table. Once it has been determined by the SLS DES Model that an off-nominal event has occurred, the model looks to the associated Classification Table to determine what off-nominal event occurred. In some instances, there is only one type of failure event but in other instances, such as Integrated Vehicle Testing, there could be a number of off-nominal events that could occur, each with their own probability of occurrence.

An example of the Frequency and Classification Tables are shown in Table 4.5.7-1 and Table 4.5.7-2. The Frequency Table states that there is a 90.25% probability of no off-nominal event occurring while there is a 9.75% chance of an off-nominal event occurring. If an off-nominal event occurs, the model then uses the Classification Table to determine which off-nominal event occurred. Based on Table 4.5.7-2, there are 6 off-nominal events that could occur, each with a certain likelihood of occurring. Based on the data, if an off-nominal event occurred, there is a 10.54% probability that the failure was a Core Stage failure that could be repaired on the launch pad and a 19.49% probability that it was a Core Stage failure that would require a roll-back in order to repair.

Table 4.5.7-1 Frequency Table

Frequency Table 6	
Number of Events	Probability
0	0.9025
1	0.0975

Table 4.5.7-2 Classification Table

Classification Table 6	
Name	Value
Core Failure - Repair on Pad	0.1054
CS Engine Failure - Repair on Pad	0.5695
Booster Failure - Repair on Pad	0.0159
Core Failure - Roll-Back	0.1949
CS Engine Failure - Roll-Back	0.0308
Booster Failure - Roll-Back	0.0834

Once it has been determined which specific off-nominal event has occurred, the model then uses the off-nominal timeline, the third part of the off-nominal analysis, to simulate the off-nominal tasks. The off-nominal timeline is a collection of all the off-nominal operations, the time required to perform the task, the distribution being used to simulate the task, the shift schedule being assumed and the number of personnel and GSE required to complete the task.

Note: For this assessment, the Core Stage reliability data is based on their PDR reliability prediction data while reliability allocations for Booster and engine are based on historical reliability data for the heritage systems and best engineering estimates, but have not yet been validated and accepted by the elements. As the design progresses, the launch reliability allocations for Booster and engine will be replaced with element reliability prediction data at the earliest opportunity. Additionally, in the absence of SLS specific maintenance and repair timelines provided by the elements the off-nominal timelines used for this analysis were based on the off-nominal timeline developed for Ares, understanding of the SLS design, the nominal timeline, and GSDO inputs.

4.5.8 Results

The following is a summary of the LA and SR assessment. A few assessments have been included in this report. The summary of the analyses included in the LA and SR Report is attached at Appendix G.

4.5.8.1 Block 1A and Block 1B Launch Availability

Table 4.5.8.1-1 through Table 4.5.8.1-3 shows the LA results for each of the SLS configurations for a 1-8-5, 2-8-5, and a 3-8-7 shift respectively. **Based on the off-nominal operations being performed using a 1-8-5 shift schedule, none of the block configurations can meet the LA TPM threshold of 96.7%.** For these cases, the achieved LA is directly attributed to the probability of successfully launching on that first launch attempt because the time to repair any failure, regardless of if the failure can be repaired at the Launch Pad or the VAB, takes longer than 30 calendar days.

Based on the off-nominal operations being performed at a 2-8-5 shift schedule, each of the block configurations experience an increase in achieved LA. The increase in LA for a 2-8-5 shift schedule is driven by the fact that the mean time to repair a failure on the Launch Pad dropped from ~37 calendar days to ~19 calendar days and under the 30 calendar day launch window associated with LA. At the same time, the decrease in the repair time of failure at the Launch Pad also resulted in an increase in the MDT at 20 calendar days. The mean time to repair a failure requiring a roll-back dropped from ~100 calendar days to ~50 calendar days.

When assuming a 3-8-7 shift schedule, the Block 1, Block 1A (Solid), and Block 2 (Solid) can achieve an LA of 96.7% or greater. The LA of the Block 1A (Liquid), Block 1B, and Block 2 (Liquid) have an LA of 96.3%, 96.3%, and 96.2% respectively. With the assumption of a 3-8-7 shifting over 80% of the failures can be repaired within the 30 calendar days, but the MDT threshold of 85% at 20 calendar days is still not met by any of the cases. The driving factor of the Block 1A and Block 2 (with liquid rocket boosters) achieved an LA result being lower is the overall launch reliability of the Liquid Rocket Boosters (LRBs) being lower as compared to the Solid Rocket Boosters (SRBs). The Block 1B LA result is lower because the vehicle configuration consists of heritage boosters, a Core Stage, and a second stage.

Table 4.5.8.1-1 Launch Availability Results (All Config. - 1-8-5 Shift)

	Block 1 (1-8-5)	Block 1A (Liquid) (1-8-5)	Block 1A (Solid) (1-8-5)	Block 1B (1-8-5)	Block 2 (Liquid) (1-8-5)	Block 2 (Solid) (1-8-5)
1st Launch Attempt						
Achieved Launch Reliability	90.87%	84.56%	91.22%	88.43%	82.11%	88.37%
10 Day Launch Window						
Maintenance Down Time	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
20 Day Launch Window						
Maintenance Down Time	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
30 Day Launch Window						
Maintenance Down Time	0.70%	0.36%	0.15%	0.35%	0.15%	0.33%
Achieved Launch Availability	90.92%	84.60%	91.23%	88.46%	82.13%	88.40%
90% Confidence Level	90.55%	84.14%	90.87%	88.05%	81.64%	87.99%
Off-Nominal Bands*						
On Pad Band 1 (Calendar Days)	36.8	37.0	37.5	36.7	36.6	36.9
Roll-Back Band 2 (Calendar Days)	110.7	104.0	107.3	98.2	98.3	99.1

* Note: The off-nominal bands are based on single point failures.

Table 4.5.8.1-2 Launch Availability Results (All Config. - 2-8-5 Shift)

	Block 1 (2-8-5)	Block 1A (Liquid) (2-8-5)	Block 1A (Solid) (2-8-5)	Block 1B (2-8-5)	Block 2 (Liquid) (2-8-5)	Block 2 (Solid) (2-8-5)
1st Launch Attempt						
Achieved Launch Reliability	90.95%	84.97%	91.57%	87.90%	81.88%	87.59%
10 Day Launch Window						
Maintenance Down Time	0.28%	0.00%	0.00%	0.00%	0.00%	0.00%
20 Day Launch Window						
Maintenance Down Time	38.52%	48.10%	35.19%	26.37%	37.98%	27.08%
30 Day Launch Window						
Maintenance Down Time	50.98%	63.24%	46.91%	34.51%	49.66%	35.31%
Achieved Launch Availability	94.63%	91.68%	94.65%	91.07%	88.50%	91.14%
90% Confidence Level	94.34%	91.32%	94.36%	90.71%	88.09%	90.78%
Off-Nominal Bands*						
On Pad Band 1 (Calendar Days)	18.2	18.9	19.1	19.0	18.8	19.2
Roll-Back Band 2 (Calendar Days)	55.5	51.7	56.5	48.8	48.2	49.7

* Note: The off-nominal bands are based on single point failures.

Table 4.5.8.1-3 Launch Availability Result (All Config. - 3-8-7 Shift)

	Block 1 (3-8-7)	Block 1A (Liquid) (3-8-7)	Block 1A (Solid) (3-8-7)	Block 1B (3-8-7)	Block 2 (Liquid) (3-8-7)	Block 2 (Solid) (3-8-7)
1st Launch Attempt						
Achieved Launch Reliability	90.29%	83.94%	91.29%	88.22%	82.37%	88.47%
10 Day Launch Window						
Maintenance Down Time	51.22%	60.69%	47.57%	33.79%	50.42%	34.90%
20 Day Launch Window						
Maintenance Down Time	68.37%	72.45%	64.65%	72.05%	76.98%	72.04%
30 Day Launch Window						
Maintenance Down Time	81.05%	89.18%	80.56%	82.70%	90.38%	85.38%
Achieved Launch Availability	97.53%	96.52%	97.64%	96.49%	96.42%	97.44%
90% Confidence Level	97.33%	96.28%	97.44%	96.25%	96.19%	97.24%
Off-Nominal Bands*						
On Pad Band 1 (Calendar Days)	8.9	8.9	8.9	8.9	8.9	8.8
Roll-Back Band 2 (Calendar Days)	25.3	24.3	25.1	23.0	22.1	22.7

* Note: The off-nominal bands are based on single point failures.

4.5.8.2 Booster Procedure Delays

This sensitivity assumes that when a booster failure occurs that there will be some type of delay due to developing procedures. The baseline for Booster is to develop the actual procedures for LRUs after the failure mode has been identified during the Block 1 launch sequence. The risk associated with this is the time required to develop the procedures and the impact it may have on SR. For this sensitivity it is assumed that 85% of the time the delay associated with having to develop procedures will be a short delay (1-5 days) because Boosters will have mitigated this risk already by having procedures developed for LRUs that have a higher potential of failure, complexity, or involve hazardous procedures. However, 15% of the time the delay could result in a 10-20 day delay.

The results in Table 4.5.8.2-1 below show that that the Booster procedure delay has no impact on SR. This is due to the minimal number of Booster failures that occur during the processing of the vehicle as compared to Core Stage or Engine failures.

Table 4.5.8.2-1 Booster Procedure SR Results

	Off-Nominal Operations (3-8-7)	Off-Nominal Operations (3-8-7)
Nominal Operations (VAB – 2-8-5) (Pad - 3-8-7)	Case 10: (Baseline) 0.0% at 160 days 98% at 232 days	Case 13: 0.0% at 160 days 98% at 233 days

4.5.8.3 Project Element Battery Service Life

Table 4.5.8.3-1 summarizes the expected life of the Elements' batteries, as well as the expected time for when the Elements will install the batteries into the vehicle. The batteries used by ICPS are the most constrained, with them being installed approximately two days before roll-out and are good for <TBR-009> days before they need to be recharged. Recharging of the battery require the batteries to be removed from the vehicle which requires VAB access.

Table 4.5.8.3-1 Element Battery Life

Element	Battery Descriptions	Installed	Life
Core Stage	large Batteries units	Preinstalled	6 year life
	FTS Batteries	Prior to FTS test and rollout	109 days from when charged (wet)
Booster	Operational Inst. Battery	installed prior to IVT	109 days from when charged (wet)
	FTS batteries	installed prior to IVT	109 days from when charged

			(wet)
ICPS	multiple batteries	~ 2 days prior to rollout	<TBR-009> days from when charge (wet)

Table 4.5.8.3-2 summarizes the time intervals for when the batteries may be installed through launch. The results represent the 98th percentile value. Based on these results the Core Stage battery life will not be an issue since the batteries would be installed prior to FTS test and rollout and have a life of 109 days. The Booster batteries that are installed prior to IVT do have an issue because they have a battery life of 109 days, and it is 146.9 days from the start of IVT through Launch. This means that at some point after IVT the booster batteries will need to be replaced. The life of the ICPS batteries which are installed just prior to the FTS test are not violated but there is minimal margin.

Table 4.5.8.3-2 Processing Intervals

IVT to Launch	WDR to Launch	FTS Test to Launch
146.9 days	79.0 days	57.9 days

The only Element that has an issue with battery life right now is Boosters due to the time between the installation and launch. The OIB and FTS batteries used by Boosters, which are installed prior to IVT, have a life of 109 days, which will be violated before launch. All batteries will continue to be assessed for service life issues.

4.5.8.4 LOGISTIC DELAY ANALYSIS

For the Logistic Delay analysis there are two types of SLS design data inputs. The first is the SLS Program Manufacturing and Assembly Operational Sequence Report which defines the nominal sequence of events that need to be performed in order to successfully process the vehicle and ready it for start of countdown. The GOPD timeline represents the operations required to process the Block 1 vehicle. The second input used by the SLS DES Model is the off-nominal analysis that is comprised of the element launch reliability data (probability of experiencing a failure during the processing of the vehicle) and the ground operations and maintenance actions necessary to repair the vehicle and continue on towards the start of countdown.

A summary of the cases and results that were run for the Logistics Delay Analysis are included in the Booster assessment in section 5.2.

4.6 SLS MAINTENANCE SIGNIFICANT ITEMS (MSIs) COMPONENTS LIST SUMMARY.

Identification of MSIs was conducted by the Project Elements using similar set of criteria and evaluation techniques. The MSI candidate list will continue to be assessed against mission requirements, as the Maintenance Engineering Analysis (MEA) defines timelines and design matures to develop LRU candidates and determine final LRUs for CDR. The Core Stage and Booster MSI candidates lists are in Appendix B. Engine and SPIO MSIs list are SBU at this time.

4.6.1 MSI Selection Criteria

A maintenance significant item (MSI) is an item that is removed and replaced upon failure to restore system operability, but does not qualify as an LRU. It may also be replaced as part of a maintenance action or based on some periodic inspection criteria. Selection of an item to be designated an MSI is based on its design and supportability characteristics and the organization's maintenance philosophy and concept for the system. The possible items that may be designated an MSI include fuses, light emitting diodes, fasteners, switches, sensors, and other such items.

Replacement of an MSI may be an incidental action as part of LRU replacement, or it may be an independent action initiated by maintenance personnel as part of an inspection or test procedure.

For SLSP, the following MSI selection criteria should be considered.

1. Item is not an integral part of any LRU.
2. Item should be accessible for removal and replacement.
3. Item can be removed and replaced without causing collateral damage to the SLS, LRUs, or other MSIs.
4. Item can be removed and replaced without exposing maintenance personnel to unacceptable levels of safety hazards.
5. Item should physically fit through the access door provided for VAB/pad maintenance.
6. Item is procurable.
7. Capability to test/evaluate/assess the item is desirable. This is often accomplished by visual or tactile inspection.

An MSI may require a maintenance task for inspection and replacement. In this instance, a simplified MTA will be prepared to identify the resources required for the task.

4.6.2 LRU Criteria

An LRU is an item that is removed and replaced upon failure to restore system operability. Further selection criteria are applied to an MSI list to develop an LRU list. LRU selection is the result of conducting a supportability analysis on an MSI to consider reliability, safety, human factors, schedule, testability, or other factors. Maintenance on items selected as an LRU will be pre-planned. A detailed decision tree for guidance in selecting LRUs is depicted in Figure 4.6.3-1. The Elements will meet SLS-RQMT-161, HSIR, for the selection of LRUs. The following criteria should also be considered when selecting an LRU.

4.6.3 LRU Selection Criteria

1. Item should be launch mission relevant, i.e., if a failure does not impact or constrain the authorization to launch, then the item is not an LRU. This determination should be based on the FMEA results.

2. SLS in stacked configuration at the VAB and complete ready-to-launch configuration at the pad should be capable of performing fault detection and fault isolation to the item or an assemblage of items that would be removed and replaced as a group to resolve a system failure or other anomaly.

3. SLS in stacked configuration at the VAB and complete ready-to-launch configuration at the pad should be capable of performing confidence testing after replacement of the item or an assemblage of items that would be removed and replaced as a group to confirm the repair was successful and that no maintenance-induced errors occurred during performance of the maintenance task.

4. Item should be designed such that it can be tested when not installed in the SLS to confirm its operability. This testing includes a pre-installation test to confirm it works and a test after removal to confirm it is non-operable. All LRU testing for SLS is to be performed at KSC or the manufacturer.

5. Item can be removed and replaced without causing collateral damage to the next higher assembly or other LRUs.

6. Item is a configuration item and appropriate configuration status accounting and documentation is maintained to assure compatibility with SLS design.

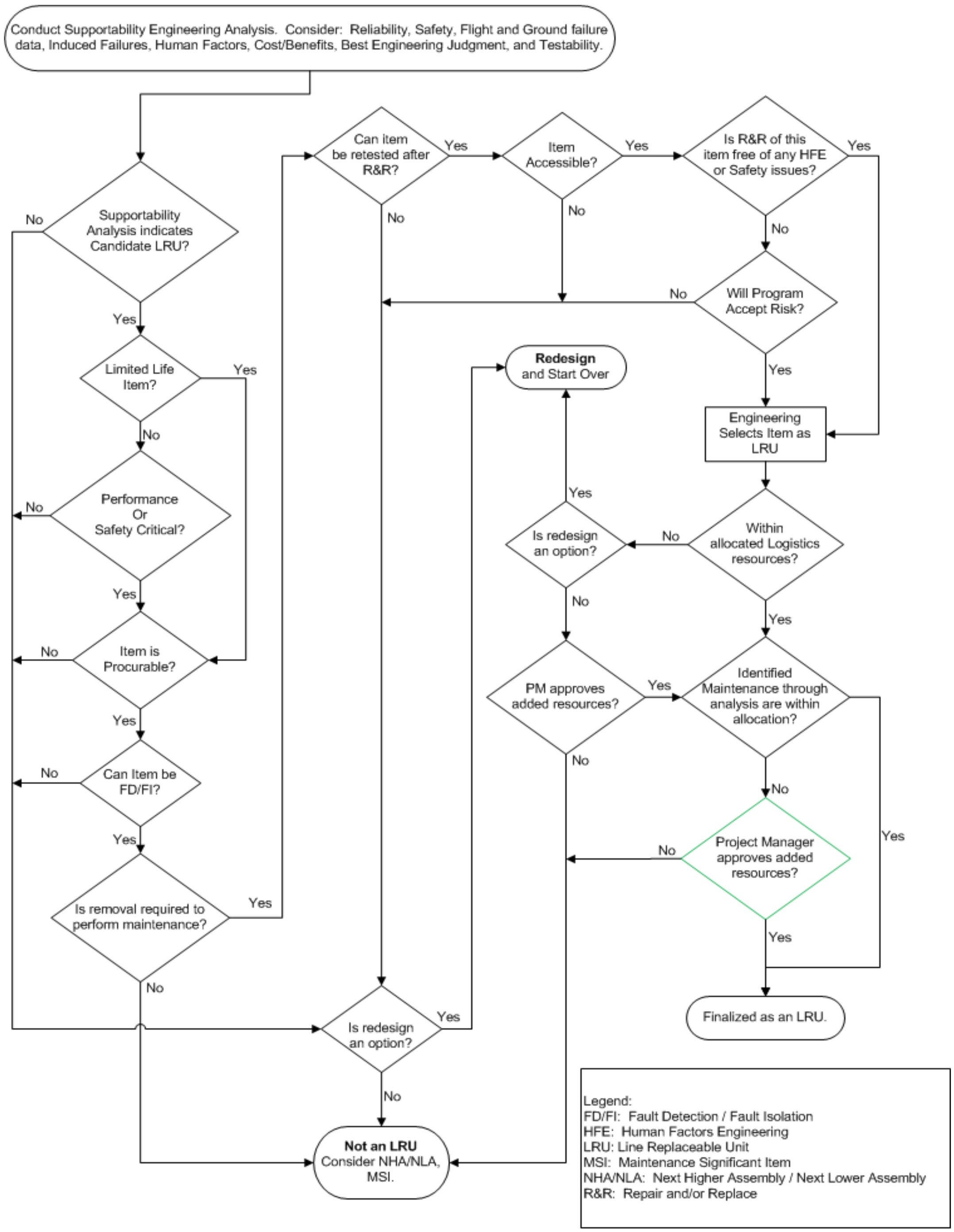


Figure 4.6.3-1 LRU Decision Tree

4.6.4 LRU Desirable Criteria

1. Item should be accessible without removal of any other item. This means it should not be behind another item that would need to be removed in order to gain access to the item.

2. Item is attached to next higher assembly using captive hardware. Where this is not feasible, then appropriate measures must be made for foreign object debris (FOD) protection.
3. Item should be capable of being moved into and out of the SLS by one person.
4. Item has handles or attachment points for lifting devices.
5. Item can be purchased as a single entity or as part of an assemblage that is replaced to restore system operability.
6. Item does not create a requirement for special internal access ground support equipment or other support equipment that has no other SLS application.

4.7 SLS SUPPORTABILITY RISKS AND RISK REDUCTION APPROACHES

The purpose of this effort is to determine the supportability risks for the SLSP system. Through trade-off analyses the potential risk that may not meet the support, design, and operation requirements for schedule, performance, readiness, and supportability, and to evaluate the new system support alternatives with regard to the proposed design, operation, and support concepts.

A number of risks have been developed during the Use Study assessment to address a number of foreseen issues with ground operations and processing. They are found in section 4.1 and listed below.

- **Candidate Risk 11626** – *PAD Access (Consistent Elevations), Vehicle Assembly Building (VAB) platforms, Umbilical Locations, Services (i.e., RP for advanced boosters), and Support Equipment required.*
- **Candidate Risk 11629** – *R-15 Launch, Availability Requirement, Maintenance Downtime, and System Readiness.* (SLS-TRADE-019).
- **Candidate Risk 11632** – *Chill down, Propellant Loading, Venting, Purge and Inerting, Detanking techniques and timelines, Prelaunch sequencing of the Main Propulsion System (MPS), Hazardous Gas detection techniques, Turnaround times from a scrub, and Demonstrate allowable hold times for launch count down.*

Internal supportability issues are being tracked and evaluated through the LSA process and assessed with the DES model. Logistics Delay Times (LDT) parameters have been added to the DES model and were utilized to assess the off-nominal procedures delay support alternative for the booster element. Table 4.7-1 describes the current supportability issues and their associated status for SLSP PDR. These issues and issues will continue to be assessed and with mitigation steps to reduce or eliminate the issue.

Issue Statement	Status	Rating Booster	Rating SLS
Given the fixed budget for booster hardware production, there is a potential of not having sufficient spares	1st flight will be supported by 2nd, cannibalized being possible; spares analysis will identify sourcing needs and timelines for items not readily available	Yellow	Yellow (May require hardware development)
Given the SLS Block 1 launch processing manifest (4-5 years with little to no activities), there is a potential of not having sufficiently trained and experienced personnel	Sufficient information should be available to support (MEAs, heritage information, nominal assembly instructions, PR database); also teaming with ground ops for optimized use of resources, information, and skills will help mitigate	Green	Yellow (May require personnel with advanced skills not readily available)

Given the limited / reduced maintenance concept approach, there is a potential of not having sufficient tooling / GSE for maintenance activities	Identified GSE needs will come from the MEAs, rollback timing will afford time to prepare	Green	Yellow (May require hardware development)
Given the limited / reduced maintenance concept approach, there is a potential for a time delay for maintenance activities (schedule may be in terms of days, not shifts)	MEAs will be to sufficient to identify concepts and needs to help capture information and sources required to prepare detailed maintenance task instructions when needed	Green	Green
Given the limited / reduced maintenance concept approach, there is a potential of not having instructions ready for corrective maintenance task in timely manner	Detailed instructions will be developed as needed once nonconformance is identified; sufficient information should be available to support (MEAs, heritage information, nominal assembly instructions, PR database)	Green	Green

Table 4.7-1 Supportability issues identified for the booster element but being assessed across SLSP.

5.0 PROJECT ELEMENT SUPPORTABILITY ASSESSMENTS

SLSP Supportability requirements assessments are to determine the maturity of analysis of design with respect to supportability for the SLSP PDR. SLSP ILS Team worked with Project Elements to determine if ILS elements have been assessed for compliance and appropriate risks identified. The following assessments were conducted for the elements and documented in the SOAR report (SLS-RPT-168).

5.1 CORE STAGE PDR ASSESSMENT

The SLS SE&I Operations Team participated in the SLS Stages PDR as members of the Operations and GSE Team. Reviewers were assigned documents to review and participated in the comment screening process. Each sub team within the SE&I Operations Team participated in the review as follows: Operations Engineering, Integrated Master Timeline, Vehicle Processing Analysis, Logistics/Supportability, GSE, and Flight Operations.

A vast amount of documentation was made available during the Stages PDR. Members of the SLS SE&I Operations team reviewed a total of 48 artifacts to include planning, requirements, drawings, and analysis. The SLS SE&I Operations team submitted a total of 48 comments, of which 4 were transferred to other teams and 2 were accepted as pre-RIDs. A total of 261 comments were screened by the Operations and GSE Team during the PDR of which 184, 71%, were accepted, as comments or pre-RIDs, after review.

There were several topics of concern for the SE&I Operations Team during the review to include a lack of Logistics Support data required, Operations Procedure development, Post-Green Run testing activities, and the planning for spare components. The availability of spares was entered as a RID, CSPDR-0029, as well as incomplete Logistics Support Data, CSPDR-0079.

The SLS DR for Element Logistics Data, 1406OP-32, lists data required at PDR. The Stages delivery of logistics data omitted items such as preliminary tools, test equipment, and common bulk items. The Operations and GSE team worked with the S&MA team to submit a combined comment based on the similar concerns. The SLS SE&I Operations Team will use this data to identify logistics risks and develop a cost-effective integrated support solution. The integrated list of resources required to maintain the flight and ground hardware in serviceable and flight ready condition is required by the launch site, KSC, logistics organization.

With the decision to not have a Main Propulsion Test Article (MPTA) the only place for the development (testing) of processing procedures for flight will be at the Green Run test. A risk was established by SLS SE&I Operations and transferred to Stages to mitigate. Stages de-escalated the risk to a candidate status with no active mitigation. This poses a risk for KSC while processing the vehicle for flight. Sequencing of the MPS system, haz gas detection, chill down, purge, venting, inerting, and de-tanking are some of the procedures that will require development. The NASA Lessons Learned data base has an item titled “Systems Test

Considerations for High Performance Liquid Propellant Rocket Engines", entry 0763, that addresses many of these concerns.

The current SLS Operations Concept states elements will not travel to KSC with open work. Currently SLS Stages is planning a Green Run of the flight articles for the 1st two flights. The Core Stage DD250 will occur at Stennis Space Center (SSC) post green run. Post- test checkout and refurbishment appeared to be omitted from current planning documentation. Items such as acceptance checkout, stage & engine leak checks, instrumentation repair, and TPS repair should be included in any planning and testing timeline. Maintenance planning at SSC should ensure the availability of GSE, identification of facility requirements, and the possibility of the return of the stage to MAF.

The current sparing philosophy for the Core Stage is to utilize production assets of the 2nd flight article as spares for the 1st flight article. The Boeing Logistics Support Plan states spares for flight articles will be available at MAF, while the Logistics Support Data document states that any replacement post DD250 will be considered a long lead item and require full procurement. If the contract is not extended past the 1st two flights, the second flight article will not have spares.

Many of the comments submitted during the Stages PDR were accepted and will be tracked to closure by the Stages prime contractor. Some agreements have already been made on the closure plans. Since the Stages PDR several other comments have been overcome by events (OBE). The following outlines currently related to several of the comments/RIDs:

1. Element Logistics Data – agreement was made to supply the missing data 60-days post Stages PDR.

2. Operations Procedure Development – the risk transferred to stages has been re-opened for assessment and SLS SE&I Operations Team members are working with Stages representatives to provide necessary mitigation steps.

3. Post-Test Checkout & Refurbishment – post PDR the Stages Test team conducted a Value Stream Mapping event to start planning for all events to include post-test activities prior to DD250. Results were provide and reviewed by the SE&I Operations Team who provided comments. Planning activities are sufficient at current state of the program/element.

4. Sparing Philosophy – documentation was updated to be consistent related to the philosophy to utilize production assets. SE&I Operations are currently working with all the elements to ensure an integrated sparing philosophy to meet the system readiness TPM.

There were many comments submitted during the PDR by the SE&I Operations team. The Stages team quickly answered many of the concerns and is currently working to develop closure to the remaining comments/RIDs from the SE&I Operations Team.

5.2 BOOSTER ASSESSMENTS

There were three assessments performed for the Booster PDR. These assessments included the PDR assessment, the maintenance approach, and the battery service life assessment.

The SLS SE&I Operations Team participated in the SLS Booster Preliminary Design Review (PDR) as members of the Operations, Logistics and GSE Team. Reviewers were assigned documents to review and participated in the RID development and screening process.

5.2.1 PDR Assessment

Key documentation was reviewed during the Booster PDR. The SLS SE&I Operations team submitted a total of 31 issues, classified with 7 pre-RIDs, 15 comments, 8 withdrawn, and 1 as risk. There were several topics of concern for the SE&I Operations Team during the review to include a lack of Logistics Support data required to support procedure development, booster batteries limited life, and the logistics support risks identified. Below, in figure 5.2.1.2-1, are the supportability risks being monitored for mitigation.

