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## 1. Introduction

### 1.1 Purpose

This guidebook is intended to provide general guidance and information on Life Cycle Logistics Support<sup>1</sup> that will be useful to NASA Programs, Projects, and logistics community and should be used as a companion for implementing NPD 7500.1, *Program and Project Life Cycle Logistics Support Policy*.

It provides a description of Life Cycle Logistics Support as it should be applied throughout NASA. A goal of the guidebook is to increase awareness and consistency across the Agency logistics community and advance the practice of Life Cycle Logistics Support. This guidebook provides perspectives relevant to NASA and data particular to NASA.

### 1.2 Scope

The Life Cycle Logistics Support (LCLS) activities and functions described in this guidebook apply to NASA Programs and Projects. This applicability includes both flight hardware systems, non-flight systems such as launch facilities and communication facilities, and ground support systems. As defined in NPD 7500.1 (Program and Project Life Cycle Logistics Support Requirements), the responsibility for developing and implementing the LCLS approach for each program or project resides with the Program Manager, Project Manager, or their designated LCLS Manager.<sup>2</sup> Execution of some or all of these activities and functions may be delegated to contractor organizations when the Program/Project Manager and/or the LCLS Manager determine that doing so will result in the most efficient solution for the Government.

These activities and functions apply to new Contractor Furnished Equipment (CFE) hardware projects or Government Furnished Equipment (GFE) or Government Developed Equipment produced by NASA or other government organizations and contractors for NASA. The overall effort begins at the Requirements Development Phase and progresses through the design phase consisting of the Preliminary Design Phase (through PDR); the Critical Design Phase (through CDR); and the Pre-Delivery Phase (which culminates with hardware DD250), the Operations and Sustainment Phase, and, finally, the Closeout Phase.

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<sup>1</sup> As used in this document and in NPD 7500.1, the term "Life Cycle Logistics Support" is synonymous with the term "Integrated Logistics Support", and the term "Product Support" (used by the Department of Defense).

<sup>2</sup> The person performing this function may have a different title – such as Logistics Manager, Product Support Manager, etc. – but the functional responsibilities are the same.

## 2. Reference Documents

NPD 7500.1C	NASA Program and Project Life Cycle Logistics Policy
NPR 7120.5	NASA Space Flight Program and Project Management Requirements.
NPR 8735.1	Procedures For Exchanging Parts, Materials, and Safety Problem Data Utilizing the Government-Industry Data Exchange Program and NASA Advisories.
ASD S3000L	International Procedure Specification for Logistics Support Analysis (available at <a href="http://www.asd-stan.org/s3000L.html">http://www.asd-stan.org/s3000L.html</a> ).
GEIA-STD-0007	Logistics Product Data (available at <a href="https://standards.nasa.gov">https://standards.nasa.gov</a> ).
MIL-STD-1388-1A	Logistics Support Analysis
MIL-STD-1388-2B	DoD Requirements for a Logistics Support Analysis Record

### **3. Fundamentals of Life Cycle Logistics Support**

#### **3.1 Life Cycle Logistics Support**

Life Cycle Logistics Support (LCLS) comprises the planning, development, implementation, and management of a comprehensive, affordable, and effective systems support strategy. LCLS encompasses the entire life cycle including acquisition (concept studies, concept and technology development, preliminary design and technology completion, final design and fabrication), final production, support (system assembly, integration and test, launch, operations and sustainment), and closeout. The principal objectives of LCLS are to:

- Ensure Life Cycle Cost (LCC) is considered along with key design and performance parameters.
- Influence product design so that the system can affordably attain required operational availability.
- Design, develop, and implement a cost-effective support system.
- Maintain and improve availability, improve affordability, and minimize the logistics footprint.

In the case of a system such as a space vehicle that is used multiple times or is in continuous operation for an extended period, the majority of the system's life cycle costs (typically 60-70%) can be attributed directly to operations and support costs, while in the case of a system such as a launch vehicle the majority of life cycle costs may be in design and production. Regardless of the type of system involved, because these costs are largely determined early in system development, it is important that system developers evaluate potential operational and support costs of alternative designs and factor these considerations into early design decisions.

#### **3.2 LCLS Implementation**

In order to achieve the LCLS objectives identified in the previous section, a set of LCLS elements have been established. The elements of LCLS are:

- Maintenance Concept and Planning
- Design Interface
- Supply Support
- Support and Test Equipment
- Manpower, Personnel, and Training
- Logistics Information Management
- Technical Data
- Packaging, Handling, Storage and Transportation
- Facilities

All elements of LCLS should be developed in coordination with the system engineering effort and with each other. Acquisition logistics requirements must be established and clearly defined early in the life cycle and be a contributor to the development of the acquisition strategy in order to minimize total ownership costs. Tradeoffs may be required between elements in order to

acquire a system that is: affordable (lowest life cycle cost), operable, supportable, sustainable, transportable, and environmentally sound.

The planning for LCLS for a system is contained in an Integrated Logistics Support Plan (ILSP). The ILSP is used to identify and define all logistics planning activities. The ILSP is used as a life cycle document to ensure logistics support over the product's entire life cycle.

The following sections provide a brief description of each of the LCLS elements, including key points to be included in the ILSP for each ILS element. In tightly coupled programs with subordinate projects, there will be an ILSP for the program and ILSPs for each of the projects. Discussion of the ILSP in the following sections covers both the program-level and project level documents. The program-level ILSP should address the broad program operational concept and operational requirements. It should be broad enough to encompass the various specific needs