DESIGN FOR SUPPORTABILITY ASSESSMENT Preliminary Design Review				
	SLS Booster			
LOGISTICS SUPPORT ELEMENTS	**Status**	**Impact/Likelihood**	**Risk**	**Comments**
Maintenance and support concept				
Have the echelons of level of maintenance been defined?	C	H/L	5	**Two level with OEM support to KSC for Organizational off-nominal tasks with minimal procedures development.**
Have basic maintenance functions been identified for each level?	O	M/L	3	
Have qualitative (quantitative) parameters been established downtimes?	O	H/L	5	**MDT and LDT are being assessed, even though there are no Booster TPMs associated with maintainability**
Have the criteria for level-of-repair decisions been adequately defined?	O	M/L	3	
Have the responsibilities for maintenance been established?	O	M/L	3	**Ongoing efforts with the GSDO LIT to define interfaces and data requirements**
MSILs				
Is the process for identification of MSIs clearly defined?	O	NA		**Robust MSI list submitted for Booster PDR**
Does the MSIL appear adequate for PDR?	Yes	NA		**Need to designate heritage vs. new hardware**
Tools, and Test Equipment (Support)				
Is the process for identification of TTEs clearly defined?	Yes	NA		Based on heritage and avionics
Is the TTE selection process based on cost-effectiveness considerations (i.e., life cycle costs?	Yes	NA		
Has existing TTE been identified that has potential for reutilization?	O	M/L	3	Process is underway for existing and potential for new hardware (TBR)
Does the TTEL appear adequate for PDR?	O	M/L	3	Process is underway for existing and potential for new hardware (TBR)
Supply Support				
Are the specified logistics pipeline times compatible with effective supply support?	O	H/L	5	Risk identified and preliminary assessment of impacts to LA and SR
Have supply availability requirements been established (the probability of having a spare available when required)?	O	H/L	5	Risk identified and preliminary assessment of impacts to LA and SR
LLTIs				
Is the process for identification of LLTIs clearly defined?	O	M/L	3	Approach is consistent with other project elements and SLSP
Manpower and Personnel				
Are maximum considerations being given to the use of existing personnel skills for new equipment?	O	M/M	6	Given the SLS Block 1 launch processing manifest (4-5 years with little to no activities), there is a potential of not having sufficiently trained and experienced personnel
Are operational and maintenance personnel requirements being minimized to the extent possible?	O	M/M	6	Given the SLS Block 1 launch processing manifest (4-5 years with little to no activities), personnel will be minimized to ther extent possible.
Facility and Storage				
Have facility and storage requirements (space, volume) necessary for system operation been defined?	O	M/L	3	Existing at KSC based on heritage shuttle
Have facility and storage requirements (space and volume) necessary for system maintenance been defined?	O	M/L	3	Existing at KSC based on heritage shuttle
Have storage environments been defined?	O	M/L	3	Existing at KSC based on heritage shuttle
Packaging, Handling, Storage, and Transportation (PHST)				
Are T&H requirements for both operational and maintenance functions defined? These functions include transportation of prime equipment, test and support equipment, spares, personnel, and data.	O	L/L	1	Transportation and handling described in the Booster ILSP
Are T&H handling environments (temperature, shock, and vibration, etc.) defined?	O	L/L	1	Transportation and handling environments known for heritage
Are the modes (air, ground, vehicle, rail, sea, pipeline, or a combination) of transportation known?	O	L/L	1	Transportation modes described in the Booster ILSP
Are the requirements for packaging known?	O	L/L	1	Current packaging requirements identified for heritage

Figure 5.2.1.2-1 shows the supportability assessment for the Booster PDR

Many of the comments submitted during the Booster PDR were accepted and will be tracked to closure by the Booster prime contractor. The following outlines currently related to several of the comments:

- Booster battery limited life is being assessed by the SLS logistics and is discussed in this version of the SOAR
- Off-nominal procedure development – The impacts of not having procedures developed for LRUs prior to the occurrence of the failure is being assessed for impacts to launch availability and system readiness and is included in this report.
- SE&I Operations are currently working with all the elements to ensure an integrated sparing philosophy to meet the system readiness TPM.

The Booster team quickly answered many of the concerns and is tracking closure to the remaining comments from the SE&I Operations Team.

5.2.2 SLS Booster Maintenance Approach

The primary focus of the LSA effort is on operational logistics. Operational logistics is considered to be those efforts and activities associated with providing support to the Booster end user to sustain launch site processing and ensure operability in support of the flight manifest for Block 1. Logistics support analysis will use Integrated Maintenance Engineering Analysis (IMEA). The IMEA integrates a basic Maintain Engineering Analysis (MEA) with Reliability-centered Maintenance (RCM) and Systems Engineering tools. Reliability information and documentation of heritage systems are available for use in supporting the two launches required of Block 1. For Launch Availability impacts, it is assumed that 85% of the time, the delay associated with having to develop procedures will be a short delay (1-5 days) and 15% of the time the delay could results in a 10-20 day delay. Boosters will have mitigated this risk by already having developed procedures for LRUs that have a higher potential of failure, complexity, or involve hazardous procedures.

The Maintenance Significant Item (MSI) list will be organized into families based on location, reliability, and accessibility (e.g. avionics batteries). A representative Maintenance Task Analysis (MTA) will be generated for each MSI family – the object being to enable early assessment of the capability to perform the required maintainability and supportability functions. Booster design development will consider MSIs as LRUs until reliability and maintainability issues are resolved. Corrective maintenance instructions will be provided at the time a nonconformance is generated for a failed MSI. A repair disposition, along with corrective maintenance instructions will be provided by ATK and will be based on applicable MTA, nonconformance database, and nominal manufacturing planning. ATK will assume the technical lead; GSDO will assume the performance lead. Time to repair could take longer with this concept which could impact operations at KSC. However, off-nominal maintenance costs are reduced.

Below is a summary of the cases that were run for the Logistics Delay Analysis. Note: These cases build off the Block 1 baseline for Launch Availability where the countdown operations and off-nominal operations are performed using a 3-8-7 shift.

Case 1: Block 1 Configuration;

- **Assumptions:** Personal, (or GSE or Procedure) delay occurs 100% of the time when there is an SLS failure. All personnel delays are a short delay (1-5 days).

- **Results:** The results for Case 1, shows that the Block 1 vehicle has an achieved launch reliability of 90.98% and an LA of 96.57% with a 90% confidence interval when the off-nominal operations are performed using a 3-8-7 shift schedule. This result is **very close** to meeting the LA TPM threshold of 96.7%. The off-nominal band for this case is **28.8** calendar days versus 25.3 for the baseline.

Case 2: Block 1 Configuration;

- **Assumptions:** Personal (or GSE or Procedure) delay occurs 100% of the time when there is an SLS failure. All personnel delays are a medium delay (10-20 days).

- **Results:** The results for Case 2, shows that the Block 1 vehicle has an achieved launch reliability of 91.25% and an LA of 94.68% with a 90% confidence interval when the off-nominal operations are performed using a 3-8-7 shift schedule. This result is **very close** to meeting the LA TPM threshold of 96.7%. The off-nominal band for this case is **39.1** calendar days versus 25.3 for the baseline.

Case 3: Block 1 Configuration;

- **Assumptions:** Personal, GSE, and Procedure delay each occurs 100% of the time when there is an SLS failure. All personnel delays are a medium delay (10-20 days).

- **Results:** The results for Case 3, shows that the Block 1 vehicle has an achieved launch reliability of 90.48% and an LA of 90.11% with a 90% confidence interval when the off-nominal operations are performed using a 3-8-7 shift schedule. This result is **NOT close** to meeting the LA TPM threshold of 96.7%. The off-nominal band for this case is **69.9** calendar days versus 25.3 for the baseline.

Case 4: Block 1 Configuration;

- **Assumptions:** Spare delay occurs 100% of the time when there is an SLS failure. All personnel delays are a long delay (1-2 years).
- **Results:** The results for Case 4, shows that the Block 1 vehicle has an achieved launch reliability of 91.25% and an LA of 90.90% with a 90% confidence interval when the off-nominal operations are performed using a 3-8-7 shift schedule. This result is **NOT close** to meeting the LA TPM threshold of 96.7%. The off-nominal band for this case is **535.4** calendar days versus 25.3 for the baseline.

Case 5: Block 1 Configuration;

- **Assumptions:** Personal delay occurs 5% of the time when there is an SLS failure. 90% of the time the delay is will be a short day (1-5 days) and 10% of the time the delay will be a medium delay (10-20 days); GSE delay occurs 15% of the time when there is an SLS failure. 90% of the time the delay is will be a short day (1-5 days) and 10% of the time the delay will be a medium delay (10-20 days); Procedure delay occurs 25% of the time when there is an SLS failure. 90% of the time the delay is will be a short day (1-5 days) and 10% of the time the delay will be a medium delay (10-20 days); Spare delay occurs 100% of the time when there is an SLS failure. 50% of the time the delay is will be a short day (1-5 days), 35% of the time the delay will be a medium delay (10-20 days), and 15% of the time the delay will be a long delay (1-2 years).
- **Results:** The results for Case 5, shows that the Block 1 vehicle has an achieved launch reliability of 91.06% and an LA of 93.90% with a 90% confidence interval when the off-nominal operations are performed using a 3-8-7 shift schedule. This result is **NOT close** to meeting the LA TPM threshold of 96.7%. The off-nominal band for this case is **119.1** calendar days versus 25.3 for the baseline.

In summary, the Launch Availability decreased slightly over the baseline, but the decrease was so small that it is likely captured within the noise associated with the model. The results from the LA impact assessment shows that the Block 1 vehicle has an achieved launch reliability of 90.9% and an LA of 97.2% with a 90% confidence interval. When comparing the results of Case 5 to the baseline (Case 4) there is a slight increase in the average repair time on the Launch Pad and in the VAB.

The SLS Operations team will continue to assess the Booster Maintenance Approach as the Reliability, Maintainability, and supportability data becomes more refined.

5.2.3 Booster Battery Life

The flight batteries cannot support the entire duration of tasks in the VAB due to their limited life of 109 days. This is part of an overall SLS battery limited life assessment documented in the SOAR.

With no pad access, rollback for limited life items may not be optimal for launch availability. Booster battery life could be consumed prior to launch, effecting system readiness and launch availability. Potentially additional batteries could be required to support testing and impact budget. Alternate power source will need to be utilized during VAB integration testing to extent booster battery life. There are 2 battery lives associated with the booster battery: dry life is 2 years and wet life of 109 days.

Booster (for its FTS batteries) is an issue due to the time between the installation and launch. The FTS batteries used by Boosters, which are installed prior to IVT, have a life of 109 days, which will be violated before launch. All batteries will continue to be assessed for service life issues. A complete assessment of the impacts of battery life on launch availability and system readiness was conducted at the SLS Program level.

Booster will need to review their battery requirements and service life to determine if: 1) Ground power is sufficient for ground processing, and/or 2) additional batteries required at KSC.

5.3 ENGINES ASSESSMENT

5.3.1 RS-25 Purge

During the Shuttle Program, the SSME nozzles were inadvertently subjected to chlorides while applying a corrosion inhibitor to the hot side of the nozzle coolant tubes. The chlorides leached into the engine nozzles and promoted corrosion when the nozzles were exposed to a humid environment. The corrosion resulted in pinholes forming in the engine nozzles which resulted in a loss of hydrogen during engine operation.

Three actions have been taken to arrest the corrosion:

- Apply corrosion inhibitor to the first 30 inches of the nozzle from the Main Combustion Chamber (MCC).
- Clear coat the first 8 inches of the nozzle from the Main Combustion Chamber (MCC).

- Maintain a dry air purge using ECS carts when the engines are not in a controlled storage environment, as shown in Figure 5.3.1-1.

Figure 5.3.1-1. SSME Engines with Nozzle Closures and Purge Air Ducts Attached

The Manufacturing and Assembly (M&A) buildings at MAF are controlled environments and an engine purge will not be required during the CS manufacturing process. Using ECS carts to maintain a purge on the *Pegasus* barge during transit of the CS between NASA centers can be accomplished with minimal impact. The ECS carts will be needed to maintain a purge while the CS is in the VAB and while the SLS vehicle is on the pad. Two Shuttle purge carts are expected to be available for use on the CS. These carts are capable of supporting the purge of 4 engines at once. The purge will not be required for the approximate 8-hour rollout operation. Current assessment indicates that the engines could withstand a 48 hour maximum duration without a purge with the covers installed.

No assessment has been made on the impacts of the EM-1 green run testing that will be performed at SSC. The issue is unique to the existing engine nozzles; a purge will not be required on any new nozzles that are supplied to the Program.

Four roll-on ECS carts exist. Two of the existing carts have been assigned to Orion; the other two are, as yet, unassigned for future use.

Further investigation is needed into the MAF assembly environment to determine what areas are and are not environmentally controlled, and if the controlled environments are capable of keeping the humidity at an acceptable level considering the coastal environment.

A further investigation into determining the feasibility of maintaining the purge during the non-engine-firing time associated with the EM-1 green run test based on the SSC environment impacts include:

- Ability to locate and operate ECS carts on the test stand
- Ability to remove the nozzle enclosures while on the test stand, as needed

Determine if there are other areas where the purge would be required and the difficulties associated with maintaining the purge in those areas. Include a comprehensive investigation of the green run test physical environment and timeline to gain a better understanding of the constraints that will be incurred during this test. Determine if the two remaining ECS carts can be dedicated to CS, or if new carts will need to be acquired. Determine the maximum cumulative time that the remaining engine nozzles can remain in a non-controlled, non-purged environment. Identify any issues with removal or reinstallation while at the launch pad.

5.3.2 Engine Access on the Pad

Assess engine access on the pad for the following: engine change out, throat plug removal, corrective maintenance, corrosion purge on the nozzle, etc., operations impacts, availability impacts, requirements impacts, and a recommendation.

The GSDO Program Review Board (PRB-R-012) decided to modify the main engine change-out requirement to apply only in the VAB.

There will be anomalies that will require access to the engines on the launch pad.

Engine change-out capability does not extend to providing access to safe the FTS.

- Nominal engine operations to be performed at the launch pad include removal of throat plugs and remove before flight covers (captured within Drop 3 of the GOPDb).
- Nominal operations require the Engine Service Platform (ESP) for access. The ESP is installed early in the VAB.
- The capability to remove the ESP is required for nominal operations. The ESP is removed at the pad and lowered onto a transporter.
- Rain and wind shields are used at the pad for protection from the environment.
- Engine change-out at the pad is a vehicle need based on LA. If engine change-out is only performed at the VAB, then LA suffers.
- Engine change-out capability at the pad significantly increases the number of repairs which can be performed at the pad; 95 percent of engine failures can be repaired at the pad versus only 60 percent without the engine change-out capability.

- Returning to the VAB to perform engine repairs or an engine replacement takes nearly 6 calendar days longer than repairing at the pad. This is due to the time required to prepare the vehicle for roll-back and roll-out, the time for the moves, and the time to perform connections in the VAB.

Plan to accommodate use of the Engine Vertical Installer in the VAB and at the launch pad.

Engine change-out location is determined on a case-by-case basis and is performed where it makes the most sense.

Identify Launch Availability impacts based on GSDO decision not to have engine change out at the PAD.

5.4 INTEGRATED SPACECRAFT & PAYLOAD ELEMENT ASSESSMENT

The Launch Vehicle Stage Adapter (LVSA) will provide access to the ICPS for nominal and off-nominal access in the VAB and at the launch pad. Currently, planned activities (TBD) inside the LVSA volume will be Safe & Arm (S&A) of the pyrotechnics, inspections, N2H4/N2O4 loading, LRU R&R, and cable mating. The access doors are currently oval in shape and 36 inches in diameter. The N2H4/N2O4 ACS servicing panel is located at 171 degrees. The LVSA/ICPS volume is depicted in Figure 5.4-1.

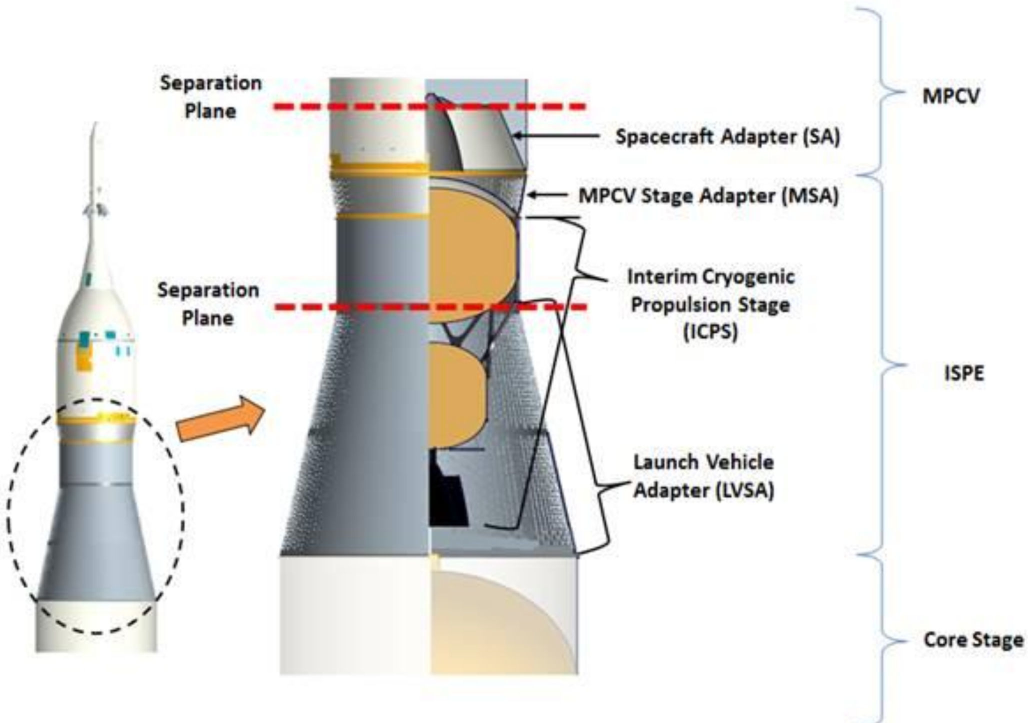


Figure 5.4-1. Access to the ICPS through the LVSA

The access doors located on the LVSA were increased in diameter from 30" to 36" based off the recommendation from SLS SE&I Operations, Human Factors Engineering (HFE), and Internal Access (IA) GSE designers since the last SOAR deliverable. It has been stated recently though that if possible we would like to see the doors diameter increased to 38", but 36" will work if unable to be increased.

Previous baseline for loading operations of N2H4/N2O4 would have required access internal to LVSA volume at the ICPS ACS located at 171 degrees if done at the Pad. N2H4/N2O4 nominal loading operations would have required ground personnel in SCAPE suits, IAGSE**,** scuppers for spill containment, hoses for loading, carry-on lighting, and ventilation. Current planning is for loading to be performed at a larger offline work area and not require IAGSE due to the ICPS not being mated to the LVSA. The engine will need a constant purge after desiccants are removed, and the N2H4/N2O4 bottles will need temperature control through the use of heaters once they are loaded through launch. GSDOP recommended the removal of the Pad access arm to the LVSA volume which would preclude doing any nominal or off nominal work while at the Pad. This work would include either loading or offloading N2H4, LRU R&R, Pyro S&A, or other TBD activities yet defined. After much discussion and analysis with SLS, the arm removal was put on hold until further studies could be done to analyze cost and schedule impacts to this decision.

The SLS SE&I Operations team is currently working with SPIO, GSE, and HFE to analyze door size requirements and tasks identified inside the LVSA volume. The SLS SE&I Operations team did not recommend loading N2H4/N2O4 internally due to contamination concerns, accessibility issues in SCAPE along with necessary IAGSE, lighting, ventilation, and safety issues concerning timely egress. Due to the use of heritage equipment and the current LVSA, the service panel cannot be relocated to the Outer Mold Line (OML). While Operations does not recommend internal loading, we recognize that loading the system with a volatile hypergolic like N2H4/N2O4 as late as possible is the best practice for safety and contingency reasons. The decision was made to load offline causing cost implications to be considered including temperature control on the N2H4/N2O4 tanks while the system is loaded with N2H4/N2O4.
SLS SE&I Operations does not agree with GSDOP's recommendation to remove the Pad access arm for LVSA and ICPS access. In an Off-nominal situation the batteries, unless redesigned, will have to be R&R prior to launch. This will require a roll back if the access arm is not there. Along with this, there will be no pyro access at the LVSA separation joint for S&A, or the ability to offload N2H4/N2O4 if the situation required it.
Along with the above recommendation, the SLS SE&I Operations team recommends relocating the pyrotechnics detonation cords and detonator manifold to within reach in distance for ground personnel in shirt sleeves to S&A the pyrotechnics from the OML of the system.
Also, if possible, use a battery with a chemistry that does not require R&R prior to launch, or redesign current batteries to have a longer service life. For further analysis refer to section 3.1.6, Battery Life Analysis.
Continue working with GSE, HFE, and SPIO to determine door sizes, ideal battery solution, off nominal activities, and nominal activities to the ICPS and LVSA volume while working to make a more supportable vehicle.

6.0 SLS LOGISTIC SUPPORT ANALYSIS RECORD (LSAR) DATABASE

The LSAR data shall serve as the ILS technical database applicable to all SLSP and Project Elements (or format equivalent). The specific data entry media, storage, and maintenance procedures are left to the Project Elements. Validated LSAR Automatic Data Processing (ADP) systems are available for automated storage of the LSAR data. The LSAR data forms a database to:

- Determine the impact of design features on logistics support.
- Determine the impact of the proposed logistics support system on the system/equipment availability and maintainability goals.
- Provide data for tradeoff studies, life cycle costing, and logistic support modeling.
- Exchange valid data among functional organizations.
- Influence the system/equipment design.
- Provide the means to assess supportability of the fielded item.
- Provide the means to evaluate the impact of engineering change, product improvement, major modification or alternative proposals.

LSAR Team will be established to:

- Guide the development of LSAR data through SLS Program
- Develop rules and assumptions that will apply across SLS with regards to the program's LSAR development
- Establish and maintain the LSAR Style Guide

The relational design of the LSAR database is intended to facilitate such integration and to encourage independent development of useful ad hoc queries which promote use of the data in the design process. The use of industry-developed, cost-effective automation tools which link "islands of automation" (e.g., computerized drawings and technical manual authoring systems) through the LSAR is encouraged.

Figure 6.0-1 depicts the flow of the LSAR database data flow through the SLSP technical data exchange to the HOSC.

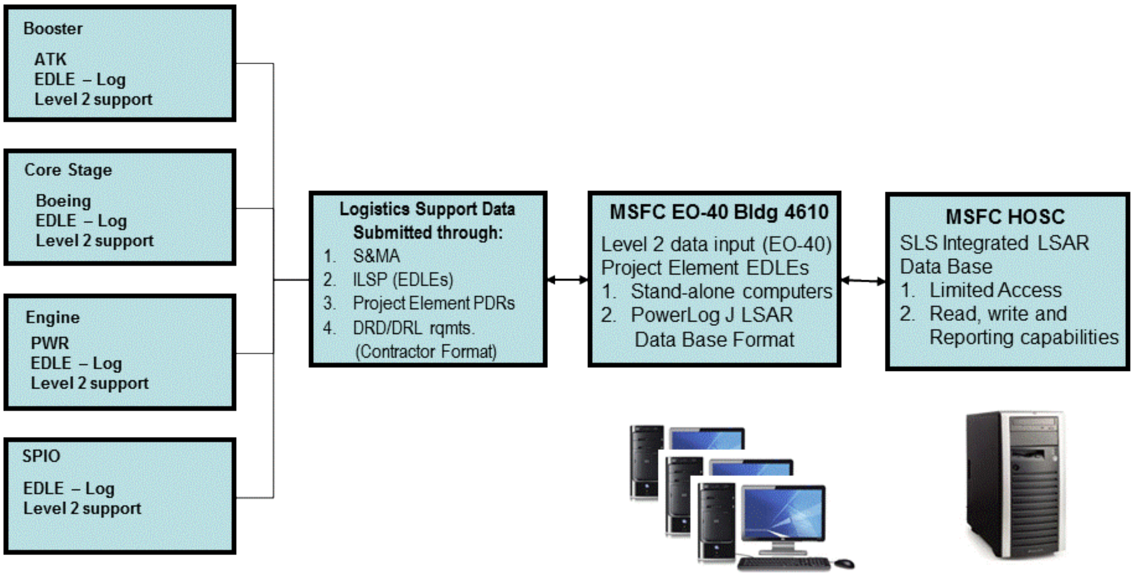


Figure 6.0-1 LSAR Data Flow

Logistics Support Analysis Record (LSAR) data base provides a standard data format integrating the following:

- Operations and Maintenance Requirements
- Reliability, Availability, and Maintainability
- Failure modes, effects and criticality analysis
- RCM
- Item Identification (Cataloging, CAGE/Ref #/NSN)
- Part Application (Provisioning, PLISN) Support Equipment
- Transportability
- Personnel (Skills and Training)
- Task Analysis
- Unit Under Test
- Facility
- Packaging
- Drawings

6.1 LSAR LOGISTICS CONTROL NUMBERS

Logistics Control Number (LCN) denotes the Logistic Support Analysis Control Number in the MIL-STD-1388-2B, LSAR database. It is defined as a code that represents a functional or hardware generation breakdown/disassembly sequence of system/equipment hardware including Support Equipment, training equipment, and installation (connecting) hardware. The LCN is the foundation against which every piece of data within the LSAR is stored. The Alternate Logistics Code (ALC) refers to an alternate item which may be used at the same Logistic Control Number (LCN) indenture level. It is a 2 position numeric left-justified data element. It is defined as a code used to allow documentation of multiple models of a system/equipment, or alternate design considerations of an item, using the same LCN breakdown. Note: ALC of zero "00" will always be used as the basic system. The End Item Acronym Code (EIAC), Usable On Code (UOC), LCN, and ALC are all keys in the LSAR data tables. All end items, system, components/LRUs/SRUs, and parts are assigned values for each of those data elements. All non-key data elements such as Mean Time Between Failure (MTBF), Operational Availability, man-hours, maintenance tasks, etc. are documented against the EIAC/LCN/UOC/ALC keys for every item that will be stored in the LSAR data base. These keys are required to add records or retrieve records from the LSAR data base.

The hardware breakdown structure in Figure 6.1-1 depicts the LCN Dictionary Codes for the SLS Program. All members of the LSAR Team and the SLS Program have adopted the LCN Dictionary. This hierarchical structure has been incorporated in the LSAR data base and will be installed on the NASA Huntsville Operations Support Center (HOSC) server post PDR. Each program element associated with SLS has been provided the information (i.e., LCN, ALC, UOC) above corresponding to their element and requested to break down their structure from that point to each level of LRUs until they get to the lowest level against which they expect to document logistic engineering data. They have been instructed to assign their LCNs in accordance with the LCN dictionary. This element hardware breakdown will be added into the LSAR package installed on the NASA HOSC server. SLS Flight Hardware LCN Structure will be 1123222221.

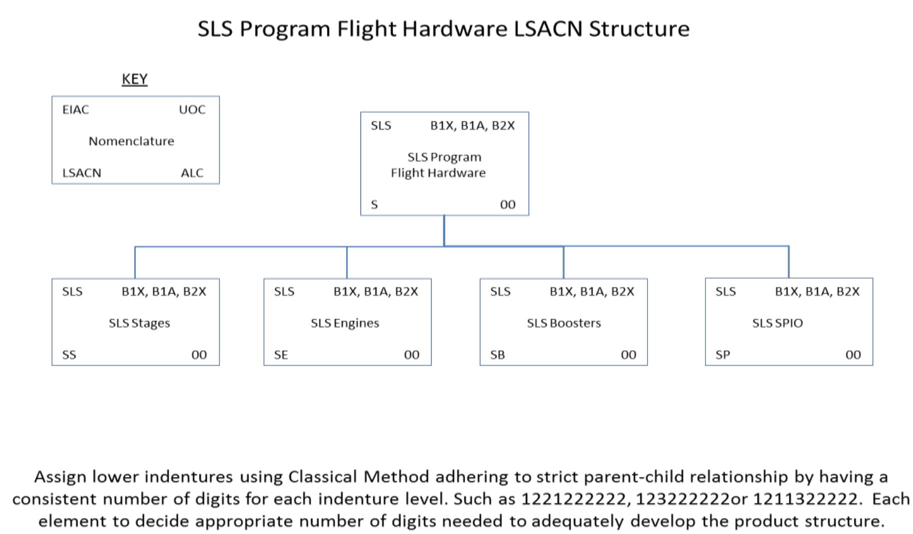


Figure 6.1-1. Space Launch System Flight Hardware Breakdown Structure

Figure 6.1-2 illustrates the actual physical GSE breakdown structure for projects currently under contract and assumed physical breakdown examples for future projects. It also illustrates the Space Launch System (SLS) GSE hardware breakdown structure will expand to include future projects under the Space Launch System (SLS) Program.

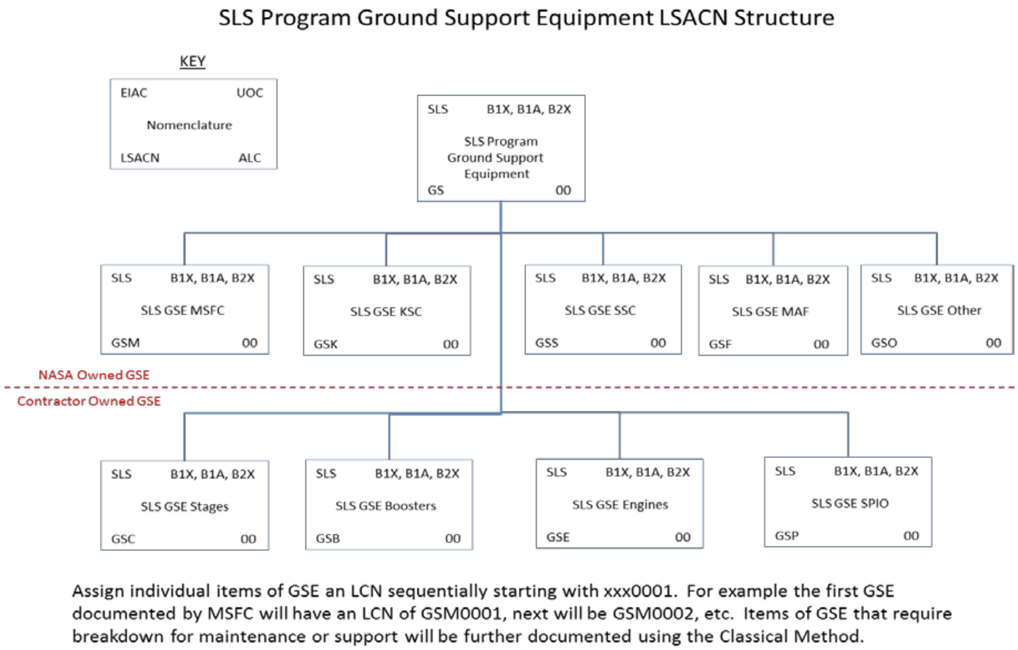


Figure 6.1-2 Space Launch System (SLS) GSE Hardware Breakdown Structure

The LSAR Team also approved schemas for creating Personnel Skill Codes and has been working with the OEMs to establish Facility Name, and Facility Category Code. All of these schemas provide the approach that the Project elements developing LSAR data will use to build their personnel skill codes, facility names, and facility category codes. Each of these codes are keys in the data base and are necessary to get non-key information in the data base regarding personnel skills and facilities. The Facility Name and Facility Category Code will also be important because they will be used to assist in identifying the LRUs and their corresponding maintenance procedures in the data base. All of the information discussed in this section of this report is also being documented in the SLS LSAR Style Guide. A summary of the Style Guide is provided in Appendix F.

7.0 ILS PLANNING AND ASSESSMENT

The SLSP Integrated Logistics Support Plan (ILSP) (SLS-PLAN-025) delineates how logistics and supportability engineering and management concepts will be applied to the Space Launch System Program (SLSP). The ILSP identifies and plan the integrated logistics support required to achieve the program operational goals. These goals include improving readiness, assuring availability, and lowering total cost of ownership by minimizing the logistics footprint required for operational sustainment. This plan addresses how the elements of Integrated Logistics Support will be integrated with disciplines set forth in other SLS program documents. The ILSP addresses supportability engineering analyses to be performed during SLS design and development and physical logistics support for the operational phase of the SLSP. The ILSP is to be baselined for PDR and has been submitted as a category 2 document.

The Supportability Operations Assessment Report (SOAR) (SLS-RPT-168) assesses the baselined design for operability and supportability, and each individual design change to the baseline. Each assessment will be against a set of operational criteria based on the operability and supportability TPMs, vehicle operations, and maintenance planning. The SOAR will be used to inform management if the baselined design or subsequent design changes are maximized for supportability, operability, and feasibility from a ground operations and logistics standpoint. Recommendations to improve these areas will be provided in the reports provided by Ground Operations and Logistics. At that point it will be up to management to push back on the Elements or accept the risk of the vehicle not being fully maximized for supportability and operability.

8.0 ILS AND LSAR TEAM MEETINGS

The ILS Team hosts monthly meetings to resolve supportability issues, LSAR database team meet bi-weekly to discuss Logistics Support Documentation and combine with LIT to coordinate bi-annually TIMs to discuss the extensive Logistics Support Analyses being performed to ensure compliance with the supportability objectives and Integrated Logistics Support requirements.

Key significant accomplishments for the LSAR Team (Project elements, OEMs, EDLEs) include:

1. Developed to implementation of the LSAR Data base flow process and consolidation process
2. Participated in the PowerLogJ training provided by LOGSA.
3. Agreed in principle to the use of LSAR database formats, deliverables and reports (126, 016, and 019) to include the 1949-3.
4. Developed standardized personnel skill specialty codes and linked them to the KSC TOSC contract labor categories and descriptions.
5. Deliver SLS baseline LSAR database for the SLS PDR data review.

9.0 SUMMARY

The LSA activities included Front-end Analysis, evaluation of system alternatives and trade studies, identification of Maintenance Significant Items (MSIs), LSAR database development, and supportability requirements assessments. These activities are supported by bi-weekly LSAR Team meetings and semi-annual Technical Interchange Meetings (TIMs).

Key results:

- **Maintenance/support concept**
  - There are two physical locations at which maintenance will be performed for SLS: Kennedy Space Center (KSC) and the manufacturing site.
  - Maintenance allocations by location are determined by access (external and internal), weight of LRUs, hazardous processing, availability of tools and test equipment. Maintenance actions are distinguished by whether de-stacking is required to perform a maintenance function on a given item.
  - Project Elements have varied approaches but fit within the SLSP maintenance concept. These variations will be assessed in the next design phase to determine the support alternative that meets the Block 1A flight test and ultimately the operational support system requirements.
  - No pad access can have impacts on LA and number of rollbacks between launch attempts.
- **SLS alternative support system trade-off assessments**
  - When assuming a 3-8-7 shift schedule, the Block 1, Block 1A (Solid), and Block 2 (Solid) can achieve an LA of 96.7% or greater. The LA of the Block 1A (Liquid), Block 1B, and Block 2 (Liquid) have an LA of 96.3%, 96.3%, and 96.2% respectively. With the assumption of a 3-8-7 shifting over 80% of the failures can be repaired within the 30 calendar days, but the MDT threshold of 85% at 20 calendar days is still not met by any of the cases.
  - LDT assessment had Case 1-4 look at the worst case scenarios for having a logistic delay associated with every off-nominal event that occurs. Case 5 looks at a mixture of logistic delays occurring. The result of this analysis shows a decrease in LA from 97.3% to 94.9% and shows that the logistics delay has an impact on the vehicle.
  - The only Element that has an issue with battery life right now is Boosters. The batteries used by Boosters, which are installed prior to IVT, have a life of 109 days, which will be violated before launch. Since the Booster silver zinc batteries

cannot be recharged this likely means that Boosters will need to have another set of batteries at KSC to be installed in the vehicle sometime prior to the FTS test and roll-out.

– The results shown in Table 4.5.8.2-1 show that that the Booster procedure delay has no impact on SR. This is due to the minimal number of Booster failures that occur during the processing of the vehicle as compared to Core Stage or Engine failures.

Supportability candidate risks:

– Block upgrades could affect the positioning and number of: *PAD Access (Consistent Elevations), Vehicle Assembly Building (VAB) platforms, Umbilical Locations, Services (i.e., RP for advanced boosters), and Support Equipment required.* **(Candidate Risk 11626)**

– Current planning by Ground S*yst*ems Development and Operations Program (GSDOP) is for no pad access; this leads to the possibility for rollback and possible launch delays. Lack of vehicle access on the launch pad for repair will impact LV: *R-15 Launch, Availability Requirement, Maintenance Downtime, and System Readiness.* There is currently a trade study being conducted to look at this risk further (SLS-TRADE-019). **(Candidate Risk 11629)**

– Given the limited development test baseline and the associated development of processing procedures, there is a possibility processing procedures will not be in place to meet first launch date at KSC. (**Candidate Risk 11632)**

Supportability issues:

– Given the fixed budget for Project Element hardware production, there is a potential of not having sufficient spares. **Issue - Yellow (May require hardware development and potential for LLTIs)**

– Given the SLS Block 1 launch processing manifest (4-5 years with little to no activities), there is a potential of not having sufficiently trained and experienced personnel**. Isssue - Yellow (May require personnel with advanced skills not readily available)**

– Given the limited / reduced maintenance concept approach, there is a potential of not having sufficient tooling / GSE for maintenance activities. **Issue - Yellow (May require hardware development for GSE)**

- Given the limited / reduced maintenance concept approach, there is a potential for a time delay for maintenance activities (schedule may be in terms of days, not shifts). **Issue - Green (limited delay, but not significant Program costs)**
- Given the limited / reduced maintenance concept approach, there is a potential of not having instructions ready for corrective maintenance task in timely manner. **Issue- Green (limited delay, but not significant Program costs)**

The SLSP LSA Report (SLS-RPT-108) will be updated for CDR and as DAC cycles dictate.

Appendix A – Acronyms List

1-8-5	1 shift a day, 8 hours a shift, 5 days a week
2-8-5	2 shift a day, 8 hours a shift, 5 days a week
3-8-5	3 shifts a day, 8 hours a shift, 5 days a week
3-8-7	3 shifts a day, 8 hours a shift, 7 days a week
ACEIT	Automated Cost Estimating Integrated Tool
BEO	Beyond Earth Orbit
BIT	Built-in Test
BITE	Built-in Test Equipment
CAP	Contractor Acquired Property
CASA	Cost Analysis Strategy Assessment
CCAFS	Cape Canaveral Air Force Station
CDR	Critical Design Review
CoFR	Certificate of Flight Readiness
Con Ops	Concept of Operations
COTS	Commercial Off-the-Shelf
CPA	Cargo Payload Adapter
CR	Change Request
DAC	Design Analysis Cycle
DD	Defense Document
DDT&E	Design, Development, Test, and Evaluation
DES	Discrete Event Simulation
DLE	Discipline Lead Engineer
DoD	Department of Defense
DOT	Department of Transportation
EDLE	Element Discipline Lead Engineer
EGSE	Electrical Ground Support Equipment
EM-1, EM-2	Exploration Mission 1, Exploration Mission 2
EPC	Enhanced Personal Computer
ESD	Exploration Systems Development
FAA	Federal Aviation Administration
FAR	Federal Acquisitions Regulation
FDDR	Fault Detection, Diagnostics, and Response
FDIR	Fault Detection, Isolation, and Recovery
FMEA	Failure Modes and Effects Analysis

FOD	Foreign Object Debris
FRR	Flight Readiness Review
ft.	Foot (Feet)
GEIA	Government Electronics and Information Technology Association
GFP	Government Furnished Property
GIDEP	Government-Industry Data Exchange Program
GIWW	Gulf Intercostal Waterway
GN_2	Gaseous Nitrogen
GR&A	Ground Rules and Assumptions
GSDOP	Ground Systems Development and Operations Program
GSE	Ground Support Equipment
HD	High Definition
HDBK	Handbook
He	Helium
HOSC	Huntsville Operations Support Center
HSIR	Human System Integration Requirements
IAGP	Installation Accountable Government Property
ICPS	Interim Cryogenic Propulsion Stage
IETM	Interactive Electronic Technical Manual
ILS	Integrated Logistics Support
ILSP	Integrated Logistics Support Plan
in.	Inch(es)
IVT	Integrated Vehicle Testing
IV&V	Integrated Verification and Validation
KSC	Kennedy Space Center
LA	Launch Availability
LCC	Life Cycle Cost
LCC	Launch Control Center
LCCA	Life Cycle Cost Analysis
LIT	Logistics Integration Team
LMI	Logistics Management Information
LORA	Level of Repair Analysis
LRB	Liquid Rocket Boosters
LRU	Line Replaceable Unit
LSA	Logistics Supportability Analysis

LSAR	Logistics Supportability Analysis Record
LSI	Logistics Support Infrastructure
LVSA	Launch Vehicle Spacecraft Adapter
M&FM	Mission and Fault Management
MAF	Michoud Assembly Facility
MBSE	Model-Based Systems Engineering
MCC	Mission Control Center
MDT	Maintenance Downtime
MEA	Maintenance Engineering Analysis
MIDDS	Meteorological Interface Data Display System
MIL	Military
ML	Mobile Launcher
MOL	Mission Operations Laboratory
MPCV	Multi-Purpose Crew Vehicle
MPEG	Moving Pictures Experts Group
MPR	Marshall Procedural Requirement
MPS	Main Propulsion System
MPTS	Multi-Purpose Transportation System
MRB	Material Review Board
MSFC	Marshall Space Flight Center
MSA	Multi-Purpose Stage Adapter
MSI	Maintenance Significant Item
MTA	Maintenance Task Analysis
MTBF	Mean Time Between Failures
MTE	Marine Transportation Equipment
MTTR	Mean Time To Repair
MWI	Marshall Work Instruction
NASA	National Aeronautics and Space Administration
NFS	NASA FAR Supplement
NPD	NASA Policy Directive
NPR	NASA Procedural Requirements
NSCKN	Network Systems Corporation Knowledge Now
NSN	National Stock Number
O&M	Operations and Maintenance
O&S	Operations and Support
O/M	Operator/Maintainer

OEM	Original Equipment Manufacturer
OPR	Office of Primary Responsibility
Ops	Operations
ORD	Operations Readiness Date
OSHA	Occupational Safety and Health Administration
P&O	Production and Operations
PCH	Program Critical Hardware
PDR	Preliminary Design Review
PHS&T	Packaging, Handling, Storage, and Transportation
PP&C	Program Planning and Control
R&M	Reliability and Maintainability
R&R	Remove and Replace
RDBMS	Relational Database Management System
S&MA	Safety and Mission Assurance
SCWI	Stennis Center Work Instruction
SDF	Software Development Facility
SDR	System Definition Review
SE	Support Equipment
SE&I	Systems Engineering and Integration
SEMP	Systems Engineering Management Plan
SEMS	Support Equipment Management System
SESC	SLS Engineering Support Center
SIL	System Integration Laboratory
SITF	System Integration Test Facility
SLS	Space Launch System
SLSP	Space Launch System Program
SOAR	Supportability and Operations Assessment Report
SPIO	Spacecraft and Payload Integration Office
SPMT	Self-Propelled Modular Transport
SQA	Structural Qualification Test Article
SR	System Readiness
SRB	Solid Rocket Booster
SSC	Stennis Space Center
STD	Standard
STS	Space Transportation System
T&H	Transportation and Handling

T&R	Transition and Retirement
TIMS	Transportation Instrumentation and Monitoring System
TM	Technical Manuals
TMP	Technical Metrics Plan
TOC	Total Ownership Cost
TOSC	Test Operations Support Contractor
TPM	Technical Performance Measure
TReK	Tele-Science Resource Kit
TRR	Transportation Readiness Review
TVC	Thrust Vector Control
U.S.	United States
USA	United Space Alliance
USCG	United States Coast Guard
USDOT	United States Department of Transportation
VAB	Vehicle Assembly Building

Appendix B – MSI candidates lists

Booster

MSI	Qty
BCPDU	
ACU	
ISC	
OPT	
OI Battery	
FTS ADU	
FTS Battery	
Cross-over to connector plate cables	
ISC - FWD BSM cables	
ISC - Sys tunnel cables	
ISC - pwr cables	
ISC - Connector Plate cables	
BCPDU pwr cables	
BCPDU - sys tunnel cables	
BCPDU - ACU cables	
BCPDU interconnect cables	
BCPDU - Connector Plate cables	
BCPDU - S&A cables	
BCPDU - OPT cables	
ACU - sys tunnel cables	
ACU - BCPDU interconnect cables	

MSI	Qty
ACU pwr cables	
FTS - Connector Plate cables	
FTS - battery cables	
FTS - BCPDU cables	
FTS - Sys Tunnel Cables	
HPUC	
Sensors?	
HPUC Pwr cables	
HPUC - HPU command cables	
HPUC - Actuator command cables	
BCPDU - HPUC command cables	
Sys tunnel - Umbilical command cables	
Sys tunnel - Umbilical power cables	
Sys tunnel - BSM cables	
Sys tunnel - HPUC cables	
Command cables	
Power cables	
DFI cables	
DFI DAU	
DFI Sensors?	
DFI cables	

MSI	Qty
RSRMV S&A / SIIs	
FTS S&A	
NSI - Fwd BSM	
NSI – Aft BSM	
NSI - Fwd Thrust assy bolt	
NSI – Upper Struts	
NSI – Lower Struts	
NSI – Middle Struts	
Hd pump	
Check valve and filter assy	
Hd accumulator	
Hd accumulator alternate	
HD pressure block assy	
Hd bootstrap Reservoir	
Manual shutoff valve assy	
Fluid Manifold Assembly	
Rock/Tilt Servoactuator	
Hd QD	
Hydraulic lines	
APU	
FSM	
Fuel Filter	
Fuel Isolation Valve	
Hz QD	
Hydrazine lines	

Core Stage MSIs (Sample)

LCNs	Noun Nomenclature
SS01	**FWD SKIRT**
SS01AVC	AVIONICS COMPONENT INSTL, FWD SKIRT
SS01AVCAA	FLIGHT COMPUTER (FC)
SS01AVCAB	FLIGHT COMPUTER (FC)
SS01AVCAC	FLIGHT COMPUTER (FC)
SS01AVCAD	COMMAND AND TELEMETRY COMPUTER (CTC)
SS01AVCAE	COMMAND AND TELEMETRY COMPUTER (CTC)
SS01AVCAF	FLIGHT SAFETY SYSTEM (FSS) - C-BAND TRANSPONDER (CBT) - RADAR TRANSPONDER
SS01AVCAG	FLIGHT SAFETY SYSTEM (FSS) - C-BAND TRANSPONDER (CBT) - TRANSPONDER ANTENNA
SS01AVCAH	FLIGHT SAFETY SYSTEM (FSS) - C-BAND TRANSPONDER (CBT) - TRANSPONDER ANTENNA
SS01AVCAJ	DFI RFCS - TRANSMITTER
SS01AVCAK	DFI RFCS - S-BAND ANTENNA
SS01AVCAL	DFI RFCS - S-BAND ANTENNA
SS01AVCAM	RADIO FREQUENCY COMMUNICATION SYSTEM (RFCS) - RF TRANSMITTER
SS01AVCAN	DEVELOPMENTAL FLIGHT INSTRUMENTATION (DFI) REMOTE DATA ACQUISITION UNIT (RDAU)
SS01AVCAP	RATE GYRO ASSY (RGA)
SS01AVCAQ	REDUNDANT INERTIAL NAVIGATION UNIT (RINU)
SS01AVCAR	MOTION IMAGERY SYSTEM (MIS) - CAMERA CONTROL UNIT (CCU)
SS01AVCAS	MOTION IMAGERY SYSTEM (MIS) - CAMERA CONTROL UNIT (CCU)
SS01HAC	HARNESS INSTL, FWD SKIRT
SS01HACAA THRU BZ	SIMPLE COMPLEXITY HARNESSES
SS01HACACA THRU CZ	MEDIUM COMPLEXITY HARNESSES
SS01HACDA THRU DZ	HIGH COMPLEXITY HARNESSES
SS01SLC	SENSOR INSTL, FWD SKIRT
SS01LSCAA	LOX PRESSURE TRANSDUCER ASSY, FWD SKIRT
SS01LSCAB	LOX PRESSURE TRANSDUCER ASSY, FWD SKIRT
SS01LSCAC	LOX PRE-PRESSURE VALVE ASSY, FWD SKIRT
SS01LVC	LOX VENT INSTL, FWD SKIRT
SS01LVCAA	LOX VENT RELIEF VALVE, MAIN PROPULSION SYSTEM, CORE STAGE
SS01LVCAB	SOLENOID VALVE THREE WAY SINGLE COIL, VALVE CONTROL, MAIN PROPULSION SYSTEM, CORE STAGE
SS01LVCAC	LOX VENT DUCT
SS01LVCAD	NAFLEX SEAL
SS01LVCAE	NAFLEX SEAL
SS01MTC	MPS TUBING INSTL, FWD SKIRT
SS01MTCAA	CHECK VALVE, PRE-PRESS, MAIN PROPULSION SYSTEM, CORE STAGE
SS01MTCAB	CHECK VALVE, PRE-PRESS, MAIN PROPULSION SYSTEM, CORE STAGE
SS01EPT	AVIONICS COMPONENT INSTL, FWD SKIRT
SS01EPTAA	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAB	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAC	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAD	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAE	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAF	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAG	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAH	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAJ	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAK	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAL	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTSAM	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAN	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAP	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAQ	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAR	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAS	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAT	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAU	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAV	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAX	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAY	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTAZ	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01EPTBA	PASSIVE ELECTRONICS PRESSURE TRANSDUCER
SS01DAC	DOOR ASSEMBLY, ACCESS
SS01DACAA	DOOR ASSEMBLY,
SS01DACAB	DOOR ASSEMBLY
SS01UPA	UMBILICAL PANEL ASSY, FLIGHT FORWARD SKIRT
SS01UPAAA	ONE INCH QUICK DISCONNECT, BLOCK OFF PLATE, FLIGHT SIDE
SS01UPAAB	COLLET RECEPTACLE ASSY, FLIGHT SIDE
SS01UPAAC	1 INCH DISCONNECT, FLIGHT HALF, NON-SELF-SEALING, MAIN PROPULSION SYSTEM, CORE STAGE
SS01UPAAD	1 INCH DISCONNECT, FLIGHT HALF, NON-SELF-SEALING, MAIN PROPULSION SYSTEM, CORE STAGE UMBILICAL PANEL ASSY, GROUND FORWARD SKIRT
SS01UPAAE	QUICK DISCONNECT ASSY, ECS PURGE, FLIGHT HALF
SS01UPAAF	FS QUICK DISCONNECTS (HAZ GAS), FLIGHT HALF
SS01UPAAG	CROGENIC LEVEL SENSOR SYSTEM (CLSS) SENSORS
SS01UPAAH	CROGENIC LEVEL SENSOR SYSTEM (CLSS) SENSORS
SS01UPAAJ	CROGENIC LEVEL SENSOR SYSTEM (CLSS) SENSORS
SS01UPAAK	CROGENIC LEVEL SENSOR SYSTEM (CLSS) SENSORS
SS01UPAAL	CROGENIC LEVEL SENSOR SYSTEM (CLSS) SENSORS
SS01UPAAM	CROGENIC LEVEL SENSOR SYSTEM (CLSS) SENSORS
SS01UPAAN	CROGENIC LEVEL SENSOR SYSTEM (CLSS) SENSORS

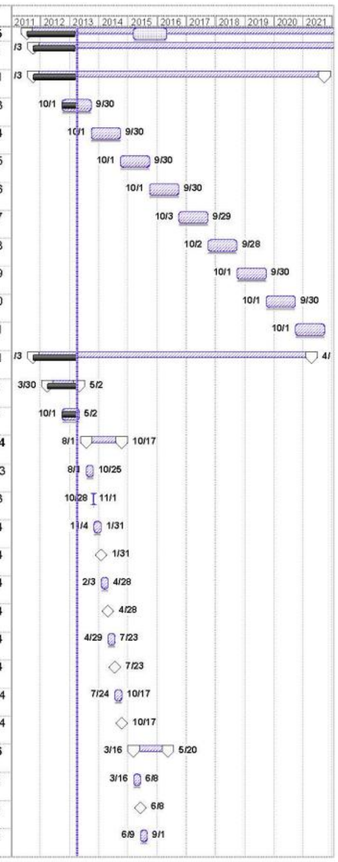
Appendix C

LSA Schedules

SLS Operations - Logistics Area To Go Only Tasks After review on 3-29-13

3/29/13

ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish
1	1	**5919**	**Mike Watson**	**Mike Watso**	**Space Launch System (SLS) Operations**	**3564d**	**21%**	**7/19/11**	**9/30/25**
1933	2	**2739**	**Kaye Inman**	**Kaye Inman**	**Logistics Team**	**2862d**	**29%**	**10/3/11**	**3/3/23**
1934	3	**7187**	**Kaye Inman**	**Jimmy Wrape**	**SLS Operations Level 2 Logistics Support to Level 1**	**2508d**	**15%**	**10/3/11**	**9/30/21**
1936	4	7195	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY13	251d	48%	10/1/12	9/30/13
1937	4	7194	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY14	251d	0%	10/1/13	9/30/14
1938	4	7193	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY15	251d	0%	10/1/14	9/30/15
1939	4	7192	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY16	252d	0%	10/1/15	9/30/16
1940	4	7191	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY17	250d	0%	10/3/16	9/29/17
1941	4	7190	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY18	250d	0%	10/2/17	9/28/18
1942	4	7189	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY19	250d	0%	10/1/18	9/30/19
1943	4	7188	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY20	252d	0%	10/1/19	9/30/20
1944	4	7186	Kaye Inman	Jimmy Wrape	SLS Operations Level 2 Logistics Support to Level 1 FY21	251d	0%	10/1/20	9/30/21
1945	3	**5865**	**Kaye Inman**	**Ruby Blackburn**	**Support to SLS Program Life Cycle Cost Analysis (LCCA) (Cat 2) (SLS-RPT-096)**	**2394d**	**16%**	**10/3/11**	**4/20/21**
1952	4	**3936**	**Kaye Inman**	**Ruby Blackburn**	**Support to SLS LCCA Development (SLS-RPT-096)**	**275d**	**90%**	**3/30/12**	**5/2/13**
1954	5	7777	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Model Development for PDR FY13	147d	82%	10/1/12	5/2/13
1955	4	**4253**	**Kaye Inman**	**Ruby Blackburn**	**Support to SLS LCCA Report Development for CDR (SLS-RPT-096)**	**305d**	**0%**	**8/1/13**	**10/17/14**
1956	5	6153	Kaye Inman	Ruby Blackburn	Support to SLS LCCA Model Update after PDR	60d	0%	8/1/13	10/25/13
1957	5	6151	Kaye Inman	Ruby Blackburn	Review SLS LCCA Model after PDR Comment Incorporation	5d	0%	10/28/13	11/1/13
1958	5	4262	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	11/4/13	1/31/14
1959	5	7160	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	1/31/14	1/31/14
1960	5	7157	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	2/3/14	4/28/14
1961	5	7161	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	4/28/14	4/28/14
1962	5	7165	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	4/29/14	7/23/14
1963	5	7164	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	7/23/14	7/23/14
1964	5	7163	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	7/24/14	10/17/14
1965	5	4263	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	10/17/14	10/17/14
1966	4	**5120**	**Kaye Inman**	**Ruby Blackburn**	**Support to SLS LCCA Report Development and Release for DCR (SLS-RPT-096)**	**300d**	**0%**	**3/16/15**	**5/20/16**
1967	5	6156	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	3/16/15	6/8/15
1968	5	6155	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	6/8/15	6/8/15
1969	5	5129	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	6/9/15	9/1/15



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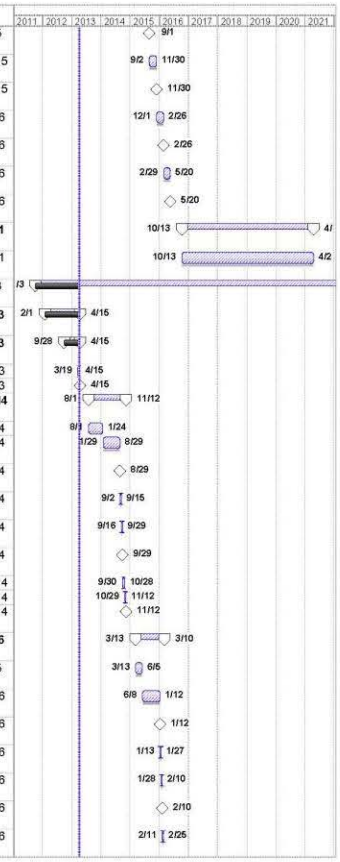
ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish
1970	5	5130	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	9/1/15	9/1/15
1971	5	5131	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	9/2/15	11/30/15
1972	5	5132	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	11/30/15	11/30/15
1973	5	5139	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	12/1/15	2/26/16
1974	5	5140	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report	0d	0%	2/26/16	2/26/16
1975	5	5141	Kaye Inman	Ruby Blackburn	Support to SLS Life Cycle Cost Analysis Model Update Development Quarterly	60d	0%	2/29/16	5/20/16
1976	5	5142	Kaye Inman	Ruby Blackburn	Provide OPS Input to LCCA Quarterly Report for DCR	0d	0%	5/20/16	5/20/16
1977	**4**	**7047**	**Kaye Inman**	**Ruby Blackburn**	**Support Life Cycle Cost Analysis Continuation to Flight #2**	**1132d**	**0%**	**10/13/16**	**4/20/21**
1978	5	7046	Kaye Inman	Ruby Blackburn	Life Cycle Cost Analysis Continuation to Flight #2	1132d	0%	10/13/16	4/20/21
1983	**3**	**4073**	**Kaye Inman**	**Kaye I./Karen B.**	**SLS Integrated Logistics Support Plan (ILSP) Development and Release (SLS-PLAN-025) (Cat 2) 1406OP-018**	**2862d**	**14%**	**10/3/11**	**3/3/23**
1995	**4**	**3735**	**Kaye Inman**	**Kaye I./Karen B.**	**SLS Integrated Logistics Support Plan (ILSP) Development and Release for PDR**	**303d**	**94%**	**2/1/12**	**4/15/13**
2002	**5**	**3749**	**Kaye Inman**	**Kaye I./Karen B.**	**SLS Integrated Logistics Support Plan (ILSP) Review Boards for Control Process**	**135d**	**86%**	**9/28/12**	**4/15/13**
2010	6	9083	Kaye Inman	Kaye I./Karen E	Mike Watson's Review	20d	0%	3/19/13	4/15/13
2011	6	8577	Kaye Inman	Kaye I./Karen E	ILSP Ready for PDR - dropped in box	0d	0%	4/15/13	4/15/13
2012	**4**	**4076**	**Kaye Inman**	**Kaye I./Karen B.**	**SLS Integrated Logistics Support Plan (ILSP) Development and Release for CDR**	**322d**	**0%**	**8/1/13**	**11/12/14**
2013	5	9084	Kaye Inman	Kaye I./Karen E	Update baseline version of ILSP after PDR with comments and RIDS	120d	0%	8/1/13	1/24/14
2014	5	4081	Kaye Inman	Kaye I./Karen B.	Update baseline version of ILSP	150d	0%	1/29/14	8/29/14
2015	5	4082	Kaye Inman	Kaye I./Karen B.	SLS ILSP Rev 1 Internal Drop for CDR	0d	0%	8/29/14	8/29/14
2016	5	4083	Kaye Inman	Kaye I./Karen B.	ILSP Rev 1 OPS Internal Team for Review	10d	0%	9/2/14	9/15/14
2017	5	4084	Kaye Inman	Kaye I./Karen B.	Update CDR ILSP Draft per reviewed comments	10d	0%	9/16/14	9/29/14
2018	5	4085	Kaye Inman	Kaye I./Karen B.	CDR ILSP Updated Rev 1 to Task Team	0d	0%	9/29/14	9/29/14
2019	5	8973	Kaye Inman	Kaye I./Karen E	CDR ILSP Rev 1 Task Team Review	20d	0%	9/30/14	10/28/14
2020	5	8974	Kaye Inman	Kaye I./Karen E	CDR ILSP Rev 1 Task Team Comments Incorporated	10d	0%	10/29/14	11/12/14
2021	5	4088	Kaye Inman	Kaye I./Karen B.	CDR Rev 1 Drop of Integrated Logistics Support Plan complete - 4511 signed	0d	0%	11/12/14	11/12/14
2022	**4**	**4411**	**Kaye Inman**	**Kaye I./Karen B.**	**SLS Integrated Logistics Support Plan (ILSP) Development and Release for DCR**	**250d**	**0%**	**3/13/15**	**3/10/16**
2023	5	5101	Kaye Inman	Kaye I./Karen B.	Incorporate CDR Comments into ILSP	60d	0%	3/13/15	6/5/15
2024	5	4417	Kaye Inman	Kaye I./Karen B.	Update ILSP for DCR	150d	0%	6/8/15	1/12/16
2025	5	4418	Kaye Inman	Kaye I./Karen B.	SLS ILSP Internal Drop for DCR	0d	0%	1/12/16	1/12/16
2026	5	4419	Kaye Inman	Kaye I./Karen B.	DCR ILSP OPS Internal Team Review	10d	0%	1/13/16	1/27/16
2027	5	4420	Kaye Inman	Kaye I./Karen B.	Update DCR ILSP Draft per reviewed comments	10d	0%	1/28/16	2/10/16
2028	5	4421	Kaye Inman	Kaye I./Karen B.	Submit DCR ILSP Updated Draft to Task Team	0d	0%	2/10/16	2/10/16
2029	5	5109	Kaye Inman	Kaye I./Karen B.	Task Team Review of ILSP for DCR	10d	0%	2/11/16	2/25/16



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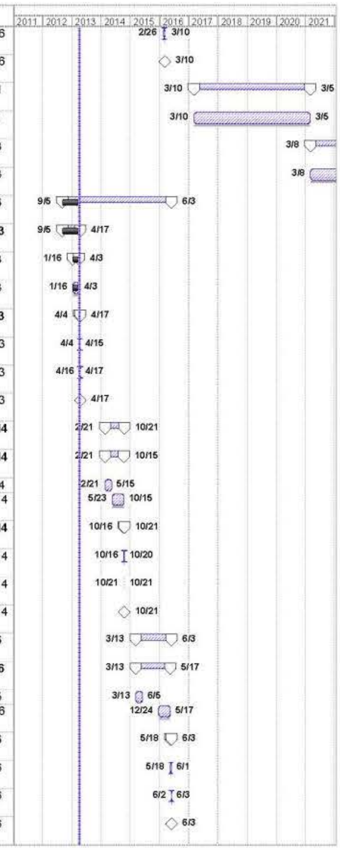
ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish
2030	5	5115	Kaye Inman	Kaye I./Karen B.	Incorporate Task Team Comments for DCR ILSP	10d	0%	2/26/16	3/10/16
2031	5	4422	Kaye Inman	Kaye I./Karen B.	DCR Updated Drop of Integrated Logistics Support Plan complete	0d	0%	3/10/16	3/10/16
2032	4	7049	Kaye Inman	Kaye I./Karen B.	**SLS Integrated Logistics Support Plan (ILSP) Development and Release for Flight #2**	1000d	0%	3/10/17	3/5/21
2033	5	7048	Kaye Inman	Kaye I./Karen B.	SLS Integrated Logistics Support Plan (ILSP) Development and Release for Flight #2	1000d	0%	3/10/17	3/5/21
2034	4	7168	Kaye Inman	Kaye I./Karen B.	**SLS Integrated Logistics Support Plan (ILSP) Development and Release for Flight #3**	500d	0%	3/8/21	3/3/23
2035	5	7169	Kaye Inman	Kaye I./Karen B.	SLS Integrated Logistics Support Plan (ILSP) Development and Release for Flight #3	500d	0%	3/8/21	3/3/23
2036	3	2758	Kaye Inman	John Smith	**SLS Logistics Support Analysis Record (LSAR) Database Development and Drops**	940d	28%	9/5/12	6/3/16
2037	4	3791	Kaye Inman	John Smith	**SLS Logistics Support Analysis Record (LSAR) Database Version A Development**	154d	88%	9/5/12	4/17/13
2052	5	6598	Kaye Inman	John Smith	**Populate Database with Element Data**	54d	85%	1/16/13	4/3/13
2053	6	4545	Kaye Inman	John Smith	Populate Database with Element Data	54d	85%	1/16/13	4/3/13
2054	5	6617	Kaye Inman	John Smith	**SLS Logistics Support Analysis Record (LSAR) Database Version A Available for PDR**	10d	0%	4/4/13	4/17/13
2055	6	6618	Kaye Inman	John Smith	Conduct Review of SLS Logistics Support Analysis Record (LSAR) Database	8d	0%	4/4/13	4/15/13
2056	6	6619	Kaye Inman	John Smith	Update SLS Logistics Support Analysis Record (LSAR) Database Version A after Review	2d	0%	4/16/13	4/17/13
2057	6	6631	Kaye Inman	John Smith	SLS Logistics Support Analysis Record (LSAR) Database Version A Avail for PDR	0d	0%	4/17/13	4/17/13
2058	4	4650	Kaye Inman	John Smith	**SLS Logistics Support Analysis Record (LSAR) Database Version B Development for CDR**	169d	0%	2/21/14	10/21/14
2059	5	6635	Kaye Inman	John Smith	**Update LSAR Database with Element PDR Data and Element CDR Data Available for SLS CDR**	165d	0%	2/21/14	10/15/14
2060	6	8976	Kaye Inman	John Smith	Populate Database with SLS PDR Comments	60d	0%	2/21/14	5/15/14
2061	6	6634	Kaye Inman	John Smith	Populate Database with Element Data after Element PDRs and CDR Drops	100d	0%	5/23/14	10/15/14
2062	5	4654	Kaye Inman	John Smith	**SLS Logistics Support Analysis Record (LSAR) Database Version B Available for CDR**	4d	0%	10/16/14	10/21/14
2063	6	4655	Kaye Inman	John Smith	Conduct Review of SLS Logistics Support Analysis Record (LSAR) Database	3d	0%	10/16/14	10/20/14
2064	6	4656	Kaye Inman	John Smith	Update SLS Logistics Support Analysis Record (LSAR) Database Version B after Review	1d	0%	10/21/14	10/21/14
2065	6	4668	Kaye Inman	John Smith	SLS Logistics Support Analysis Record (LSAR) Database Version B Avail for CDR	0d	0%	10/21/14	10/21/14
2066	4	6638	Kaye Inman	John Smith	**SLS Logistics Support Analysis Record (LSAR) Database Version C Development for DCR**	310d	0%	3/13/15	6/3/16
2067	5	6639	Kaye Inman	John Smith	**Update LSAR Database with Element CDR Data after Element CDR**	298d	0%	3/13/15	5/17/16
2068	6	8977	Kaye Inman	John Smith	Populate Database with SLS CDR Comments	60d	0%	3/13/15	6/5/15
2069	6	6645	Kaye Inman	John Smith	Populate Database with Element Data after Element CDR	100d	0%	12/24/15	5/17/16
2070	5	6647	Kaye Inman	John Smith	**SLS Logistics Support Analysis Record (LSAR) Database Version C Available for DCR**	12d	0%	5/18/16	6/3/16
2071	6	6648	Kaye Inman	John Smith	Conduct Review of SLS Logistics Support Analysis Record (LSAR) Database	10d	0%	5/18/16	6/1/16
2072	6	6649	Kaye Inman	John Smith	Update SLS Logistics Support Analysis Record (LSAR) Database Version C after Review	2d	0%	6/2/16	6/3/16
2073	6	6661	Kaye Inman	John Smith	SLS Logistics Support Analysis Record (LSAR) Database Version C Avail for DCR	0d	0%	6/3/16	6/3/16



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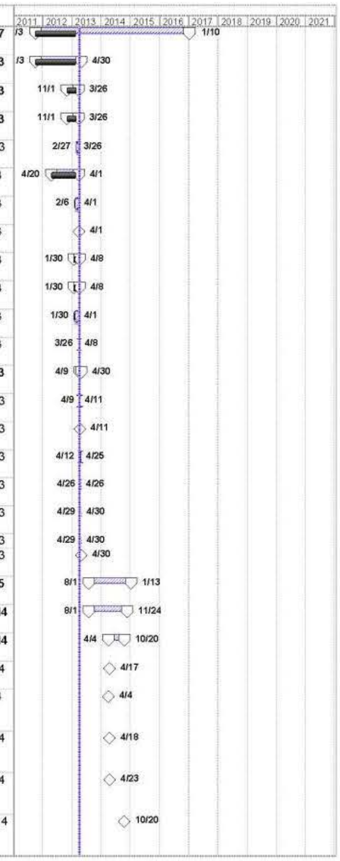
ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish
2074	3	6615	Kaye Inman	John Smith	**SLS Logistics Support Analysis (LSA) Report (SLS-RPT-108) Development and Release (Cat 2) 1406OP-012**	1322d	45%	10/3/11	1/10/17
2075	4	4074	Kaye Inman	John Smith	**SLS Logistics Support Analysis (LSA) Report (SLS-RPT-108) Development and Release for PDR (Cat 2) 1406OP-012**	395d	86%	10/3/11	4/30/13
2088	5	4523	Kaye Inman	John Smith	**Off-Nominal Timeline Analysis for PDR**	98d	80%	11/1/12	3/26/13
2089	6	6943	Kaye Inman	John Smith	**Conduct Off-Nominal Timeline Analysis for PDR**	98d	80%	11/1/12	3/26/13
2091	7	4534	Kaye Inman	John Smith	Document Off-Nominal Timeline Analysis	20d	0%	2/27/13	3/26/13
2092	5	3585	Kaye Inman	John Smith	**Conduct Evaluation and Support Analysis for SLS Vehicle Design for PDR**	237d	93%	4/20/12	4/1/13
2099	6	6610	Kaye Inman	John Smith	Evaluation and Support Analysis Documented in Assessment Report	38d	5%	2/6/13	4/1/13
2100	6	3661	Kaye Inman	John Smith	Provide Recommendations to Improve System Supportability & Operations	0d	0%	4/1/13	4/1/13
2101	5	4072	Kaye Inman	John Smith	**Evaluate Design, Operation and Support Concepts for PDR**	48d	20%	1/30/13	4/8/13
2102	6	4058	Kaye Inman	John Smith	**Conduct Key Tradeoffs and Evaluation**	48d	20%	1/30/13	4/8/13
2103	7	4057	Kaye Inman	John Smith	Maintenance Analysis	43d	25%	1/30/13	4/1/13
2104	7	4053	Kaye Inman	John Smith	Document the Results of Evaluation or Tradeoff Analysis	10d	0%	3/26/13	4/8/13
2105	5	6685	Kaye Inman	John Smith	**LSA Report 1406OP-012 for PDR (Cat 2) SLS-RPT-108**	16d	0%	4/9/13	4/30/13
2106	6	6611	Kaye Inman	John Smith	Document in LSA Report for PDR	3d	0%	4/9/13	4/11/13
2107	6	5117	Kaye Inman	John Smith	Provide PDR LSA Report to Teams for Review	0d	0%	4/11/13	4/11/13
2108	6	6665	Kaye Inman	John Smith	PDR LSA Report Review by OPS and Others	10d	0%	4/12/13	4/25/13
2109	6	6664	Kaye Inman	John Smith	Comment Review for PDR LSA Report	1d	0%	4/26/13	4/26/13
2110	6	6663	Kaye Inman	John Smith	Update LSA Report for PDR with comments	2d	0%	4/29/13	4/30/13
2111	6	8471	Kaye Inman	John Smith	Form 4511 Signed for Logistics Support Analysis Report	2d	0%	4/29/13	4/30/13
2112	6	6666	Kaye Inman	John Smith	Provide Logistics Support Analysis (LSA) Report for PDR - Cat 2	0d	0%	4/30/13	4/30/13
2113	4	6688	Kaye Inman	John Smith	**SLS Logistics Support Analysis (LSA) Report (SLS-RPT-108) Development and Release for CDR (Cat 2) 1406OP-012**	363d	0%	8/1/13	1/13/15
2114	5	6702	Kaye Inman	John Smith	**Off-Nominal Timeline Analysis for CDR**	330d	0%	8/1/13	11/24/14
2115	6	7173	Kaye Inman	John Smith	**Receive Inputs from Other Elements for LSAR and LSA CDR Version**	137d	0%	4/4/14	10/20/14
2116	7	6633	Kaye Inman	John Smith	Receive Input - SPIO Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts	0d	0%	4/17/14	4/17/14
2117	7	4651	Kaye Inman	John Smith	Receive Input - Stage Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - Element CDR Drop	0d	0%	4/4/14	4/4/14
2118	7	4652	Kaye Inman	John Smith	Receive Input - Engine Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts	0d	0%	4/18/14	4/18/14
2119	7	7175	Kaye Inman	John Smith	Receive Input - Booster Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - Element CDR Drop	0d	0%	4/23/14	4/23/14
2120	7	7174	Kaye Inman	John Smith	Receive Input - SPIO Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - Element CDR Drop	0d	0%	10/20/14	10/20/14



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ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish	2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021
2121	7	6640	Kaye Inman	John Smith	Receive Input - Stage Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - After Element CDR	0d	0%	9/16/14	9/16/14	9/16
2122	7	6641	Kaye Inman	John Smith	Receive Input - Engine Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - After element CDR	0d	0%	9/8/14	9/8/14	9/8
2123	7	9085	Kaye Inman	John Smith	Receive Input - Booster Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts -	0d	0%	9/22/14	9/22/14	9/22
2124	6	6998	**Kaye Inman**	**John Smith**	**Conduct Off-Nominal Timeline Analysis for CDR**	**330d**	**0%**	**8/1/13**	**11/24/14**	8/1 11/24
2125	7	8975	Kaye Inman	John Smith	Update Off-Nominal Timeline Analysis with PDR comments	60d	0%	8/1/13	10/25/13	8/1 10/25
2126	7	6713	Kaye Inman	John Smith	Integrate Maintenance Task Analysis Results	34d	0%	9/3/14	10/21/14	9/3 10/21
2127	7	6714	Kaye Inman	John Smith	Update Off-Nominal Analysis	20d	0%	10/22/14	11/19/14	10/22 11/19
2128	7	6715	Kaye Inman	John Smith	Document Off-Nominal Timeline Analysis Assessment	3d	0%	11/20/14	11/24/14	11/20 11/24
2129	5	6740	**Kaye Inman**	**John Smith**	**Conduct Evaluation of Alternatives and Trade off Analysis for CDR**	**82d**	**0%**	**8/1/13**	**11/28/13**	8/1 11/28
2130	6	6741	Kaye Inman	John Smith	Conduct Evaluation of Trade off Process	5d	0%	8/1/13	8/7/13	8/1 8/7
2131	6	6742	Kaye Inman	John Smith	Identify the Criteria for Evaluation or Tradeoff	40d	0%	8/1/13	9/26/13	8/1 9/26
2132	6	6748	Kaye Inman	John Smith	Conduct the Initial Evaluation or Trade-off Analysis of Each Alternative and Select the most Appropriate Alternative	25d	0%	9/27/13	11/1/13	9/27 11/1
2133	6	6749	Kaye Inman	John Smith	Provide Trade-off Analysis Report to OPS Team and Elements for Review	0d	0%	11/1/13	11/1/13	11/1
2134	6	6750	Kaye Inman	John Smith	Review Time for Trade-off Analysis	10d	0%	11/4/13	11/18/13	11/4 11/18
2135	6	6751	Kaye Inman	John Smith	Comment Review of Trade-off Analysis	2d	0%	11/19/13	11/20/13	11/19 11/20
2136	6	6752	Kaye Inman	John Smith	Update to Evaluation/Tradeoff Analysis after Comments Accepted	5d	0%	11/22/13	11/28/13	11/22 11/28
2137	6	6754	Kaye Inman	John Smith	Provide Output - To DAC3	0d	0%	11/28/13	11/28/13	11/28
2138	5	6755	**Kaye Inman**	**John Smith**	**Evaluate Design, Operation and Support Solution for CDR**	**155d**	**0%**	**4/25/14**	**12/5/14**	4/25 12/5
2139	6	6769	**Kaye Inman**	**John Smith**	**Conduct Key Tradeoffs and Evaluation**	**155d**	**0%**	**4/25/14**	**12/5/14**	4/25 12/5
2140	7	6770	Kaye Inman	John Smith	Maintenance Analysis	120d	0%	4/25/14	10/15/14	4/25 10/15
2141	7	6771	Kaye Inman	John Smith	Diagnostic Tradeoffs	20d	0%	4/28/14	5/23/14	4/28 5/23
2142	7	6772	Kaye Inman	John Smith	Document the Results of Evaluation or Tradeoff Analysis	20d	0%	10/16/14	11/13/14	10/16 11/13
2143	7	7183	Kaye Inman	John Smith	Provide Evaluation to Ops Team for Review	0d	0%	11/13/14	11/13/14	11/13
2144	7	7182	Kaye Inman	John Smith	Review Time	10d	0%	11/14/14	11/28/14	11/14 11/28
2145	7	7181	Kaye Inman	John Smith	Update after review	5d	0%	12/1/14	12/5/14	12/1 12/5
2146	5	6778	**Kaye Inman**	**John Smith**	**LSA Assessment Report for CDR**	**25d**	**0%**	**12/8/14**	**1/13/15**	12/8 1/13
2147	6	6777	Kaye Inman	John Smith	Document the Results in LSA Report	3d	0%	12/8/14	12/10/14	12/8 12/10
2148	6	6779	Kaye Inman	John Smith	Provide CDR LSA Report to Teams for Review	0d	0%	12/10/14	12/10/14	12/10
2149	6	6780	Kaye Inman	John Smith	CDR LSA Report Review by OPS and Others	10d	0%	12/11/14	12/24/14	12/11 12/24

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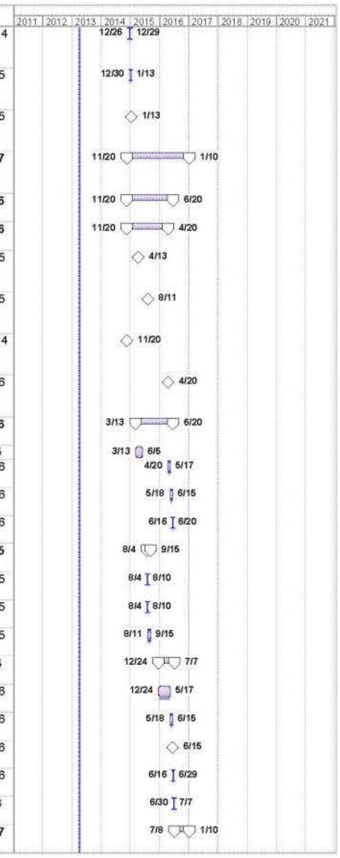
ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish
2150	6	6781	Kaye Inman	John Smith	Comment Review of CDR LSA Report	2d	0%	12/26/14	12/29/14
2151	6	6782	Kaye Inman	John Smith	Update LSA Report for CDR with Accepted comments	10d	0%	12/30/14	1/13/15
2152	6	6783	Kaye Inman	John Smith	Provide LSA Report for CDR - 4511 SIGNED	0d	0%	1/13/15	1/13/15
2153	4	6802	Kaye Inman	John Smith	**SLS Logistics Support Analysis (LSA) Report (SLS-RPT-108) Development and Release for DCR (Cat 2) 1406OP-012**	**535d**	**0%**	**11/20/14**	**1/10/17**
2154	5	6816	Kaye Inman	John Smith	**Off-Nominal Timeline Analysis for DCR**	**396d**	**0%**	**11/20/14**	**6/20/16**
2155	6	7176	Kaye Inman	John Smith	**Receive Inputs from Other Elements for LSAR and LSA DCR Version**	**353d**	**0%**	**11/20/14**	**4/20/16**
2156	7	6643	Kaye Inman	John Smith	Receive Input - SPIO Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - After Element CDR	0d	0%	4/13/15	4/13/15
2157	7	6642	Kaye Inman	John Smith	Receive Input - Booster Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - Element DCR Drop	0d	0%	8/11/15	8/11/15
2158	7	7180	Kaye Inman	John Smith	Receive Input - Stage Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - Element DCR Drop	0d	0%	11/20/14	11/20/14
2159	7	7179	Kaye Inman	John Smith	Receive Input - Engine Element Logistics Support Analysis Data for Evaluate Design, Operation and Support Concepts - Element DCR Drop	0d	0%	4/20/16	4/20/16
2160	6	7000	Kaye Inman	John Smith	**Conduct Off-Nominal Timeline Analysis for DCR**	**321d**	**0%**	**3/13/15**	**6/20/16**
2161	7	8978	Kaye Inman	John Smith	Update Off-Nominal Timeline Analysis with CDR Comments	60d	0%	3/13/15	6/5/15
2162	7	6827	Kaye Inman	John Smith	Intergrate Maintenance Task Analysis Results	20d	0%	4/20/16	5/17/16
2163	7	6828	Kaye Inman	John Smith	Update Off-Nominal Analysis	20d	0%	5/18/16	6/15/16
2164	7	6829	Kaye Inman	John Smith	Document Off-Nominal Timeline Analysis Assessment	3d	0%	6/16/16	6/20/16
2165	5	6854	Kaye Inman	John Smith	**Conduct Evaluation of SLS Support Solution for DCR**	**30d**	**0%**	**8/4/15**	**9/15/15**
2166	6	6855	Kaye Inman	John Smith	Conduct Evaluation of Trade off Process	5d	0%	8/4/15	8/10/15
2167	6	6856	Kaye Inman	John Smith	Identify the Criteria for Evaluation or Tradeoff	5d	0%	8/4/15	8/10/15
2168	6	6862	Kaye Inman	John Smith	Conduct the Initial Evaluation or Trade-off Analysis of Each Alternative and Select the most Appropriate Alternative	25d	0%	8/11/15	9/15/15
2169	5	6883	Kaye Inman	John Smith	**Conduct Key Tradeoffs and Evaluation**	**135d**	**0%**	**12/24/15**	**7/7/16**
2170	6	6884	Kaye Inman	John Smith	Conduct Key Tradeoffs and Evaluation Analysis	100d	0%	12/24/15	5/17/16
2171	6	6886	Kaye Inman	John Smith	Document the Results of Evaluation or Tradeoff Analysis	20d	0%	5/18/16	6/15/16
2172	6	6887	Kaye Inman	John Smith	Provide Plan to Ops Team for Review	0d	0%	6/15/16	6/15/16
2173	6	6888	Kaye Inman	John Smith	Review Time	10d	0%	6/16/16	6/29/16
2174	6	6890	Kaye Inman	John Smith	Update after review	5d	0%	6/30/16	7/7/16
2175	5	6892	Kaye Inman	John Smith	**LSA Assessment Report for DCR**	**127d**	**0%**	**7/8/16**	**1/10/17**



SLSP SE&I OPS

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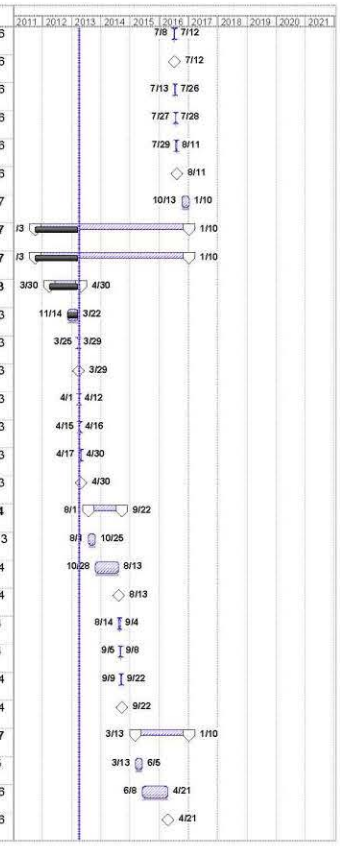
SLS Operations - Logistics Area To Go Only Tasks After review on 3-29-13

3/29/13

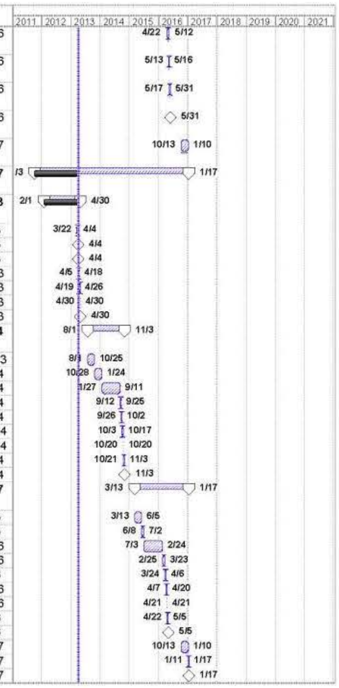
ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish
2176	6	6867	Kaye Inman	John Smith	Document the Results in LSA Report	3d	0%	7/8/16	7/12/16
2177	6	6893	Kaye Inman	John Smith	Provide DCR LSA Report to Teams for Review	0d	0%	7/12/16	7/12/16
2178	6	6894	Kaye Inman	John Smith	DCR LSA Report Review by OPS and Others	10d	0%	7/13/16	7/26/16
2179	6	6895	Kaye Inman	John Smith	Review Comments for DCR LSA Report	2d	0%	7/27/16	7/28/16
2180	6	6896	Kaye Inman	John Smith	Update LSA Report for DCR with Accepted comments	10d	0%	7/29/16	8/11/16
2181	6	6897	Kaye Inman	John Smith	Provide LSA Report for DCR	0d	0%	8/11/16	8/11/16
2182	6	6898	Kaye Inman	John Smith	Update LSA Report with Comments after DCR	60d	0%	10/13/16	1/10/17
2183	**3**	**2738**	**Kaye Inman**		**Supportability & Operations Assessment (SOA)**	**1322d**	**64%**	**10/3/11**	**1/10/17**
2196	**4**	**2754**	**Kaye Inman**	**James Bruce**	**SLS Supportability & Operations Assessment Report (SOAR) (SLS-RPT-168) Development and Release - Cat 2 1406OP-026**	**1322d**	**39%**	**10/3/11**	**1/10/17**
2204	**5**	**6521**	**Kaye Inman**	**James Bruce**	**SLS Supportability & Operations Assessment Report (SOAR) (SLS-RPT-168) Development for PDR - CAT-2 1406OP-026**	**273d**	**89%**	**3/30/12**	**4/30/13**
2220	6	7760	Kaye Inman	James Bruce	SLS Supportability & Operations Assessment Report (SOAR) Development for DAC2 and PDR	88d	97%	11/14/12	3/22/13
2221	6	8386	Kaye Inman	James Bruce	SLS Supportability & Operations Assessment Report (SOAR) Development of Report for PDR	5d	0%	3/25/13	3/29/13
2222	6	5783	Kaye Inman	James Bruce	Release for Internal Review with Ops Team and with affected External Teams	0d	0%	3/29/13	3/29/13
2223	6	5782	Kaye Inman	James Bruce	Review Time for SLS Supportability & Operations Assessment Report (SOAR)	10d	0%	4/1/13	4/12/13
2224	6	5781	Kaye Inman	James Bruce	Comment Review of SLS Supportability & Operations Assessment Report (SOAR)	2d	0%	4/15/13	4/16/13
2225	6	5780	Kaye Inman	James Bruce	Incorporate Comments into SLS Supportability & Operations Assessment Report (SOAR)	10d	0%	4/17/13	4/30/13
2226	6	5787	Kaye Inman	James Bruce	Release SLS Supportability & Operations Assessment Report (SOAR) for PDR - Form 4511 signed - Cat 2	0d	0%	4/30/13	4/30/13
2227	**5**	**2753**	**Kaye Inman**	**James Bruce**	**SLS Supportability & Operations Assessment Report (SOAR) (SLS-RPT-168) Development and Release for CDR - Cat-2**	**287d**	**0%**	**8/1/13**	**9/22/14**
2228	6	5785	Kaye Inman	James Bruce	Incorporate Comments from PDR into SLS Supportability & Operations Assessment Report (SOAR)	60d	0%	8/1/13	10/25/13
2229	6	2938	Kaye Inman	James Bruce	SLS Supportability & Operations Assessment Report (SOAR) Development	200d	0%	10/28/13	8/13/14
2230	6	6581	Kaye Inman	James Bruce	Release for Internal Review with Ops Team and with affected External Teams	0d	0%	8/13/14	8/13/14
2231	6	6582	Kaye Inman	James Bruce	Review Time for SLS Supportability & Operations Assessment Report (SOAR)	15d	0%	8/14/14	9/4/14
2232	6	6583	Kaye Inman	James Bruce	Comment Review of SLS Supportability & Operations Assessment Report (SOAR)	2d	0%	9/5/14	9/8/14
2233	6	6584	Kaye Inman	James Bruce	Incorporate Accepted Comments into SLS Supportability & Operations Assessment Report (SOAR)	10d	0%	9/9/14	9/22/14
2234	6	6585	Kaye Inman	James Bruce	Release SLS Supportability & Operations Assessment Report (SOAR) for CDR - 4511 Signed	0d	0%	9/22/14	9/22/14
2235	**5**	**8980**	**Kaye Inman**	**James Bruce**	**SLS Supportability & Operations Assessment Report (SOAR) (SLS-RPT-168) Development and Release for DCR - Cat-2**	**460d**	**0%**	**3/13/15**	**1/10/17**
2236	6	8981	Kaye Inman	James Bruce	Incorporate Comments from CDR into SLS Supportability & Operations Assessment Report (SOAR)	60d	0%	3/13/15	6/5/15
2237	6	8982	Kaye Inman	James Bruce	SLS Supportability & Operations Assessment Report (SOAR) Development	220d	0%	6/8/15	4/21/16
2238	6	8983	Kaye Inman	James Bruce	Release for Internal Review with Ops Team and with affected External Teams	0d	0%	4/21/16	4/21/16



SLS Operations - Logistics Area To Go Only Tasks After review on 3-29-13

3/29/13

ID	Outline Level	UID#	Team Resp	Work Resp	Task Name	dur	% COMPL	Start	Finish
2239	6	8984	Kaye Inman	James Bruce	Review Time for SLS Supportability & Operations Assessment Report (SOAR)	15d	0%	4/22/16	5/12/16
2240	6	8985	Kaye Inman	James Bruce	Comment Review of SLS Supportability & Operations Assessment Report (SOAR)	2d	0%	5/13/16	5/16/16
2241	6	8986	Kaye Inman	James Bruce	Incorporate Accepted Comments into SLS Supportability & Operations Assessment Report (SOAR)	10d	0%	5/17/16	5/31/16
2242	6	8987	Kaye Inman	James Bruce	Release SLS Supportability & Operations Assessment Report (SOAR) for DCR - 4511 Signed	0d	0%	5/31/16	5/31/16
2243	6	8988	Kaye Inman	James Bruce	Incorporate Comments from CDR into SLS Supportability & Operations Assessment Report (SOAR)	60d	0%	10/13/16	1/10/17
2244	3	2760	Kaye Inman	J.V. Jones / Jim Neely	**SLS Sustaining Engineering Plan Development and Release (SLS-PLAN-093) - Cat 2 1406OP-007**	1327d	35%	10/3/11	1/17/17
2250	4	6028	Kaye Inman	J.V. Jones / Jim Neely	**SLS Sustaining Engineering Plan Development and Release (SLS-PLAN--093) for PDR - Cat 2 1406OP-007**	314d	92%	2/1/12	4/30/13
2254	5	6031	Kaye Inman	J.V. Jones / Jim	Incorporate Comments from Ops Review into Sustaining Eng Plan	10d	30%	3/22/13	4/4/13
2255	5	9086	Kaye Inman	J.V. Jones / Jim	Task Team Approved	0d	0%	4/4/13	4/4/13
2256	5	8579	Kaye Inman	J.V. Jones / Jim	Provide Sustaining Eng Plan to Task Team	0d	0%	4/4/13	4/4/13
2257	5	6041	Kaye Inman	J.V. Jones / Jim	Task Team Review of SLS Sustaining Eng Plan	10d	0%	4/5/13	4/18/13
2258	5	6042	Kaye Inman	J.V. Jones / Jim	Incorporate Comments from Task Team into Sustaining Eng Plan	6d	0%	4/19/13	4/26/13
2259	5	8478	Kaye Inman	J.V. Jones / Jim	Form 4511 Signed for Draft Sustaining End Plan for PDR	1d	0%	4/30/13	4/30/13
2260	5	6032	Kaye Inman	J.V. Jones / Jim	Drop Draft of Sustaining Eng Plan for PDR	0d	0%	4/30/13	4/30/13
2261	4	6044	Kaye Inman	J.V. Jones / Jim Neely	**SLS Sustaining Engineering Plan Development and Release (SLS-PLAN--093) for CDR - Cat 2 1406OP-007**	316d	0%	8/1/13	11/3/14
2262	5	6037	Kaye Inman	J.V. Jones / Jim	Incorporate Sustaining Eng Plan with Comments from PDR	60d	0%	8/1/13	10/25/13
2263	5	9087	Kaye Inman	J.V. Jones / Jim	Review MRB (Material Review Board) Processes for data incorporation	60d	0%	10/28/13	1/24/14
2264	5	6045	Kaye Inman	J.V. Jones / Jim	SLS Sustaining Engineering Plan Development After PDR	160d	0%	1/27/14	9/11/14
2265	5	6047	Kaye Inman	J.V. Jones / Jim	Internal (EO and OPS) Review of SLS Sustaining Eng Plan	10d	0%	9/12/14	9/25/14
2266	5	6048	Kaye Inman	J.V. Jones / Jim	Incorporate Comments from Internal Review into Sustaining Eng Plan	5d	0%	9/26/14	10/2/14
2267	5	6051	Kaye Inman	J.V. Jones / Jim	Task Team Review of SLS Sustaining Eng Plan	10d	0%	10/3/14	10/17/14
2268	5	6052	Kaye Inman	J.V. Jones / Jim	Comment Review of Sustaining Eng Plan for CDR	1d	0%	10/20/14	10/20/14
2269	5	6053	Kaye Inman	J.V. Jones / Jim	Incorporate Accepted Comment into Sustaining Eng Plan	10d	0%	10/21/14	11/3/14
2270	5	6054	Kaye Inman	J.V. Jones / Jim	Provide Sustaining Eng Plan for CDR - 4511 signed	0d	0%	11/3/14	11/3/14
2271	4	6073	Kaye Inman	J.V. Jones / Jim Neely	**SLS Sustaining Engineering Plan Development and Release (SLS-PLAN--093) for DCR - Cat 2 1406OP-007**	465d	0%	3/13/15	1/17/17
2272	5	6055	Kaye Inman	J.V. Jones / Jim	Incorporate Sustaining Eng Plan with Comments from CDR	60d	0%	3/13/15	6/5/15
2273	5	6074	Kaye Inman	J.V. Jones / Jim	SLS Sustaining Engineering Plan Development After CDR FY15	19d	0%	6/8/15	7/2/15
2274	5	6075	Kaye Inman	J.V. Jones / Jim	SLS Sustaining Engineering Plan Development After CDR FY16	160d	0%	7/3/15	2/24/16
2275	5	6076	Kaye Inman	J.V. Jones / Jim	Internal (EO and OPS) Review of SLS Sustaining Eng Plan	20d	0%	2/25/16	3/23/16
2276	5	6077	Kaye Inman	J.V. Jones / Jim	Incorporate Comments from Internal Review into Sustaining Eng Plan	10d	0%	3/24/16	4/6/16
2277	5	6080	Kaye Inman	J.V. Jones / Jim	Task Team Review of SLS Sustaining Eng Plan	10d	0%	4/7/16	4/20/16
2278	5	6081	Kaye Inman	J.V. Jones / Jim	Comment Review of Sustaining Eng Plan for DCR	1d	0%	4/21/16	4/21/16
2279	5	6082	Kaye Inman	J.V. Jones / Jim	Incorporate Comments into Sustaining Eng Plan	10d	0%	4/22/16	5/5/16
2280	5	6083	Kaye Inman	J.V. Jones / Jim	Provide Sustaining Eng Plan for DCR - 4511 Signed	0d	0%	5/5/16	5/5/16
2281	5	6084	Kaye Inman	J.V. Jones / Jim	Incorporate Sustaining Eng Plan with Comments from DCR	60d	0%	10/13/16	1/10/17
2282	5	6085	Kaye Inman	J.V. Jones / Jim	Review within OPS for Comment Incorporation	5d	0%	1/11/17	1/17/17
2283	5	6086	Kaye Inman	J.V. Jones / Jim	Provide Sustaining Eng Plan - 4511 Signed	0d	0%	1/17/17	1/17/17



APPENDIX D
USE STUDY

D1.0 Introduction

D1.1 Purpose

The purpose of the SLSP Use Study is to identify and document supportability factors related to the intended use of the SLSP. The SLSP Use Study will encompass all mission scenarios and configurations that are currently planned. The Use Study is Logistics Support Analysis (LSA) Task 201, and is accomplished at the front end of any program or project.

D1.2 Scope

The SLSP Use Study is focused on two specific areas: design supportability factors and providing SLSP with the facts needed to configure an efficient and cost-effective support system while making maximum use of the National Aeronautics and Space Administration’s (NASA) current support infrastructure. The Use Study provides a single reference source, consistent input, benchmark for change, and continuity for the program.

D2.0 Quantitative Supportability Factors

This section focuses on what capabilities and infrastructure the SLSP currently has in place to support the program. Issues and possible improvements are addressed in order to focus on improvements that could be utilized during the life of the program to reduce costs and schedule.

D2.1 Operating Requirements

The SLSP is facing a number of issues related to vehicle processing, infrastructure, and personnel, among others that are in place to support a new vehicle. The Block 1 vehicle will utilize heritage solid rocket boosters (SRBs), Orion Multi-Purpose Crew Vehicle (MPCV), and RS-25 engines while designing a new core stage (CS). Block 1A and 2 vehicles plan to design to liquid rocket boosters (LRBs). Requirements addressing ground operations greatly limit what can be done to the vehicle at the launch site (Kennedy Space Center (KSC)) as well as limit NASA’s ability to modify or upgrade the vehicle design.

Operations requirements for SLSP were originally housed in SLS-SPEC-043, SLSP Ground Operations Specification Volume I: Vehicle Operability and Supportability Requirements. The Program has decided to delete this document, and instead of having operational requirements levied on the Elements, believe that they can be worked informally with the Element because the vehicle designers already know how to design a vehicle that includes planning for ground operations and supportability.

Due to this change in philosophy, the Ground Operations team will assess the baselined design for operability and supportability, and each individual design change to the baseline. Each assessment will be against a set of operational criteria based on the deleted operability and supportability requirements, vehicle operations, and maintenance requirements. These assessments will be called Supportability and Operations Assessment Reports (SOARs). The SOAR will be used to inform management if the baselined design or subsequent design changes are maximized for supportability, operability, and feasibility from a ground operations and logistics standpoint. Recommendations to improve these areas will be provided in the reports provided by Ground Operations and Logistics. At that point it will be up to management to push back on the Elements or accept the risk of the vehicle not being fully maximized for supportability and operability.

This philosophy creates a significant risk for ensuring a supportable design as has been identified in Section D3.0, Lessons Learned. Without upfront requirements and design integration across elements, stages, and programs, vehicle design changes are inevitable and will cost more to operate the vehicle. A number of risks have been developed by the SLS Operations team at Marshall Space Flight Center (MSFC) to address a number of foreseen issues with ground operations and processing.

Along with risks that have been identified, there are other areas of concern that can affect the vehicle's cost, schedules, and NASA's ability to properly operate and process the vehicle on the ground.

Without proper integration efforts from SLSP to the Elements, the stages and individual components may be designed without proper transportation environments addressed. If the individual element's environmental constraints do not fall within expected constraints, specialized ground support equipment (GSE) for temperature and humidity control, purging, pressurization, and monitoring will need to be developed that will lead to increased costs to the Elements and Program.

Due to the use of heritage hardware and infrastructure, the design of SLSP is limited by the existing infrastructure at KSC. Below are some examples of constraints on SLSP by the existing infrastructure at KSC.

- High Bay (HB) crane hook height limits integrated height of the vehicle with the primary concern being the encapsulated payload.
    - 462.5 ft. hook height restricts maximum integration height to include: vehicle stack on ML, encapsulated payload integrations, CS transfer to HB, and total integrated height (see VAB Door Restrictions).
- VAB door height limits the integrated height of the vehicle.
    - The VAB door height is 456 ft. from ground level. Exact dimension is 455 ft. 10 3/8 in. per door manual.

  - Integration of the vehicle onto ML cannot exceed the door height.

- VAB door width limits the integrated width of the vehicle.
  - VAB door width is 71 ft. (per door manual). Current SLSP diameter only leaves for a clearance of 4.9 ft. on either side of the vehicle.

- VAB diaphragm height limits the stage height.

D.2.2 Number of Systems Supported and Scheduling

Regarding scheduling, there are two primary concerns for the SLS design: Element delivery dates in support of the 2017 launch, and the processing time required to support a multiple launch campaign. The 2017 launch is a Block 1 configuration with an assumed hard deadline of December 31, 2017, for the Program to launch the first vehicle. As a result, the vehicle needs a high probability of launching by this date. The concern is understanding all of the operations required for that first flight (different integration assumptions, additional first flight test, off-nominal events, additional processing time due to learning curve, etc.) and using that information to determine when the elements are needed at the VAB for integration and comparing that need date with the projected delivery date provided by the prime contractors. This ensures that the elements are available when needed to support the 2017 launch date.

The second scheduling issue is in regard to supporting a launch campaign of three flights per year. The requirement is to achieve a three flight per year launch-to-launch interval of 180 calendar days. This means that from the launch of one vehicle, all the operations required to integrate, test, prep for launch, and launch the next vehicle needs to be completed within 180 calendar days. However, the entire 180 calendar days is not available to the vehicle. Since the current Program baseline is a single-string system, 10 calendar days is held back to refurbish the Mobile Launcher, and another 30 calendar days is held back to allow time to recover from any failure that may occur during the countdown. This leaves the vehicle with 140 calendar days to integrate, test, and prep the vehicle for launch, as well as recover from any off-nominal event that occurs prior to start of countdown, including a late delivery of an element. The design needs to be analyzed to ensure that planned operations and potential off-nominal operations can be performed within 140 calendar days. Figure D2-3 shows a breakdown of the launch-to-launch interval.

D2.3 Transportation Factors

D2.3.1 Ground Handling: Core Stage

Ground handling of the CS and structural test articles (STAs) will be accomplished by means of modular common carriers.

The GSE will be designed to provide the interface of the CS with the modular common carriers. The common carrier modules will be designed to be compatible with the existing MSFC kneel-down transporters (KDTs) for items up to 72 ft. in length (two modular common carriers). The KDTs have a width of 20 ft. wide and a load carrying surface that is approximately 52 ft. in length. The KDTs have the capability to lower to a 47 ft. deck height and can lift to a 71 ft. deck height. The modular common carriers should allow for "drive-under, lift-up, lower-down, drive out" loading and unloading on a flat horizontal surface. Modular common carriers should also be designed to be compatible with the transporters selected for use at the manufacturing facility and at the launch facility at KSC. Means of securing the modular common carriers to the transporters must be provided.

Loading the CS onto the modular common carrier will be performed by the prime contractor at the manufacturing facility. Unloading the CS will be performed at KSC utilizing facility cranes within the VAB. Lifting slings/beams, fixtures, and attach points will be needed to facilitate these operations.

No current barge operations exist to support the usage and maintenance of NASA barge *Pegasus*. Personnel of specific skills required to maintain marine structures and systems need to be identified and (at least) partially dedicated to maintaining the NASA barging operations.

D2.3.3 Ground Handling – SLS STA

The STA for the forward skirt (FS), instrument unit (IU), liquid oxygen (LO_2) tank, interstage (IS), and liquid hydrogen (LH_2) tank will be shipped by barge on modular common carriers. One or two "simulators" are expected to accompany each STA article. Each STA article and its respective simulator(s) will be bolted together and shipped horizontally. Simulators must be equipped to lift the STA assembly to vertical with a two-crane lift approach and must support lifting operations associated with placing the STA into the test location. Simulators must be capable of being removed from the STA with the STA still supported by the modular common carrier. The STA must be capable of being lifted to vertical with or without the simulators attached. Lifting slings/beams, fixtures, and attach points will be needed to facilitate these operations.

D2.3.3 Handling – Boosters

Ground handling for existing reusable solid rocket motors (RSRMs) is expected to utilize existing infrastructure, fixtures, and modes of transportation and handling.

Ground handling for proposed LRBs on Block 1A and Block 2 SLS is yet to be determined as the LRBs have not been designed. Utilizing the existing infrastructure, fixtures, GSE, and modes of transportation and handling will be maximized.

D2.3.4 Handling – Payload Shroud

Air Transportation – The payload shroud should be compatible with the NASA "*Guppy*" if shipped to the launch facility by air. The *Guppy* has a cargo bay that is 125 ft. in length and is 25 ft. in diameter. Segmenting the payload shroud may be necessary. Fixtures to support the payload shroud must be compatible with the existing rail system within the *Guppy*. The *Guppy*'s cargo area is an unpressurized and unconditioned volume.

Marine Transportation – The payload shroud should be compatible with the modular common carriers if shipped by barge.

Over the Road – The payload shroud should be segmented to allow over-the-road transport by special carrier (truck/trailer). Rules vary state to state. Route surveys may be required. Overpasses may only provide 13 ft. 6 in. headroom. Any load over 8 ft. 0 in. falls into the category of wide load. Larger loads require special permits. Loads more than 20 ft. wide may not be possible.

Lifting slings/beams, fixtures, and attach points will be needed to facilitate these operations.

D2.3.5 Marine Transport

Modular common carriers will interface with marine transportation equipment to secure the modular common carriers to the NASA barge(s).

The CS is of such dimension that the current means of marine transportation, via *Pegasus*, is insufficient. The anticipated size requires *Pegasus* to be "stretched" approximately 50 ft. to accommodate. This necessitates extensive structural modifications, modifications to several barge systems, and will require a major dry dock. These modifications will require significant investment in time and a cost of $2.5 million.

Marine infrastructure assessments are needed at Michoud Assembly Facility (MAF), KSC, Stennis Space Center (SSC), and MSFC. The relevant docks at each NASA center are in varying degrees of condition. A survey (above and below the water line) may be required at each location to determine the current condition. Assessments are required to ensure the relevant docks have adequate capacity to accommodate anticipated loading conditions. At KSC, a waterway assessment of the "Saturn Channel" in the Banana River is needed between Port Canaveral and the KSC turn basin. This assessment is needed to determine current condition and the navigability of this channel to accommodate a modified *Pegasus*.

D2.4 Environmental Factors

NASA will follow all Environment Protection Agency (EPA) standards and regulations to the fullest extent possible. In any case where NASA cannot meet EPA standards and regulations, waivers will be filed and NASA will work closely with the EPA to minimize any environmental impacts.

D3.0 Summary of Previous or Similar Systems (Lessons Learned)

This section contains facts, both quantitative and qualitative, about previous or similar systems. The focus in this section is to create the primary source for follow-on analyses for the following LSA tasks: 202, Standardization Analysis; 203, Baseline Comparative Analysis; and 204, Technology Opportunities Analysis.

D3.1 Operating Requirements

Throughout the development and design of launch vehicles, there are obstacles to properly support and operate the launch vehicle on the ground. Risks are developed and mitigated, requirements changed, and designs altered to help meet logistics and supportability requirements and desires. Section D3.1 focuses on "lessons learned" from previous similar systems so as to avoid repeating similar mistakes on SLSP where they can be avoided.

D3.1.1 Ares I-X

See Section D3.2.1 for Ares I-X specifics as they pertain to the ground infrastructure.

D3.1.2 Ares – Design Impacts

On the Ares Projects, there were many challenges to designing a supportable vehicle on the ground while still meeting the flight requirements. This section outlines examples that were encountered by the Ares team. Each one of these examples required extensive work with other NASA centers, design teams, the Program and Project offices, review boards, and other NASA organizations to ensure work was done properly and the changes were documented adequately.

- Through the addition of a second IS door to the upper stage (US) of Ares I, the NASA team was able to reduce ground processing times at KSC, decrease operations costs, and increase safety while working interior to the US IS.
- The original IS access door was relocated in order to be properly aligned with the reaction control system (ReCS) servicing panel location, allowing for use of the double-decker arm on the pad – eliminating the need for two separate access arms, and enhancing vehicle access at the pad.
- Relocated the ReCS and roll control system (RoCS) servicing panels from the inner mold line (IML) to the outer mold line (OML) of the vehicle. This move eliminated internal access to the vehicle for ReCS and RoCS pressurant and propellant servicing while reducing the chance of a dangerous chemical leak inside the vehicle.
- Minimized the number of attach points in the IS for internal access (IA) GSE.
- Recommended the use of common battery chemistry.

- Routed the common bulkhead serving port to the ReCS service panel for accessibility.
- Relocated VAB platforms to adapt to changes in vehicle designs.
- Developed component access requirements for initial IA GSE concepts for the IS and IU.
- Combined the FS and IU.
- Provided input to the hydrazine loading trade – Preferred loading at the pad to reduce hazardous operations in the VAB.
- Worked with ReCS and RoCS service panel designers to ensure proper spacing of valves.

D3.2 Number of Systems Supported and Locations

Section D3.2 is similar in nature to Section D3.1, and focuses on "lessons learned" from Space Shuttle Program (SSP) as they were projects that actually utilized the NASA infrastructure that was in place.

D3.2 Space Shuttle Program (SSP)

- Problem: There was insufficient definition of operational requirements during the development phase of the space shuttle that led to a very intensive (high operational cost) vehicle that was deployed into operation.
    - Concentration on performance requirements but not on operational considerations.
    - Shuttle design organizations were not responsible for operational cost.
    - Very few incentives for development contractors.
- Lessons Learned:
    - Must have the Concept of Operations defined.
    - Levy the requirements on contractors to support the Concept of Operations.
    - Must have continuity and integration between designers, ground operations, and flight operations requirements during the developmental phase.
- Problem: The cost of reusability of complex, multifunctional, aging vehicle.
    - Every orbiter function, whether used or not on a given mission, must be verified and checked out prior to flight.

    - Every function must also be monitored and failures managed to avoid a catastrophic event.
    - Reusability of aging complex systems requires ever increasing attention to maintain performance and safety.
    - Complex paper system "touched" by too many organizations governs every step of the operation.
        - Early 1980s heritage.
        - Only limited streamlining over the life of the program.
- Lessons Learned:
    - Complexity creates flight operational cost.
        - Minimize complexity.
    - Manual approach adds to operational cost.
        - Automate.
    - Realistically define operational life prior to development.
- Design Lesson:
    - Develop and maintain a strong integration team throughout the program life cycle.
    - Empower integration to challenge the elements and program on issues of design flaws and interaction between the elements.
        - Continuously monitor performance and safety throughout the transition to operations and the operations phase.
    - Integration and element engineering should be staffed with the best in their field…inquisitive by nature, respected by peers and management, and who have the courage to take on the program regarding issues.
    - Transition to operations should be made consistent with vehicle operational capabilities embedded in the design.

D3.2 International Space Station (ISS)

D3.2.1 Programmatic Lessons

- Establish Acquisition Logistics early as a systems engineering discipline.

    - Putting Logistics in Operations tempts deferring Logistics budget and products.
    - Need Acquisition Logistics to be an integral part of the design development effort.
    - Logistics effort could migrate to Operations as operations phase begins.
        - It still must work with both organizations.
- Treat Acquisition Logistics as an integrated product support function.
    - Not just spares and resupply.
    - Includes maintenance, tech data, personnel and training, PHS&T, facilities, automation support.
        - System/subsystem maintenance/support on-orbit.
        - Orbital replacement unit (ORU)/equipment maintenance/support on the ground.
- Program Logistics Manager Position.
    - No more than two levels below the program manager.
        - Equal to, or reporting to, the systems engineering manager.
        - Possibly a direct report to the program manager.
        - Integrate reliability and maintainability into logistics supportability.
        - Logistics was buried in Space Station Freedom organization, resulting in a lack of program visibility and lack of access to program management.
- Expect Space Launch Initiative (SLI) to have low quantities of unique hardware as have shuttle and station.
    - One station – no more production units (space stations) coming down the line.
        - Built in segments and operated in segments for some amount of time.
    - Four shuttles – could use production diversion to support operational units for a while.
        - Built as a single unit and flown.
- Spares analysis must include in-depth consideration of the expected operating environment including:

    - Duty cycle.
    - Mission profile.
    - Failure efforts on mission profile.
    - Supply/pipeline constraints.
- Must require detailed production schedules from manufacturers.
    - Key to ability to buy spares on the end of production run (Spares Acquisition Integrated with Product (SAIP)).
    - Changes to production impact spare buys.
    - Use production diversion to support initial operations needs.
- Integrate sustaining engineering and spares procurement.
    - Avoid costly life of type buys by pre-planning upgrades.
- Maintenance concept is the basis for all logistics support planning.
    - Must be detailed.
    - Describe each level of maintenance adequately such that logistics engineers and designers at all levels understand.
- Structure maintenance concept based on:
    - Location.
    - Tools/support equipment available.
    - Response time for mission success.
    - Skill level.
- ISS maintenance concept originally used remove/replace of ORU as the dividing line between organizational-level maintenance and all others – led to many misunderstandings about on-orbit maintenance.
- Hold design teams accountable for logistics supportability.
    - Give designers incentive for designing supportability into their systems.
    - Create a partnership between logistics and designer, instead of an adversarial relationship.

        - Embed logistics engineers in design teams as a contributor to design, not a reviewer.
    - Make life cycle cost model a part of the design process.
        - First thing thrown out of station program when budget got tight.
    - Ensure requirements for supportability, maintainability, and reliability start with the highest level program document and flow down to the lowest level specification.
        - Ensure requirements are verifiable.
        - Track requirements to completion.

D3.2.2 Design Lessons

- Establish a requirement for operational availability.
    - Expected operational hours over possible operational hours.
    - Decompose into tiered functions.
    - Drives the relationship between design reliability/maintainability and establishment of the logistics support infrastructure.
        - Spares quantities.
        - Repair turnaround time.
        - Facilities.
        - Maintenance time.
    - Station reliability and maintainability (R&M) requirements based on crew time only.
        - No constraint on other elements of support, such as upmass, volume, and storage.
- Standardize.
    - No standardization requirement/constraint on station designers.
        - Proliferation of connector types.
        - Proliferation of ORU interfaces.
    - Logistics costs increased by:

        - Having to buy/stock multiple nonstandard connectors.
        - Create unique packaging for nonuniform ORUs.
        - Buy unique tools/support equipment for each ORU type.
        - Buy special handling equipment for large, unwieldy ORUs.
        - Training requirements increased by having to learn numerous unique ORU attributes.
    - Counter-argument is that requirements for standardization unnecessarily constrain the designer – not a valid argument – standardization reduces life cycle cost significantly.
- ORU/LRU size and access.
- Station had no constraint on ORU size:
    - ORUs weigh up to 2300 pounds.
    - Many functions combined into a single ORU in order to reduce initial launch weight – failure of a single function in the ORU causes need to replace entire ORU.
    - Options to design for small ORUs (direct access to circuit cards) rejected in favor of aluminum chassis with high weight penalty.
    - Recommend SLI conduct a study of ORU/LRU handling and select a size/weight that can be easily handled at all levels.
- No direct access requirement/constraint; only overall crew time requirement.
    - For many ORUs, access takes longer than the remove/replace procedure.
    - The preventive maintenance requirement for a valve had to be waived because access is too difficult.

D3.2.3 Supporting ISS Maintenance

- Shuttle built before ISS, no opportunity to tailor shuttle design to support ISS.
- ISS maintenance is very complex and is dependent on shuttle capabilities.
    - Requires (for the US segment):

        - 8900 lb. of unpressurized spares per year, plus field support equipment (FSE).
        - 2500 lb. of pressurized spares per year, plus packing.
        - Twenty extravehicular activity (EVA) sorties per year.
        - 150 hours using dexterous robotics.
        - 180 hours intra-vehicular activities (IVAs) crew time per year.
    - Desire is to perform maximum amount of maintenance possible from shuttle.
        - Frees up station crew to perform science.
        - Much easier to train shuttle crew for maintenance – station crew training template is full.
- Desired attributes of SLI for performing maintenance of ISS:
    - Flexibility of accepting multiple deployable carriers.
        - ISS planning calls for up to three cargo carriers on a single shuttle mission.
        - Ability to deploy carriers from shuttle to ISS by robotics is vital to reducing EVA time.
        - Shuttle is limited by latch functions to two deployable carriers.
    - Ability to accept different carrier types and cargo complements without extensive analysis.
        - ISS maintenance requires changes to spares manifest throughout the preparation for shuttle launch.
        - Need to be able to change spares manifest without costly reverification of loads, vibro-acoustic properties.
    - Extended stay time on ISS.
        - Shuttle docked time of 7–8 days severely constrains how much EVA shuttle crew can perform.
        - Would prefer 15 or more days from SLI.
    - Include ability to transfer consumables to ISS:

- Water.
- O_2.

D3.2.4 Summary

- Establish acquisition logistics at the right level as a systems engineering discipline.
- Spares procurement is based on low equipment densities in a unique operating environment.
- Detailed maintenance concept is key.
- Incorporate life cycle cost into program requirements.
- Develop operational availability requirements.
- Standardize design attributes.
- Constrain ORU/LRU size and access.
- Include ability to carry/deploy multiple carrier types.
- Extended stay time.
- Ability to transfer consumables to ISS.

D3.3 Non-Design/Program Specific Lessons Learned from Past Endeavors

Launch vehicles often experience vast knowledge growth from cradle to grave of any system. This knowledge gained is most often in the form of lessons learned and often doesn't deal with design itself. Below are some non-design and facility based lessons learned.

- Integration between NASA centers is vital at an early stage.
- Requirements development integration is needed within a project.
- Set up a test organization early so as to interface directly with requirements development.
- Enforce requirements not developed by design groups.
- Establish a tracking system for all SE from a program level.
- Minimize the constant change of management.
- Internal integration needs to be better promoted.
- Have a strict NASA-wide DD250 and DD1149 process in place for the movement of goods.

D3.4 Transportation Factors

The Space Transportation System (STS) Program and the Ares I tackled many transportation issues regarding the movement of the elements of each system. The primary mode of transportation for the STS external tank (ET) and Ares I US was marine transport via a barge. The orbiter was transported via a modified Boeing 747 if an Edwards Air Force Base landing was required. The STS SRB segments and Ares I first stage segments were transported via a rail system from Utah to Florida. There were several considerations in the design that drove increased costs during transport, especially marine transport.

D3.4.1 Monitoring Condition during Transport

Preservation/instrumentation/monitoring requirements aboard an enclosed NASA barge should consider other periphery transportation regimes into consideration when they are developed. More of these requirements were imposed during marine transportation while the same or very similar environments experienced in other transportation regimes (transportation to the launch pad, for example) were far less extensive. The marine environment does have unique parameters to consider, but before imposing requirements that may impact vessel capabilities, additional vessel personnel, additional secondary systems, and instrumentation, this mode of transportation should be balanced against the overall transportation concept.

The monitoring capability during transport is something that was required for both STS and Ares I. The STS Program monitored the ET during transport utilizing manual gauges to determine the pressure within the tank. This required a human presence during transport in order to manually read gauges with binoculars. The main system used for in-transit monitoring of the Ares I US was planned to be the Transportation Instrumentation and Monitoring System (TIMS). This system monitored real-time environments encountered during land transport and at sea. The TIMS would have had sensors on and around the vehicle to monitor LO_2/LH_2 tank pressures, reaction control system (RCS) tank and system pressures, IU and IS volume temperature and humidity, common bulkhead pressure, and transporter shock loads. The system would have read and stored the data for a detailed analysis upon arrival of the US at its destination. It also included special instrumentation that could be used to monitor system pressures after the vehicle had been removed from the transporter, but before it has power applied to read flight sensors.

D3.4.2 Configuration Control of Transportation Interfaces

Configuration control over NASA barge interfaces and clearances is needed to prevent requirements creep and design inconsistencies at interfaces. Several *Pegasus* and ET tie-down equipment inadequacies developed when design requirements were updated, but not considered and levied on *Pegasus* and ET tie-down equipment. Several separate project offices/contractors were responsible for specific items used to support ET transportation. This created a difficult environment to appropriately coordinate, incorporate, and track hardware, and desired functional/operational outcomes.

Appendix E

Baseline Comparative Analysis

The purpose of the Comparative Analysis is to select or develop a Baseline Comparison System (BCS) representing characteristics of the new system/equipment for (1) projecting supportability related parameters, making judgments concerning the feasibility of the new system/equipment supportability parameters, and identifying targets for improvement, and (2) assist in determining the supportability, cost, and readiness drivers of the new system/equipment. The main purpose for PDR is to conduct data collection on these similar systems and identify "Lessons Learned" from these previous systems. The approach of this subtask is to identify systems and subsystems which may be useful for comparative purposes with new system/equipment alternatives. These systems were chosen for their functional similarity to the new system.

SYSTEM LEVEL COMPARISONS

For the system level comparisons, information was obtained on three comparison systems to baseline, Ares 1, Ariane 5 and the Atlas V. These were picked for their similarity to SLSP. Data was collected on the maintenance approach to develop similarities and to benchmark potential "good ideas" for the current SLS design. Below are excerpts from these reports that are applicable to the supportability of the SLS design.

ARES I Comparison

For Ares I, there were several items developed prior to the Ares 1X flight. Items contained below include the Ares maintenance concept, latest Ares LRU and limited life components candidates list assessment, supportability requirements, and support system alternatives.

Ares I Maintenance Concept

The concept for Ares I was a two level maintenance concept with items identified with the potential for on-pad removal and replacement. The Ares I levels of maintenance was described in terms of "operations location." These are Launch Site (which includes both the Vehicle Assembly Building (VAB) and Pad) maintenance, Manufacturing and Assembly Site (Michoud Assembly Facility (MAF), Stennis Space Center (SSC), and Kennedy Space Center (KSC)) maintenance, and Component Vendors/Off-Site Vendors maintenance.

Launch Site (VAB & Pad) Maintenance Summary

Launch Site maintenance will consist of maintenance actions performed in direct support of ground operations. National Aeronautics and Space Administration (NASA) Kennedy Space

Center (KSC) and TOSC Contractor will perform the Launch Site maintenance requirements on the Ares I System. Launch Site maintenance requirements on the Ares I system will be performed by NASA, KSC, and support contractors' maintenance personnel on a day-to-day basis in the support of launch site operations. The Launch Site maintenance personnel will keep the Ares I in a full mission-capable status while it is at the launch site. Launch Site maintenance will be limited to periodic checks of equipment performance, visual inspections, cleaning of equipment, some servicing, external adjustments, handling, and the removal and replacement (R&R) of Line Replaceable Units (LRUs). Fault isolation times and corrective maintenance actions are reduced through the limited, but effective, use of system built-in test features. Components that are removed at this level are forwarded to the Manufacturing and Assembly (MAF, SSC, and KSC) or Off-Site Vendors for repair. Recordkeeping and reports preparation are also performed at the launch site.

Table 1 provides additional information about the Ares I maintenance concept.

Table 1 Ares I Maintenance Concept Summary

Two Levels of Maintenance	**Organizational Level**		**Depot Level**
Location	**PAD**	**VAB**	**Manufacturing and Assembly Site**
Responsible Organization (pre- DD250)	N/A	Ares (VI)	Elements
Upper Stage/J-2X	N/A	Support	TBS
First Stage	N/A	Support	TBS
US Engine*	N/A	N/A	TBS
Responsible Organization (post DD250)	NASA (KSC) and TOSC Contractor Support	NASA (KSC) and TOSC Contractor Support	Elements
Upper Stage	Specialty Support	Specialty Support	TBS
First Stage	Specialty Support	Specialty Support	TBS
US Engine	Specialty Support	Specialty Support	TBS

Two Levels of Maintenance	**Organizational Level**		**Depot Level**
Location	**PAD**	**VAB**	**Manufacturing and Assembly Site**
Repair Policy			
Organizational Level Activities and Locations			
Corrective (Unscheduled) Maintenance	Perform adjustment and alignment, R&R and retest LRUs.	Perform adjustment and alignment, R&R and retest LRUs.	TBS
Preventive (Scheduled) Maintenance	Servicing of fluids, nitrogen, etc., and visual inspection.	Servicing of fluids, nitrogen, etc. and visual inspection.	None
Repairable & Discard LRUs	N/A	N/A	TBS
Support Factors			
Test & Support Equipment			
Built-in self-test	Yes	Yes	Yes
External Test, Measurement, & Diagnostic Equipment (common and peculiar)	Yes –list per ILSP	Yes – list per ILSP	Yes
Automatic Test Equipment	Yes – list per ILSP	Yes – list per ILSP	Yes
Handling and Support Equipment			
Unique Equipment	Yes – list per ILSP	Yes – list per ILSP	Yes

Two Levels of Maintenance	**Organizational Level**		**Depot Level**
Location	**PAD**	**VAB**	**Manufacturing and Assembly Site**
Common Equipment	Yes –list per ILSP	Yes –list per ILSP	Yes
Facilities			
Storage Facility	No		Yes
Maintenance Facility	No	No	Yes
Supply Support			
Spares and/or Repair Parts Reqs.	N/A	On Site Storage	TBS
Initial Provisioning	N/A	N/A	Yes
Transportation			
Mode			
Integrated Upper Stage	N/A	Truck	
First Stage	N/A	Rail and Truck	TBS
Manpower and Personnel			
Skill level	TBS	TBS	TBS
Quantities	TBS	TBS	TBS
Training and Training Support	Yes	Yes	Yes
Effectiveness Requirements			
Ao	98%	N/A	

Two Levels of Maintenance	**Organizational Level**		**Depot Level**
Location	**PAD**	**VAB**	**Manufacturing and Assembly Site**
System Readiness		85% (TBS)	
Reliability			
Mean Time Between Failures (MTBF)	TBS	TBS*	
Probability of Failure During Ground Processing Operations	TBS	TBS*	
Maintainability			
Mean Time To Repair (MTTR)*	8 hrs.	4 hrs.	
Maintenance Downtime	TBS	TBS	
Administrative and Logistic Delay Time	24 hrs.	24 hrs.	
Maintenance Man-Hour (MMH)/ Operating Hour (OH)	TBS	TBS	TBS
Supportability			
LRU Accessibility	TBS	TBS	
GSE Setup/Removal Time	8 hr.	8 hr.	
Fault Detection & Isolation	Fault Isolation to LRU	Fault Isolation to LRU	TBS
Automatic Fault Detection & Isolation	100%	100%	TBS
Manual Fault Detection & Isolation %	No	Yes	Yes

Ares I LRU candidates

The candidate selection criterion utilized by Ares I is below. Essentially, an LRU was maintenance significant items that are testable, removable, and procurable.

- Likelihood of pre-launch contingency event
- GSE Complexity
- Retest at the Pad after replacement
- Liquid consumables considerations
- Detectable failure modes
- Human Factors (Weight & size)
- Current accessibility
- Minimal Maintenance Down Time
- Safety Impacts (High/Med/Low)
- Preliminary Cost Impacts (High/Med/Low)
- Risks (Time on Pad, Readiness/Availability)

The LRU candidates list for Ares comprised of 165 LRUs for the Ares Integrated Upper Stage and 80 for the Ares First Stage.

Ares LRU Candidates List First Stage LRU Candidates

INDENTURE LEVEL	CANDIDATE LRU NOMENCLATURE
A	ARES I (CLV)
B	FIRST STAGE
C	AVIONICS
D	DEV FLT INSTM (DFI)
E	DFI BATTERY
E	DFI MASTER UNIT
E	DFI PDU
E	DFI RECORDER
E	DFI SENSOR
E	DFI SLAVE
D	OI CTRL/MON
E	OI ACU
E	OI BCPDU
E	OI DARU
E	OI HPU CONT
E	OI ISC
E	OI BATTERY
E	OI RCU
E	OI RATE GYRO ASSY
D	VIDEO SYSTEM
E	VID SYS CAMERAS
E	VID SYS SSVR
C	FLIGHT SAFETY SYS
D	FLIGHT TERMN SYSTEM
E	FTS ANTENNA
E	FTS BATTERY
E	FTS DIR COUPLER
E	FTS HYB COUPLER
E	FTS COM REC DCDR
E	FTS FCDC ASSY
E	FTS LSC
E	FTS NSD
E	FTS SAFE ARM ASSY
D	RADAR BEACON TRKG
E	RBT CBAND ANT HELIX
E	RBT POWER CABLE
E	RBT CBAND TRANSPONR
C	RECOVERY
D	AEROSHELL SEP ASSY
E	DETONABLE BSTR ASSY
E	FLEXIBLE CD CORD
E	FLEXIBLE CDC INITR
E	THRUSTER ASSY
E	THR PRESS CRTG
D	FWD SKT EXT SEP
E	DETONATOR BSTR ASSY
E	FCDC ASSEMBLY

INDENTURE LEVEL	CANDIDATE LRU NOMENCLATURE
E	LIN SHAPED CHARGE
C	PROPULSION
D	IGNITION SUBSYSTEM
E	SRM IGN INITIATOR
E	SAFETY/ARMING DVC
E	PYRO BASKET ASSY
C	SEPARATION
C	STRUCTURE
C	THRUST VECTOR CTRL
D	HPS
E	FUEL SUPPLY MODULE
E	HYDR BTST RSVR

Integrated Upper Stage LRU candidates

A	ARES I (CLV)
B	INTEGRATED UPPER STAGE
C	AVIONICS, ARES I
D	AVIONICS RING
E	BATTERY UNIT, AFT
E	ANTENNA,C-BAND
E	CAMERA CONTROL,AFT
E	FTS ANTENNA
E	POWER AMP, SS
E	ANTENNA, S-BAND
E	BATTERY UNIT, FTS
E	CAMERAS, STD AFT
E	CAMERAS, STD FORWAR
E	FTS HYBRID COUPLER
E	RF HYBRID COUPLER
E	FTS COM/REC/DECODE
E	COMP,COMMND&TELEM
E	AFT DATA ACQ&CNTR
E	IU DATA ACQ&CNTR
E	DIRECT COUPLER, FTS
E	AFT DATA BUS ISO AM
E	IU DATA BUS ISO AMP
E	CAMERA CONTROL,FWD
E	FLIGHT COMPUTER
E	FLIGHT COMPUTER
E	FLIGHT COMPUTER
E	GPS RECEIVER
E	CAMERAS, HS AFT
E	BATTERY UNIT, IU
E	INERTIAL NAV UNIT
E	LIGHTNING STUB,FTS
E	MAIN PROP SYS ELECT
E	PWR DIST&CNTRL,AFT
E	PWR DIST&CNTRL,IU
E	PUMP MOTOR INV UNIT
E	REACT CNTRL SYS ELE
E	FILTER,S-BAND REJCT
E	TRANSMITTER,S-BAND
E	TRANSPONDER,C-BAND
D	INTERSTAGE AVIONICS
E	PWR DIST&CNTRL,IN
E	RATE GYRO ASSY
E	ROLL CNTRL SYS BATT
E	ROLL CTRL SYS ELECT
C	ENGINE, UPPER STAGE
D	ANCILLARY SYS
E	BLEED VALVE,FUEL
E	BLEED VALVE,OXIDZ
E	VALVE,HELIUM SPIN
D	CHAMBER,THRUST
E	IGNITER,INJECTOR
D	DUCTING INSTALL
E	VALVE,GAS GEN FUEL
E	VALVE,GAS GEN OXIDZ
E	VALVE,MAIN FUEL
E	VALVE,MAIN OXIDZ
D	DUCTING,PROP & GAS
E	INLET DUCT,FUEL
E	INLET DUCT,OXIDZ
D	INSTRMT&ELEC INSTAL
E	ENGINE CONTROL UNIT
E	MAIN INJ EXITE UNIT
E	SENSOR,VIB (ACCEL)
E	SENSOR,SPEED
D	LOOSE EQUIPMENT

E	IGNITER,PYRO
D	PNEUMATIC SYS
E	VALVE,PNEUM ACT
E	VALVE,PNEUM PURGE
C	MAIN PROPULSION SYS
D	LIQUID HYDROGEN SYS
E	HYD REPRSS ENG CRYO
F	PANEL,REG SUBASSY
F	VALVE,CHECK
E	HYD FILL&DRAIN ASSY
F	DUCT, H2 F&D
F	VALVE, H2 F&D
E	HYD MAIN FEED ASSY
F	DUCT,FEED,H2 FWD
F	DUCT,FEED,H2 AFT
F	FILTER, H2 F&D
F	PREVALVE, H2 F&D
E	HYD RECIRC SUP ASSY
F	FILTER,H2 RECIRC
F	PUMP, H2 RECIRC
F	LINE ASSY,H2 RECIRC
F	VALVE,H2 CHECK
F	VALVE,H2 SHUTOFF
E	PRE-PRESS ASSY,H2
F	VALVE,CHECK,H2
E	PRESS ASSY, H2
F	DIFFUSER,H2 PRESS
F	PLENUM
F	VALVE, CHECK, H2
F	VALVE,CNTRL PNL,H2
E	RECIRC,H2 RETURN LN
F	LINE ASSY,H2 RECIRC
E	RE-PRESS ASSY,H2
F	FILTER,INLET,H2
F	VALVE ASSY, QUAD IS
F	VALVE,CHECK,ISO
E	VENT/RELIEF ASSY,H2
F	LINE,H2VENT/RELIEF
F	VALVE,H2VENT/RELIEF
D	HELIUM SUPPLY SYSTE
E	SUPPLY ASSY,HE AMBT
F	PREVALVE, PNEU CONT
F	PLENUM
F	SUPPLY BOTTLE,PNU
F	PNU CNTRL,RECIRC IS
F	REGULATOR,AMBT HEL
F	SUPPLY BOTTLE,REPRS
F	VALVE,CHECK
F	VALVE,DUMP
E	SUPPLY ASSY,HE CRYO
F	REGULATOR, CYRO HEL
F	RELIEF SYS,HI PRESS
F	RELIEF SYS,LOW PRES
F	TANK
F	VALVE,CHECK
F	VALVE,DUMP
E	SPIN START ASSY,HE
F	TANK ASSY,HE SUPPLY
F	VALVE,CHECK
F	VALVE,DUMP
D	LIQUID OXYGEN SYSTE
E	FILL&DRAIN,O2 ASSY
F	DUCT,O2 FILL&DRAIN
F	PREVALVE, O2 F&D
F	VALVE, O2 F&D
E	RECIRC SUPP ASSY,O2
F	FILTER,O2 RECIRC
F	PUMP,O2 RECIRC
F	LINE ASSY,O2 RECIRC
F	VALVE,CHECK,O2
F	VALVE,O2 SHUTOFF
E	PRE-PRESS ASSY,O2
F	VALVE,CHECK,O2
E	PRESS ASSY, O2
F	DIFFUSER,O2 PRESS
F	VALVE,CHECK,O2
F	VALVE,CNTRL PNL,O2
F	VALVE, ISO, O2
E	RECIRC,O2 RETURN LN
F	LINE ASSY,O2 RECIRC
E	RE-PRESS ASSY,O2
F	FILTER,INLET,O2
F	VALVE ASSY,QUAD ISO
F	VALVE,CHECK ISO
E	TEMP BYPASS CONTROL
E	VENT/RELIEF ASSY,O2
F	LINE,O2VENT/RELEIF
F	VALVE,O2VENT/RELEIF
D	PRESSURIZATION AND
E	PNEUN SUP ASSY
F	PANEL,REG DUAL REDN
F	VALVE,CHECK
E	PREVALVE,PNU CNTRL
E	RECIRC ISO PNU CNTR
C	ROLL CONTROL SYSTEM
D	REACTION CONTROL, U

D	ROLL CONTROL,FIRST
C	SMALL SOLIDS SYSTEM
D	PYRO SUBSYSTEM
E	NASA STD DET, SEP
E	NASA STD DET,ULLAGE
E	NASA STD DET,SAFETY
E	SAFE&ARM DEVICE,FTS
D	SMALL SOLIDS SUBSYS
E	BOOSTER DECEL MOTOR
E	ULLAGE SETTL MOTOR
C	STRUCTURE & THERMAL
D	AFT SKIRT
D	COMMON BULKHEAD
D	HYDROGEN TANK
D	INTERSTAGE
D	AVIONICS UNIT RING
D	OXYGEN TANK
D	SYSTEM TUNNEL
D	THRUST CONE
C	THRUST VECTOR CNTRL
D	ACTUATORS SUBASSY
E	CONTROLLER,ACTUATOR
E	CABLES,ACT CONTROL
E	HYD ACTUATOR
D	CONTROL & DATA BOX
E	CABLES,CDIU TO HYD
E	CABLES,CIRCLTN PUMP
E	CDIU
E	CABLES, TPA SYS
D	HYD POWER SUBASSY
E	CHECK VALVE,HEL SUP
E	CHECK VALVE,HYD SUP
E	GH2 INLET LINE
E	GHE INLET LINE
E	TURBINE PUMP ASSY
E	PROPELLANT SUP LINE
D	HYDRAULICS SUBASSY
E	ACCUMULATOR
E	PUMP/MOTOR,CIRCULTN
E	MANIFOLD
E	RESERVOIR
E	CHECK VALVE,FILTER

Ares I Limited Life Components

An initial data collection effort for the Ares I Program determined a list of Limited life components from the LRU list.

139 Inch ETL

309 Inch ETL

110 Inch ETL

NASA Standard Detonator (NSD)

NASA Standard Detonator (NSD)

279 Inch ETL

109 Inch ETL

Safe & Arm Device (S&A)

NASA Standard Detonator (NSD)

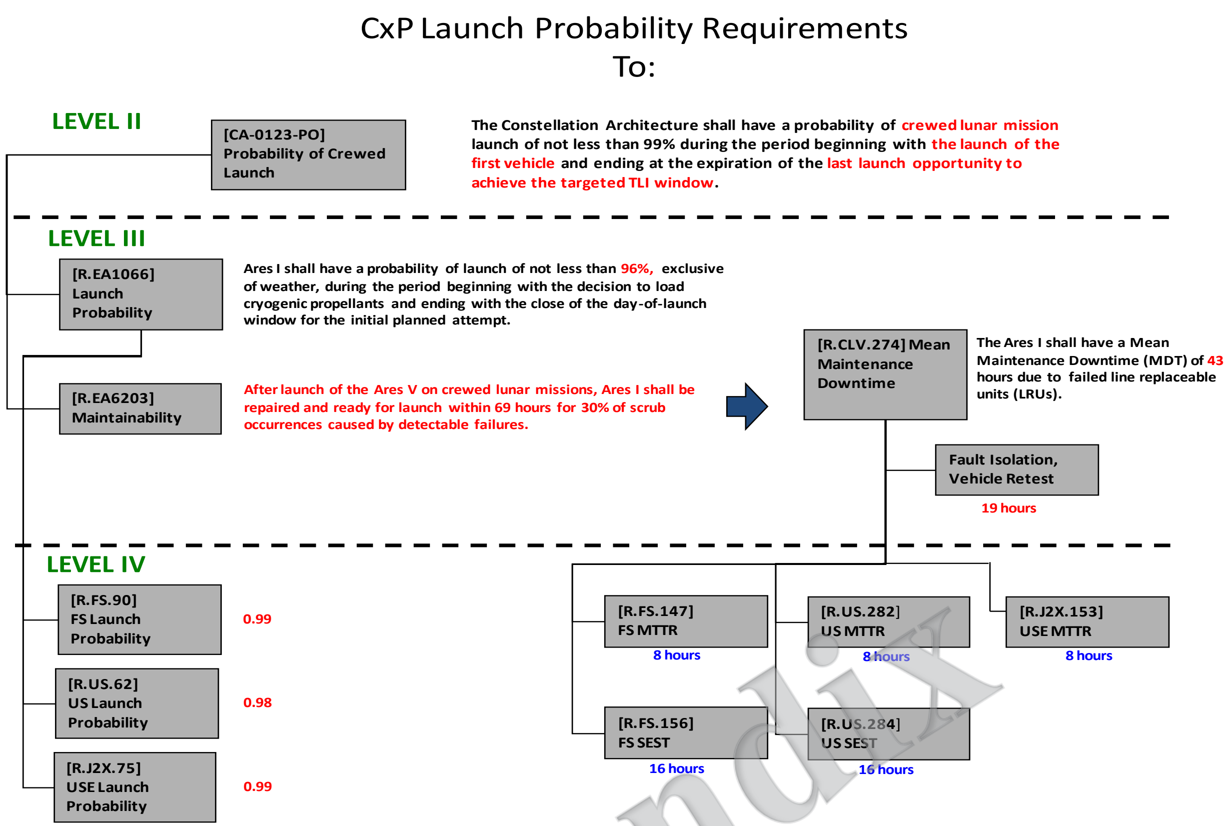
319 Inch Explosive Transfer Line (ETL)

375 Inch ETL

FTS Battery Unit (BU)

Ares I SUPPORTABILITY REQUIREMENTS

Ares I specific supportability related factors are identified and applied with the objective of ensuring that the system will be designed and developed such that it will satisfactorily accomplish its intended mission(s). These were identified as supportability requirements to be assessed during design for the prime mission-related elements of the system and for those elements that are necessary for the support.



Ares I Derived Level 3-4 Maintainability Requirements and TPMs

Analyses of potential timelines for contingency activities are to consider both Ground Operations processing and the Vehicle maintenance down time activities to be completed in the times consistent with a more affordable system. These derived requirements are:

- Maintenance Downtime (MDT) = 40 hours (3 hour reserve)
- MTTR = 8 hours
- MaxTTR = 12 hours
- System Retest times = 8 hours
- SEST = 16 hours
- Isolation times = 4 hours
- Order Ship Times (OST) = 24 hours.

ARES I SUPPORT SYSTEM ALTERNATIVES

Listed below were the support system alternative(s) identified for the Ares I system. SLSP is evaluating similar system support alternatives with regard to the proposed design, operation, and support concepts.

The following are the current support system alternatives identified by Ares I are:

- Baseline
  - Two Levels of Maintenance
  - Optimize access for R&R of Mission critical LRUs
  - KSC (GOP) and launch site contractor is responsible for maintenance support (R&R of LRUs and Standard Repairs)
  - Ares I (OEMs) provide maintenance support as requested by EGLS contractor repairs at launch site
  - EGLS Contractor Ship Removed LRUs back to Depot
  - Mission Critical LRUs will be Stored at launch site
  - No US Stored at launch site
- Alternative 1
  - Two Levels of Maintenance
  - Minimize Maintenance at the Pad
  - Optimize access for R&R of LRUs in VAB
  - KSC (GOP) and launch site contractor provide all maintenance support
  - EGLS Ship Removed LRU back to Depot
  - No Storage facility for LRUs
  - Provisioning is Just-in-Time
- Alternative 2
  - Two Levels of Maintenance
  - Optimize access for R&R at Pad
  - KSC (GOP) with Support contractor is responsible for maintenance
  - Ares I (OEMs) provide maintenance support at Launch site
  - Ship Removed LRU back to Depot
  - Mission Critical LRUs and spare US Stored at launch site
- Alternative 3
  - Three Level of Maintenance
  - Optimize design for VAB off-nominal Repair
  - Offline Capability provided for Ares I at launch site
  - KSC (GOP) and launch site contractor is responsible for maintenance

- Ares I project elements provide maintenance support
- Storage facility for PRUs and LRUs
- Offline stacking for FS element

Atlas and Ariane 5 Comparison Systems

The following areas of comparison were implemented for both Programs. These approaches are being considered for the Support Alternatives for Ares I.

- Ground Operations
  - There is no vehicle access at the pad for maintenance. The vehicle is rolled back to the BIL or BAF for Ariane V and VAB for Atlas V for maintenance.
  - Most of the Ariane V and Atlas V boxes/components and LRUs are all accessible in the integrated stacked configuration. Access doors are located 360° around the vehicle. Both vehicles require 24 hours to rollback, repair, and roll-out if problems are detected prior to tanking. After tanking, the requirement is 48 hours to allow time for safing and de-tanking.
  - Vehicle engine and engine parts repairs/ maintenance are off-nominal
- Sparing
  - No spares are kept on hand. Spares and repair parts are taken from the next vehicle in line being processed or by having a replacement part shipped via air from the production line to the launch site.
  - Ariane V stores at 2 set of batteries on hand since they cannot be easily transferred.
- Launch Operations
  - Minimum amount of seats during Launch countdown
  - Atlas has minimal fault detection and isolation system. They want to keep the system simple which also keeps the cost down.

ARIANE 5

The Ariane Launch System is composed of the Launcher (Launch Vehicle) and the Launch Complex. The Ariane 5 launch vehicle is composed of a liquid core stage using composite tanks for the liquid oxygen and liquid hydrogen propellant. Two strap-on solid boosters are attached to the cryogenic propellant core stage. The Ariane 5 has operational heritage from the Ariane 4 and can deliver 21 metric tons (46,200 lbs.) to low earth orbit and has a five meter diameter payload fairing. The Ariane 5 delivers the 21 metric ton Automated Transfer Vehicle (ATV) to orbit in February 2008 which will rendezvous with the ISS. This mission requires a re-ignition of the EPS (upper stage engine) to place the ATV in a circular orbit.

OPERATIONAL REQUIREMENTS

To meet the goals of designing to operations and cost the launch vehicle and the launch complex were required to support the following requirements:

i) Capable of supporting 8 launches per year
j) Capable of supporting a one month inter-launch period
k) Launch Pad capable of surviving a serious accident at lift off
l) Capable of supporting two launch campaigns in parallel (using two mobile launch tables)
m) Probability to postpone a launch (1 day): < 6.5×10^{-2} (with the exception of weather)
n) Probability to postpone launch (> 1day): < 1.8×10^{-2} (with the exception of weather)
o) Minimization of launcher preventive maintenance on the launch site
p) Minimization of operations during launch vehicle assembly, integration, and test (ship and shoot philosophy for core and upper stages)

All of the above requirements were identified and implemented based on the knowledge gained from the design and operations of the Ariane 1, 2, 3 and 4 vehicles. The following findings and observations are grouped according to Ground Operations, Logistics, and Flight / Engineering Support Operations during launch.

GROUND OPS

The Atmospheric Explorer (AE) implements a ship and shoot philosophy for the main cryogenic propellant and the ECS stages. Additionally, minimal testing is conducted at the launch site other than post shipment inspections. The solid rocket boosters are loaded with propellant and assembled offline at the launch facility.

The cryogenic propellant stage and the solid rocket boosters are mated and the European Communication Satellite (ECS) is mated to the cryogenic propellant stage in the launcher integration building and verification of the launcher is completed. The launcher is then rolled to the final assembly building where the payload is integrated to the launcher and verified. The vehicle is readied for launch and rolled to the Pad.

Items of interest relative to Ariane 5 ground processing:

- No access is available at the launch pad except at the ground level
- Capability of offline stacking of SRB segments removing the activity from the critical processing flow
- Only 1 launch pad with as many of the launch pad systems underground to avoid loss if catastrophic event occurs

- SRB's are recovered approximately once every 10 launches for engineering assessment and the Ariane 5 is certified for flight with and without SRB recovery parachutes
- Launch Vehicle Commit Criteria is automated in Ground Software (green light philosophy)
- Testing of the software with hardware in the loop is accomplished in France at a Systems Integration Laboratory. Non-flight software is used in all the hardware testing and checkout, even the integrated stack test. The flight software is loaded 4 hours prior to launch and all non-essential software is removed. The avionics boxes are operated for 40 hours during testing for "burn-in".

LOGISTICS

The approach taken was that no spares are kept on hand for contingency reasons. The sparing was accomplished by either borrowing parts from the next vehicle in line being processed or by having a replacement part shipped via air from the production line to the launch site in Kourou. AE has a contract with Air France to provide a shipment of the part and airline seats to critical engineering personnel within 24 hrs. from France to Kourou. The only exception was that two sets of batteries were kept on hand since they could not easily be transported via airlines. At a flight rate of at least four per year, the processing model allows for up to one spare vehicle at the launch site and for the production line to have a spare far enough in production to be flight ready. At flight rates less than four, spares may not be ready from the production line. Also, the production lines are sized to be able to sustain low disturbances in production due to sparing requirements.

In the event of a contingency, the decision to borrow parts versus have a new one shipped was based on how quickly the spare was needed. If time permitted a part was shipped from the production line to avoid interruption in the ground processing for launch phase. During the down time, several key activities would occur; 1) the required piece or equipment is removed, controlled, packed, and sent to Kourou by commercial airlines. The commercial flights to Kourou occur at once per day and the ordered spare would be on hand in 24 to 48 hours. 2) On the same day the suspect part is removed from the launch vehicle. If required, the suspect part would be sent via air to Europe for examination by the experts. 3) The team at the launch site in the meantime would investigate the failure, prepare contingency procedures and plan the recovery including approval authority and safety buy off. If required, design engineers were sent to Kourou within a days' notice to address the failure and help resolve any issues. To date Arian has performed many of these contingency operation and have done so with no loss of time due to sparing with this philosophy.

The **LRU selection criteria** were based on previous program experiences, new program experience, engineering judgment, and risk analysis. The development philosophy was to lower launch pad vulnerability to the Vehicle during on pad stay time as well as the launch pad infrastructure damage in the event of a failure. The Ariane 5 team has what they called the flat Pad concept. The vehicle has no pad access for vehicle mechanical access or contingency resolutions other than flight software updates. All contingencies can be addressed in the launch integration building (BIL) or the final assembly building (BAF). All contingencies requiring maintenance while at the launch pad require a vehicle rollback. Vehicle design aspects for LRU's included mechanical interchangeability, accessibility to equipment, and testability. To date, no contingencies have been identified that would require the vehicle to be shipped back to the manufacturer. Two major contingency operations were sited. The replacement of a Vulcan engine took approximately 10 days and experts came in from Europe to help with the repair. The replacement of an upper stage took approximately 2 weeks and included a new upper stage shipped overseas in 48 hours.

No **vehicle access** at the pad is possible so all maintenance is accomplished at the BIL or BAF. The avionics boxes located in the Vehicle Equipment Bay (VEB) are all accessible in the integrated stacked configuration and all boxes are within arm's reach from one of the many access doors. Eight (8) access doors are on the VEB in two levels and are located 360 degrees around the vehicle. Figure 5 shows the interior of the VEB and Figure 6 shows the access panels on the VEB. All electronics boxes in the VEB are considered LRU's and have a mean time to repair requirement of 6 hours. GSE was considered in the design and some maintenance items require special tools. NOTE: The Ariane team questioned the single door concept of the Ares I from a safety prospective.

Engine access is available in the BIL with very easy access to the throat plug. Two to three access doors are used and the capability for up to four people to perform maintenance on the engine from platforms is possible. Engine activities have taken up to 1 week. If the vehicle is de-stacked, the engine can be replaced at the launch complex. When asked if there has ever been a roll-back that Ariane had wished pad access was available, the answer was absolutely, but not possible. In 30+ Ariane-5 launches 4 rollbacks have been performed.

The key **availability requirements** for the Ariane Vehicle are:

- 0.065 probability to postpone launch (1 day – excludes weather)
    - 93.5 % launch probability
- 0.018 probability to postpone launch (> 1 day – excludes weather)
    - 98.2% launch probability

The time from roll-out to launch is 36 hours. Ariane has the philosophy to minimize the Vehicle preventative maintenance at the launch site as well as to minimize the operations during ground operations i.e. vehicle assembly, integration and test, and launch countdown. The Ariane rollback requirement is 24 hours, which includes preparation for rollback prior to tanking. Included in the rollback requirement is the detection, roll-back time, 6 hours for replacement, test, and rollout to the pad. In reality, an Ariane roll-back usually means 48 hours. In the event the tanking has been performed the requirement is 48 hours to include time for safing and de-tanking the vehicle.

For **Sustaining Engineering Support,** Vehicle design and production engineers in Europe work closely with the ground operations engineers prior to and during a launch campaign. During countdown, Ariane 5 real-time telemetry parameters are sent back to a single Ariane Space sustaining engineering facility in Evry, France. Twenty people support countdown ops from that location in case of an anomaly. No real-time decisions or commands are made or sent from France. European Space Agency (ESA)/Centre National d'Etudes Spatiales (CNES)/Ariane Space has an agreement to provide continuous pre-launch support by the development agency to provide independent technical support. A summary of the Ariane 5 Anomaly resolution process follows:

1. Once an anomaly has been detected during the countdown process a Quality team records the Non-compliance Report (NCR)
2. The Launch Vehicle ops team: 1) ensures the safety of the launch site and vehicle 2) investigates the anomaly to the extent possible via telemetry, 3) presents their findings and planning impacts to the lead Ariane 5 Technical Manager (Ariane Space Office of Defense Trade Controls (DTC)).
3. The Launch Vehicle technical authority (Sustaining Engineering community for the launch vehicle: 1) investigates/confirms the anomaly analysis, 2) coordinates all recovery/repair processes, 3) presents their findings and recovery/repair plans to the lead Ariane 5 Technical Manager (Ariane Space DTC).
4. The lead Ariane 5 Technical Manager (Ariane Space DTC): 1) verifies the problem and solution, 2) accepts the findings and recovery procedures, 3) presents the analysis and recovery plan to the CEO of Ariane Space for final approval.

ATLAS V

The Atlas V was evolved from the previous Atlas family of rockets. The Atlas V uses the Russian RD-180 engines on the Common Core Booster for the first stage and can use up to five Aero jet strap-on solid boosters when needed. The Common Core Booster uses liquid oxygen and RP-1 (kerosene) rocket fuel propellants. The upper stage is a liquid oxygen – liquid hydrogen powered Centaur. The Atlas V is 58.3 m (191.2 ft.) tall and accommodates a 5 meter diameter fairing. The Atlas V can deliver to just over 20 metric tons (44,400 lbm) to LEO.

The Atlas Program developed operational requirements that were continuously validated and driven back into the design to validate the availability assumptions defined in the specification tree. The process used to validate the design specifications was initiated as soon as schematics were available for the Atlas systems and were allowed to change until Critical Design Review (CDR). The ground operations representatives from previous Atlas programs worked directly (embedded directly with the design teams) with the design engineers early in the program prior to PDR and up until the CDR Timeframe. The ground operations representatives physically relocated to the design / engineering sites on 6 month rotations. After CDR, the design engineers became embedded in the operational teams to support development of the ground processing procedures and physically relocated to the ground operations / launch sites on 6 month rotations. Additionally the launch operators would operate the Atlas V System Integration Lab to become familiar with the hardware and characteristics of the Launch Vehicle.

A processing flow timeline was used to validate assumptions and the defined steps and also to ensure the design could meet the defined activities. The integrated design/operations team documented the operational requirements (similar to the Operations and Maintenance Requirements and Specifications Document (OMRSD) requirements on shuttle) derived from the timeline and worked directly with the designers to ensure the design supported the defined activities. This process has continued thru the life of the Program with the processing continually evaluated and appropriate design changes made.

Other key operational metrics included managing a head count level at the launch facility to reduce recurring cost. This was accomplished through the timeline process defined above where actual headcount was applied to the defined task. Additionally, there was a drive to keep the design simple. An Atlas V launch requires about 200 people which also include engineering support at the design center.

The overall design philosophy of the Atlas V was driven by the availability requirement and the idea of a simplistic design. The Atlas representatives emphasized that the process defined above was successful because there was a Chief Engineer in the Program that acted as the operability “800 lb. Gorilla” and continually emphasized and championed the operability of the vehicle through the availability and simplicity philosophy. There were also champions for commonality and the common core booster has scarring to add the strap-on solids even if the solid boosters are not used. This makes every common core booster the same no matter the flight configuration. Batteries are as common as possible.

The Atlas V team also implemented the concept of performing as little testing at the manufacture and maximizing the testing at the launch facility. This was implemented based on the idea that they did not want to duplicate testing at the two sites and realized they needed the capability at the launch site for the first few flights. Therefore the initial concept was to implement the testing at the launch facility and move it back to the manufacturer later. What they found was that there were little problems found during testing at the manufacturer and the majority of failures were transducer related and may be caused during shipment. The Atlas V program continues to perform a horizontal integrated test of the electrical components at the launch facility today and minimizes testing at the manufacturer. After the horizontal test is complete, the vehicle is stacked and other tests are performed.

The designers were asked if they would implement the clean pad concept for future vehicle designs based on their knowledge today. The Atlas team made it clear that there are benefits of the clean pad to meet high flight rates but since the Atlas V is not flying at the expected rate the full benefit of the clean pad concept may not be realized. However, they have found few situations where access to the launch vehicle at the pad would have resulted in quicker resolution of an anomaly than rolling back to the assembly building. The key driver for resolving any issue found during the processing flow is the root cause analysis. They have found that the majority of anomalies require a root cause analysis before the anomaly can be closed for flight. Therefore if you are going to attempt to have any type of maintenance activity on the pad there must be a root cause analysis process that supports the required turn-around time.

OPERATIONAL REQUIREMENTS

Avionics are powered up for the first time at the launch site in the integrated stack test. Twenty-four hour rollback, repair, and roll-out if problem detected prior to tanking. After tanking, the requirement is 48 hours. (Similar to Ariane 5). The engine and engine parts can be changed near the launch site but this is not a nominal operation. Avionics boxes can be accessed without de-stacking but some require going inside the vehicle. Atlas uses diving board approach for getting inside vehicle. Operational access is different than developmental access. No inventory of spares at launch site (similar to Ariane 5). The next vehicle in the production line can provide a spare if needed. Or a part from the production site can be shipped or flown in, just-in-time. Atlas has minimal fault detection and isolation system. They want to keep the system simple which also keeps the cost down. Each sensor had to "buy" its way onto the vehicle. The chief engineer had to understand and approve each sensor added to vehicle. And he followed up to see if the data was used after the flight. Atlas 5 does "maintain clean" throughout process, i.e., no checks or samples at the pad. Atlas warns of provisioning too many requirements. Requirement reduction and simplification is recommended.

MAINTENANCE CONCEPT/MAINTENANCE POLICY

Two Levels of Maintenance

- **Organizational – launch Site**: All contingencies requiring maintenance while at the launch pad require a vehicle rollback to the VAB. Most of the components are accessible while in the VAB.
- **Depot**: All LRUs/Components needing repairs are shipped back to the vender.

There was no pre-operational provisioning of **spares/repair parts**. Spares and repair parts are taken from the next vehicle in line at the launch site. The reason for this philosophy is that the time required to obtain a spare is less than the time required to perform a root cause analysis.

There is no **Vehicle access** at the pad for maintenance. The vehicle is roll back to the VAB for maintenance. Most of the Atlas 5 boxes/components and LRUs are all accessible in the integrated stacked configuration. Most boxes can be reach by adding platforms, which is attached to the ground support Equipment not the vehicle. The vehicle has a number of access doors located 360 degrees around the vehicle.

Appendix F

LSAR LCN Dictionary/Style Guide Summary

This document establishes the uniform style, format, encoding structures, definitions, and maintenance concepts to be followed by all Projects under the Space Launch System (SLS) Program in the development of project peculiar Logistics Support Analysis Record (LSAR) databases. In order to establish commonality of Logistics Support Analysis (LSA) data and implement a uniform LSA database format, the Space Launch System (SLS) Program has adopted MIL-STD-1388-2B – DoD Requirements for a Logistics Support Analysis Record, as the structural backbone for the Oracle database formats. This style guide provides clarification for items described in GEIA STD/HB 0007.

In order to generate a collaborative database environment and establish commonality within the encoding structures required within such database environments, the Space Launch System (SLS) Program is imposing this style guide upon all Projects under the Space Launch System (SLS) Program to support the development of all LSAR databases. All Projects developing LSAR databases under the Space Launch System (SLS) Program are required to utilize the Space Launch System (SLS) LSAR Style Guide in conjunction with MIL- STD-1388-2B – DoD Requirements for a Logistics Support Analysis Record to develop their databases.

PHYSICAL LSAR NUMBERING STRUCTURE

The physical breakdown structure within the Space Launch System (SLS) Program for Flight Hardware (reference Figure 1) and ground support equipment (GSE) (reference Figure 2) includes assignments for:

- End Item Acronym Code (EIAC), located in the top left box corner
- Logistics Control Number (LCN), located on the bottom left box corner
- Usable On Code (UOC), located on the top right box corner
- Alternate Logistic Control Number Code (ALC), located on the bottom right box corner
- Item under analysis nomenclature, located in the center of each box

The physical breakdown structure will be applied to all projects under the Space Launch System (SLS) Program. The combination of codes will uniquely identify the vehicle subassembly under analysis in each box and is the underlying frame work within the LSAR against which logistic data is documented.

Figure 1 illustrates the actual physical flight hardware breakdown structure for projects currently under contract and assumed physical breakdown examples for future projects. It also illustrates the Space Launch System (SLS) flight hardware breakdown structure will expand to include future projects under the Space Launch System (SLS) Program.

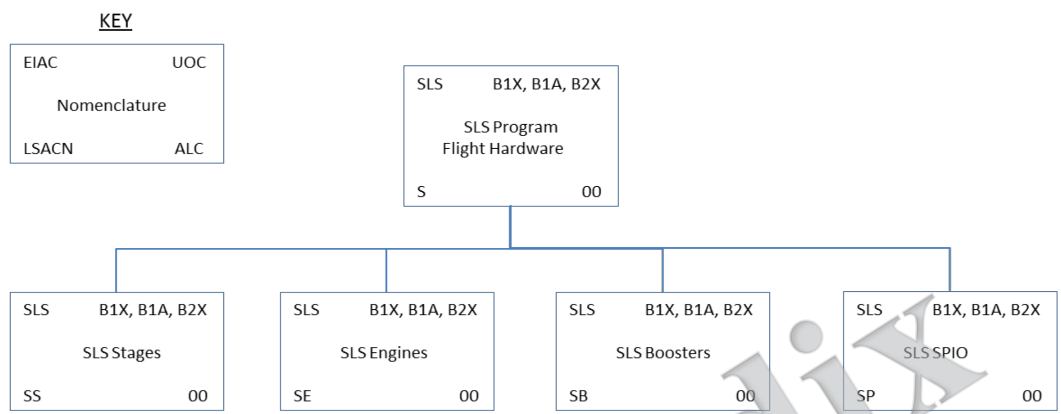
SLS Flight Hardware LCN Structure will be 1123222221.

Figure 2 illustrates the actual physical GSE breakdown structure for projects currently under contract and assumed physical breakdown examples for future projects. It also illustrates the

Space Launch System (SLS) GSE hardware breakdown structure will expand to include future projects under the Space Launch System (SLS) Program.

Figure 1. Space Launch System (Sls) Flight Hardware Breakdown Structure

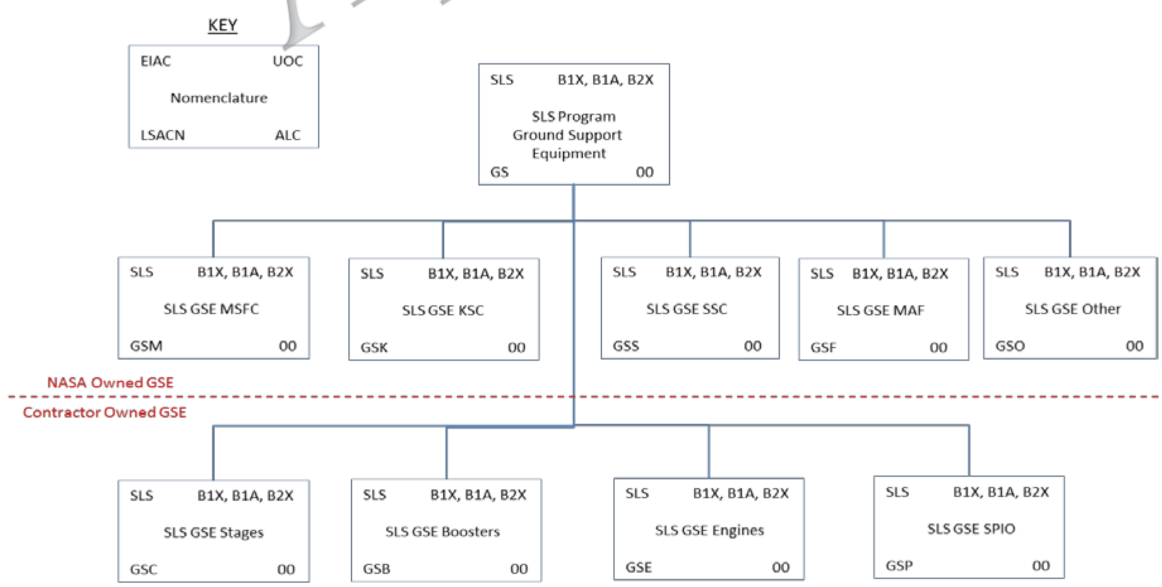
SLS Program Flight Hardware LSACN Structure



Assign lower indentures using Classical Method adhering to strict parent-child relationship by having a consistent number of digits for each indenture level. Such as 1221222222, 123222222or 1211322222. Each element to decide appropriate number of digits needed to adequately develop the product structure.

Figure 2. Space Launch System (SLS) GSE Hardware Breakdown Structure

SLS Program Ground Support Equipment LSACN Structure



Assign individual items of GSE an LCN sequentially starting with xxx0001. For example the first GSE documented by MSFC will have an LCN of GSM0001, next will be GSM0002, etc. Items of GSE that require breakdown for maintenance or support will be further documented using the Classical Method.

LSAR TABLE APPLICATION TO INDIVIDUAL PROJECTS

Individual projects under the Space Launch System (SLS) Program will complete the tables within the MIL-STD-1388-2B LSAR database structure in accordance with the applicable project's DD 1949-3 LSAR Data Requirements Form submittal; therefore, the level of completion of the LSAR Data Tables will differ from project to project. As a result, many data entries will be left blank which may limit the types and completeness of the data reports that will be available as an output of the database.

LOGISTICS SUPPORT ANALYSIS RECORD RELATIONAL TABLES

This section establishes the format of the Logistic Support Analysis (LSA) Record (LSAR) relational tables. The data content and specific formats for each table are provided in the appendices. This section and the appendices together define all the relational tables that comprise an LSAR database.

In a relational database system, information is organized in the form of tables. Within each table, certain data may be defined as Foreign (F), a Mandatory (M), or Key (K) data. These data keys comprise a unique set of identifiers for each row of information in the data table. Relational tables are structured according to the data associations which dictate the table configuration. Although each relational table is independent and equal, data integrity rules will dictate that a row of information be established in a table from which foreign keys originate, prior to the establishment of the lower-tiered data table. The interrelationships and data hierarchy between tables are only established through common data element keys and data values. The tables listed in the appendices comprise the total LSAR relational database.

Figure 3 depicts the functional relationship of all the data tables within the LSAR database. Refer to the appropriate appendix for a brief description of the contents of each of the LSAR tables contained within the LSAR database and any tailored encoding that has been established for each table.

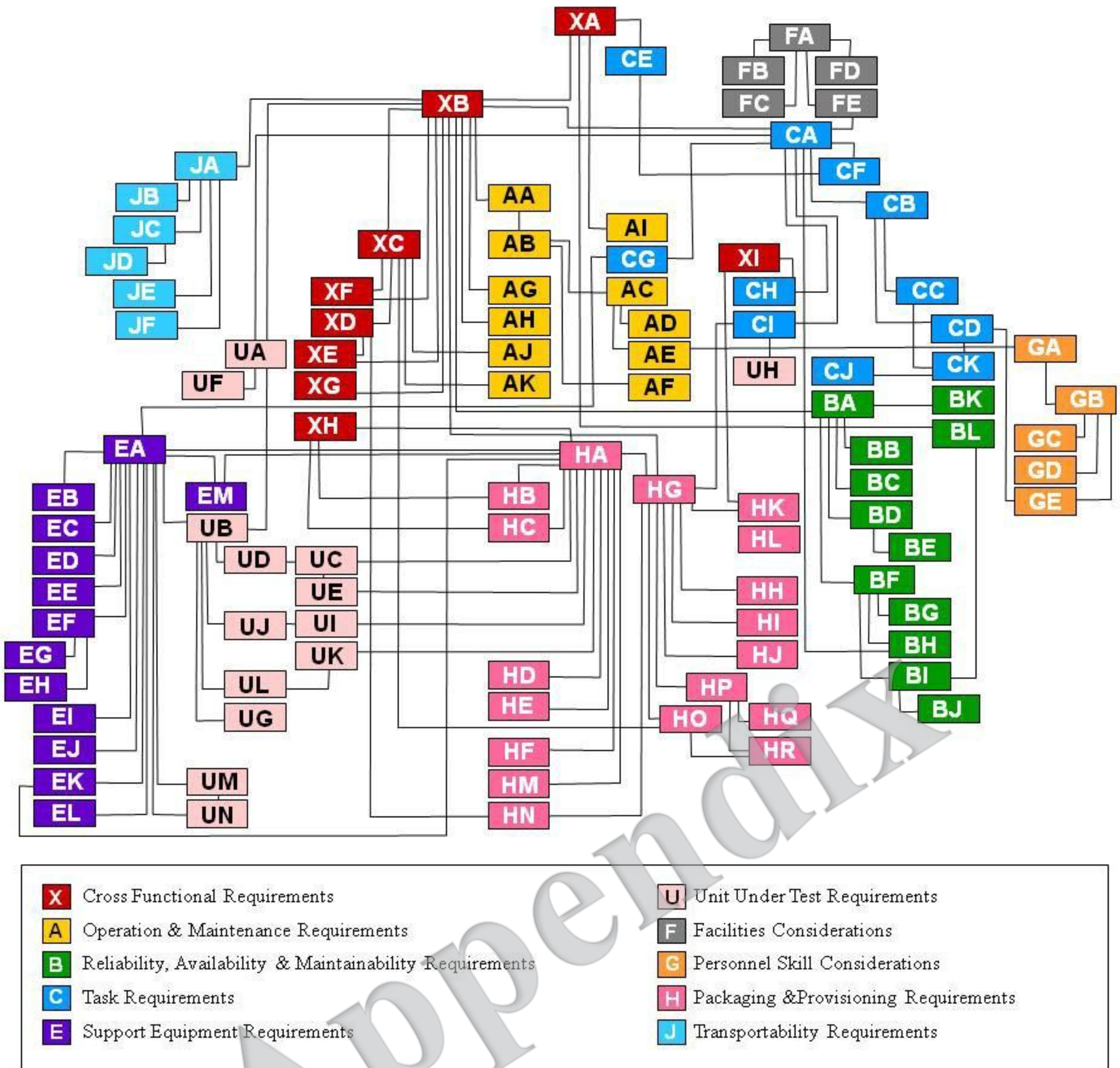


FIGURE 3. LSAR TABLE RELATIONSHIPS

The tables of a LSAR database can be grouped into 4 main categories.

- Cross functional data (X Table)
- Mission and support system definition (A, B, G Tables)
- Functional requirements identification data (A, B, C, G Tables)
- Logistic support resource requirements (C, E, U, F, G, H, J Tables)

The key data elements of the X tables form a common thread that serves to tie together the various logistic considerations documented in the LSAR database. X table data must be established prior to populating other tables. Facilities (F tables) and Personnel Skills (G tables) are the only exception.

Establishment of an EIAC and LCN structure is usually the first step in establishing a LSAR database. The XA table establishes the key field of EIAC and contains the LCN structure. LCNs can now be assigned in the XB table. Following data entry into the XA and XB tables, Remaining data tables can be populated. Prerequisite data must be entered prior to population of dependent tables.

SLS LSAR Data Requirements

A detailed analysis of the data required to identify, acquire and manage support for the SLS Program resulted in a very tailored number of data elements that are necessary to assure operability while at the same time minimizing cost of ownership. Combining the tailoring results in Attachment 1 with the applicability and interpretation instructions in Attachment 2 provides a complete description of LSAR requirements for SLS.

Attachment 1 – Data Tables

Attachment 1 contains a standard DD form 1949-3 LSAR Data Selection which has been annotated with the data elements that have been identified as applicable for SLS. These individual data elements that have been noted with “X” in the right hand selection column.

Attachment 2 – Data Element Instructions

The instructions for applicability and interpretation of each data element are provided in Attachment 2 which indicates how and when data elements should be generated to record the results of expected analyses.

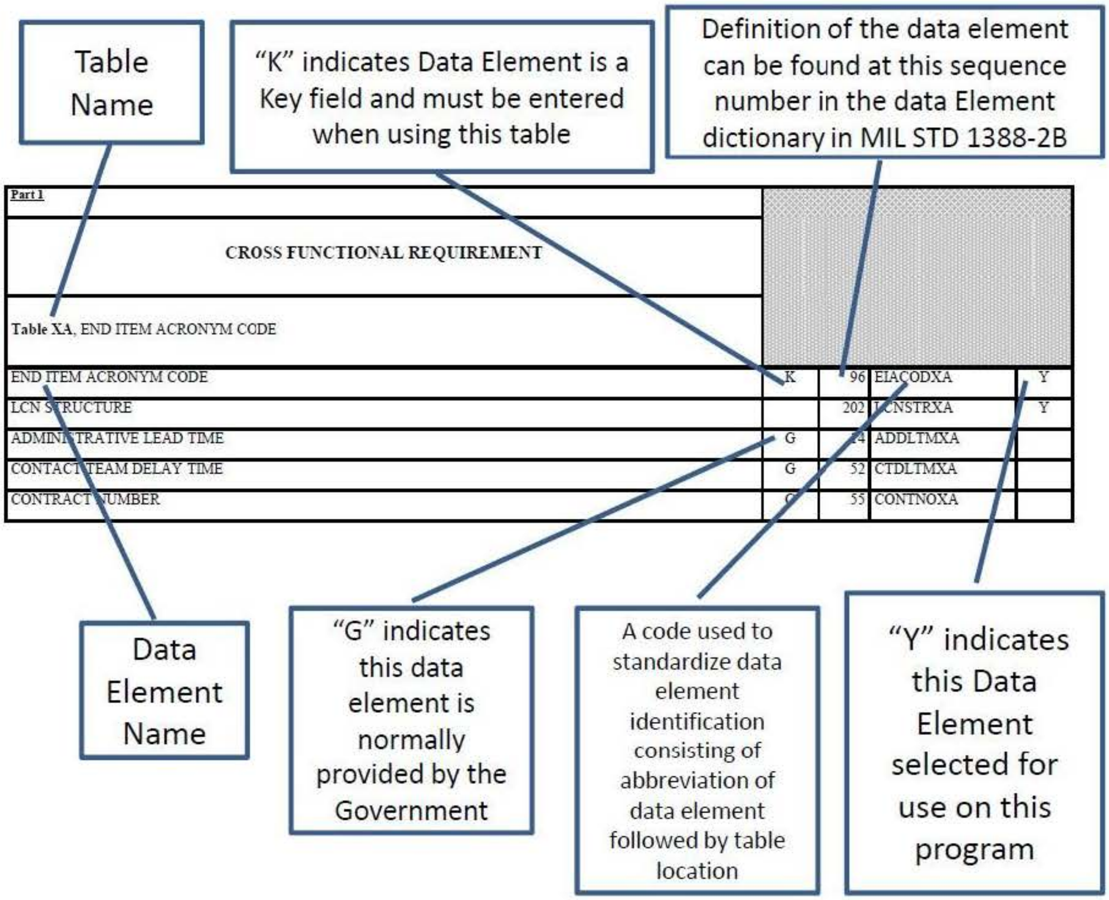
Attachment 3 – Maintenance Task Analysis Writing Guide

Unlike the majority of the tables in the LSAR, the maintenance task narratives are not generated from an existing encoding structure but rather developed as free-style narratives by Logistics Engineers while writing maintenance tasks. The narrative descriptions must be consistent, clear, comprehensible, unambiguous, and free of jargon. The narrative descriptions should ideally appear to have been written by the same author in a factual and neutral writing style.

In order to achieve a factual and neutral writing style, a Maintenance Task Narrative Writing Style Guide has been adopted by the SLS Program as guideline for development of narrative data within all projects under the SLS Program. Refer to Attachment 3 for the Maintenance Task Narrative Writing Style Guide.

The LSAR consists of pre-formatted relational data tables. Each table has a specific use in recording the information about acquisition, operation and support of a system. The data table guide identifies all the data elements that have been selected for use by SLS Elements and other program organizations in recording acquisition, operation and support requirements for the Space Launch System Program. This guide must be used in conjunction with the data element guide to understand how and why data is being recorded.

ATTACHMENT 1 – DATA TABLES



ATTACHMENT 2 - DATA ELEMENTS

Introduction

The data elements recorded in the LSAR are what actually document the results of the LSA process and associated engineering analyses. A clear and concise understanding of the data elements of the LSAR is mandatory to document useful information. All the data elements that can be recorded in the LSAR are described in the Data Element Dictionary which provides both a generic definition and indication of the Tables where the data is recorded.

Description of the Data Elements

The Data Element Description matrixes of this Section provide information on the interpretation of data elements to determine whether or not the data should be used on a specific program.

Data Selection: The Data Selection matrix indicates if the data element should be used on a specific program.

Data Selection	
	Mandatory
	Normally
	Conditional
X	Rarely

Mandatory - The data element is mandatory to create minimum LSAR content and should always be used. This data element must be used.

Normally - The data element is normally used on the typical LSAR. There may be some issues that indicate whether or not the data element is used for specific items.

Conditional - The data element should only be used when justified based on the specifics of a project. Many data elements are linked to others and this specific data element should be used when a stated criteria exists. The criteria are normally stated in the Explanation block of the page.

Rarely - Most data elements that have been marked “Rarely” will not be used unless there is a specific requirement that has been identified by the SLS Element or the SLS ILS Team. Otherwise, the data element is not used. The data element should not be used unless there is a unique project requirement which justifies the cost of recording.

Applies To: Each data element must only be recorded when the information applies to a specific instance. Care must be given to only record data for a specific instance that makes sense when using the data in the future.

Applies To:	
X	System

	Subsystem
	Repairable Item LRU/MSI
	Part
	SE/TE
	Project
	Project Neutral

System - the data element records data specific to a system and should only be used at that level. For example, operational availability applies only to system level, so that data should only be recorded for the system.
Subsystem - the data element records data specific to a subsystem
Repairable Item LRU/MSI - the data element records data specific to an LSA Candidate or similar item being documented.
Part - the data element records data specific to a part. This data may include information required for provisioning.
SE/TE - the data element records data specific to an item of support equipment, test equipment, training equipment, or tool.

Project - the data element records data specific to a project. Modeling data is an example of Project level data.
Project Neutral - the data element records data that is non-specific to any of the above and is linked to its applicability through key data fields on one or more Tables.

Source: LSAR data originates from many sources. The two most common sources are design documentation such as specifications, engineering analyses such as reliability or maintainability, engineering drawings and manufacturer's data sheets; and logistics data produced by analyses and modeling. Other Sources include program documentation or other organizations such as DLIS.

Source	
	Design Data
	Logistics Data
	Other Source

Design Data – the data normally comes from engineering analyses such as reliability or maintainability or related design documentation

Logistics Data – the data normally comes from logistics related analyses or documentation

Other Source – the data comes from program documentation or other recognized appropriate sources.

Applicable to: Data has various specific and generic applicability depending on the information that is being recorded. It is important to use the data appropriately to assure the proper context is presented.

Applicable To:	
	All
X	Flight Hardware
	Ground Support Equipment
	Other

All – The information be recorded applies to all situation and locations equally.

Flight Hardware – The information being recorded is only applicable to Flight Hardware.

Ground Support Equipment – The information does not apply to Flight Hardware, but has use ashore. This may include Ground Support Equipment installations of a system or it may be related to deport repair facilities and workshops.

Other – Occasionally, information may not be specific about operating and supporting a system, but may be useful for transportation of the system or it may be added information about an item of support equipment.

Data Use: Any data entered in the LSAR must have a purpose and a beneficial use to justify its generation. Normally, data can be traced to some output from the LSAR that will be used to support the system being documented. Some data has only one use while others have multiple applications.

Data Use	
	Maintenance
	Spares
	Parts
	SE/TE/Tools
	Personnel
	Training
	Facilities
	Transportability
	Modeling Data
X	Mgmt Info

Maintenance Requirements – The data will be used to compute or quantify maintenance requirements for the system.

Spares Requirements – The data describes specific information pertaining to spares needed to support the system. The data may be used to compute requirements or document how the spare is used in the maintenance process.

Parts Requirements – The data is used for provisioning the item, or link it to a maintenance process.

Support Equipment/Test Equipment/Training Equipment/Tools Use and Requirements – The data describes the characteristics, acquisition, use and support requirements for an item of equipment that is not an integral part of the system but needed to operate, support or maintain the system.

Personnel Requirements – The data is used to identify and quantify requirements for personnel that have been identified as needed to operate or support the system.

Training Requirements – The data will be used to develop a training needs analysis and then feed information into development of training course materials for operation or support of the system being documented.

Facilities Requirements – The data describes how facilities will be used to operate and support the system. This may include changes or modifications to a facility for installation of support equipment.

Transportability – Transport of the system, separated transportable subsystems and support materials is documented with data elements normally located on the HF Table (spares and parts) or the J Tables (system and separated subsystem).

Modeling Data – The LSAR is used to store data that is used as either constants or variables in various modeling tools. Storing the data in the LSAR allows consistency of modeling over many years through use of the same input data.

Management Information – There are many statistics and informational issues that can be recorded in the LSAR. This information is normally not used to calculate support requirements, but can be beneficial in continuity of the program.

Explanation: Contains specific issues and other information pertaining to the data element selection or use.

ATTACHMENT 3 MAINTENANCE TASK NARRATIVE WRITING STYLE GUIDE

1.0 GENERAL

The maintenance task narratives are not generated from an existing encoding structure but rather developed as free-style narratives by Logistics Engineers while writing maintenance tasks. The narrative descriptions must be consistent, clear, comprehensible, unambiguous, and free of jargon. The narrative descriptions should ideally appear to have been written by the same author in a factual and neutral writing style.

In order to achieve a factual and neutral writing style, this Appendix (Maintenance Task Narrative Writing Style Guide) has been adopted as the sole guideline for development of narrative data within all projects under the Space Launch System (SLS) Program.

Ground Rules

Authors should provide procedural information for their own tasks only and not alter another author's tasks. Use narrative text to assist in understanding procedural data.

Technical information will contain all information necessary for a user to perform a task or to understand a description. In all cases, the narrative descriptions will contain enough information to allow the user to perform the documented maintenance without error or loss of time due to insufficient information.

The narrative descriptions will provide all technical information necessary to perform a task. It should not contain extraneous material. Helpful, but not required, information should be included as a note.

2.0 COMPREHENSIBILITY

Writing should be factual, specific, concise and simply illustrated so as to be understandable to a user who has the required knowledge, training and experience. To ensure maintenance task narratives can be easily understood, follow the principles when authoring technical information:

Essential Information

Essential information in narrative text will:

Describe the system and its components, identifying special or outstanding features.

Describe which functions are performed, including inputs, outputs, interfacing with other systems and so on; emphasize end results.

Describe how functions are performed, including associated principles of operation.

Describe at what point the function is performed in an overall process.

Describe the location of the component or part.

Use of Definite and Indefinite Articles

Eliminate unnecessary articles (a, an, the).

Incorrect: Remove the component from the mount.

Correct: Remove component from mount.

Task Structure

Begin procedural sentences with transitive verbs (action verbs).

Use the imperative mood to give an instruction, order or command. Do

not use the second-person pronoun "you."

Task Clarity

Confusion could result as to which item the text is referring; therefore, provide descriptive details. Example: Washer types must be described to enhance clarity. Because the quantity of components does not change, the quantity is called out only on the first component in the group.

Incorrect: Install three screws and washers. **Correct:** Install

three screws and flat washers. **Incorrect:** Remove three screws,

washers and washers.

Correct: Remove three screws, lock washers and flat washers.

When confusion could result regarding the quantity of components being removed or installed, provide descriptive details. In the following example, the quantity of components being removed is different; therefore, all component quantities should be called out.

Incorrect: Remove three screws, lock washers and flat washers.

Correct: Remove three screws, three lock washers and six flat washers

Begin sentences with "when" clauses to indicate time.

Example: "When power supply voltage stabilizes..."

Task Brevity

Write as simply as possible. Limit paragraphs to a single idea. Limit sentences to a single thought; use no compound or complex sentences. Use words that are short and familiar to the target audience (for example, use "near" rather than "adjacent").

Sentence length should not exceed an average of 20 words. While the average paragraph will not exceed six sentences, the desired paragraph length is three to four sentences.

Use as few words as possible to make the point.

Incorrect: Visually inspect engine oil filter cartridges for signs of oil leakage.

Correct: Inspect engine oil filter cartridges for leaks.

Keep descriptive text consistent in terminology, style and format throughout the narrative descriptions.

Appendix G

LAUNCH AVAILABILITY AND SYSTEM READINESS ANALYSIS OVERVIEW

Launch Availability and Maintenance Downtime Analysis

Level I sub-allocated to SLS an LA TPM that is intended to ensure a high likelihood of launching the SLS vehicles within a specified timeframe. Launch Availability is a function of both launch reliability (probability of launching on a given attempt) and MDT (ability to repair the launch vehicle in time to achieve additional launch attempts in the given timeframe). The LA TPM is defined in the SLS Program (SLSP) Technical Metrics Plan (TMP) Revision A as the probability of the SLS successfully launching within 30 calendar days of the start of countdown for the initial launch attempt, exclusive of weather. The threshold value for the LA TPM is 96.7%.

A secondary component of the LA analysis is the MDT analysis. The SLSP TMP Revision A describes the MDT as follows; The MDT TPM assesses the degree to which the SLS is repairable to support additional launch attempts in the event of a launch scrub due to a hardware/software failure. MDT is inclusive of all the time from the point a launch scrub is declared until the vehicle is ready to restart countdown for the following launch attempt, exclusive of weather delays. The threshold for MDT is 85% of all failures can be repaired in a maximum of 20 calendar days.

The LA analysis is focused on the timeframe from the start-of-countdown through launch and the probability of launching the vehicle within 30 calendar days. Launch Availability is independent of anything that may occur before the start-of-countdown. The MDT analysis is concerned with single point failures and what percentage of failures can be repaired within 20 calendar days. Scenarios where multiple failures occur, a second off-nominal failure occurring while working a previous off-nominal event, are not considered as part of the MDT because the TPM is focused on single point failures. The impact of multiple off-nominal failures is captured within the LA analysis.

System Readiness Analysis

The SLS SR TPM covers all the operations from the start of manufacturing through launch and encompasses two distinct operational phases; 1) Manufacturing – the phase in which various elements are manufactured and delivered to the Vehicle Assembly Building (VAB) at a successful rate to not delay the start of stacking, 2) Ground Operations – the phase in which the operations at the VAB and at the Launch Pad are performed to meet a specific launch date. For

EM-1 (Block 1), the interval that the SR analysis is measured against is 160 calendar days. The 160 calendar days is derived from the GSDO facility Operational Readiness Date (ORD), June 19, 2017, and the need to be ready to launch the SLS vehicle by December 13, 2017. See Figure 4.5.3-1.

The SR TPM is defined in the SLSP TMP Revision A as the likelihood that the SLS vehicle can be processed in time to be ready for the start of countdown in order to meet a launch date set at mission manifest approval. The SR TPM encompasses all of the operations from the start of manufacturing through start-of-countdown and includes transportation, element checkout, vehicle integration, vehicle testing, closeout, pad operations, and off-nominal events.

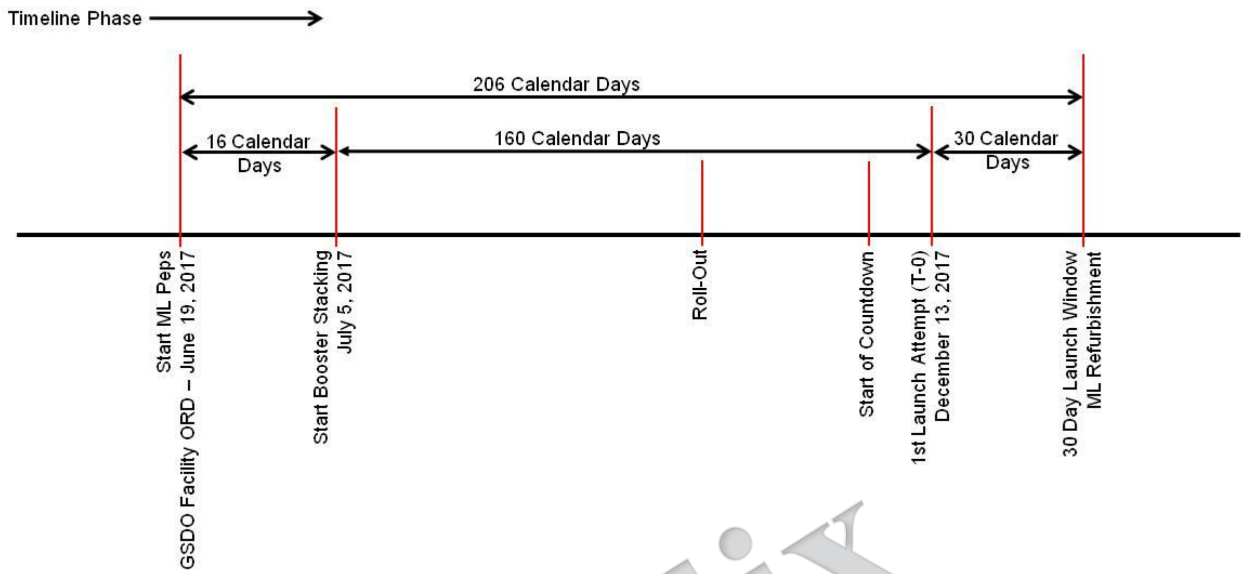


Figure 0-1 Launch-to-Launch Interval

Element Delivery Analysis

The Block 1 Element Delivery analysis is used to determine the delivery milestones for the element hardware and software to support a December 2017 launch. The element delivery milestones are based on an integrated timeline output from the cross-program Ground Operations Planning Database (GOPDb). This database provides the vehicle integration processes and sequencing performed at KSC that are imported into the SLS Program Manufacturing and Assembly Operational Sequence Report. The approach for determining when elements need to arrive at the VAB for processing is very similar to the analysis approach used for the SR assessment. The approach, models the nominal and off-nominal operations that occur at KSC

(VAB and Launch Pad) to determine when the key elements need to be delivered to the VAB for vehicle integration. The primary focus of this analysis is ensuring that a 98% probability of SLS being ready for launch December 13, 2017.

It is not the intent of this analysis to validate or verify the SLS Element or Multi-Purpose Crew Vehicle (MPCV) delivery dates currently captured in the Integrated Master Schedule or the requirements of the System Specification, but to document the predicted vehicle integration time based on the VAB and Launch Pad operations tasks and point out potential issues.

Vehicle Stack and Pad Stay Time Analysis

The Vehicle Stack and Pad Stay Time Analysis looks at the current design of the Block 1 configuration to see if the Vehicle Stack Time or Pad Stay Time requirements are being violated based on the operations for processing the vehicle. The vehicle stack time is measured from the time that the Interim Cryogenic Propulsion Stage (ICPS) is stacked on the vehicle and concludes when the vehicle has been launched. The Vehicle Stack Time requirement states that the vehicle shall be capable of remaining in a stacked configuration for a minimum of 140 calendar days without being de-stacked.

The pad stay time measures the cumulative amount of time that the vehicle is exposed to the Launch Pad environments. If the vehicle has to be rolled back from the Launch Pad to the VAB for repairs, the actual time the vehicle is in the VAB is not considered part of the pad stay time. The Pad Stay Time requirement states that the vehicle shall be capable of being exposed to the launch pad environments for a minimum of 120 calendar days.

Battery Life Analysis

The Battery Life Analysis looks at the current design of the Block 1 configuration and the operations that are performed from the start of Integrated Vehicle Testing (IVT) through launch to see if the life of any of the Element batteries onboard the vehicle are violated based on when they are planned to be installed in the vehicle.

This analysis looks at three possible times that the Element batteries may be installed within the vehicle.

4) Prior to the start of IVT.

5) Prior to roll-out for the Wet Dress Rehearsal (WDR).

6) Prior to the Flight Termination System (FTS) Test and final rollout before the first launch attempt.

Logistic Delay Analysis

The Logistic Delay Analysis looks at the impact of four types of logistic delays on the Block 1 configuration LA. There are four logistics delays that are considered as part of this analysis and they are Procedure Delays, Ground Support Equipment (GSE) Delays, Personnel Delays, and Spare Delays. The Procedure Delays assume that when an Element failure occurs that there will be some type of delay due to developing the required procedures. The assumptions are that the Element will develop actual procedures for Line Replaceable Units (LRUs) after the failure mode has been identified but all other items that may fail will not have procedures developed in advance.

The Personnel and GSE delays assume that the personnel and GSE required to performed an off-nominal task are not available at the Kennedy Space Center (KSC) and that the personnel and/or GSE will need to be shipped to KSC. The delay impact will be based upon how readily available the required personnel and/or GSE is. The final logistic delay is a Spare Delay. The current SLS baseline is that there will be no spares located at KSC and if a spare is needed it will be sent from the Element manufacturing site. This philosophy can have a significant impact from the stand point of Core Stage since for Block 1 the next Core Stage will not be in production until after the first flight in 2017 this means that there could be a significant delay because there may be no spares available. The other Elements are based on heritage hardware and therefore spare components may exist resulting in a shorter delay.

Analysis Tool

The analysis tool used to perform the analysis documented within this report is the SLS Discrete Event Simulation (DES) Model, which is a DES tool that was developed using ExtendSim™, a commercially available software package developed by Imagine That Inc. The SLS DES Model simulates the processing flow of the SLS launch vehicle from the beginning of manufacturing through launch. Currently the model encompasses work performed at the Michoud Assembly Facility (MAF), Stennis Space Center (SCC), VAB, and Launch Pad. In the future, the model can be expanded to simulate other facilities at the KSC, Alliant Techsystems Incorporated - Thiokol (ATK), and other sites as required. Regardless of the facility, each process simulated takes into consideration whether the process is performed in series or parallel, the number of personnel and GSE required, the shift schedule being assumed, whether any unplanned event may occur, and what is required to get back on the nominal path. The SLS DES Model is used to support trade studies to determine how changes in the design or processes affect the SLS SR and LA. The results of the analyses are flowed back to the designers so that changes can be made to the design or the ground processing to resolve potential issues.

Appendix H
To Be Resolved

Table G2-1 lists the specific To Be Resolved (TBR) issues in the document that are not yet known. The TBR is inserted as a placeholder wherever the required data is needed and is formatted in bold type within carets. The TBR issue is sequentially numbered as applicable (i.e., **<TBR-001>** is the first unresolved issue assigned in the document). As each TBR is resolved, the updated text is inserted in each place that the TBR appears in the document and the issue is removed from this table. As new TBR issues are assigned, they will be added to this list in accordance with the above described numbering scheme. Original TBRs will not be renumbered.

Table G2-1. To Be Resolved Issues

TBR	Section	Description
TBR-001	2.1	HSIR is not baseline matures.
TBR-002	2.1	Certificate of Flight Readiness is not baselined
TBR-003	2.1	Fault Management Report is not baselined
TBR-004	2.1	SE Spec-030 are not baselined
TBR-005	2.1	SE Spec-030 are not baselined
TBR-006	2.1	SE Spec-030 are not baselined
TBR-007	2.1	SE Spec-030 are not baselined
TBR-008	2.1	VOMR is not baselined
TBR-009	4.5.8.3	ISPE batteries service life still being determined and may change as the program matures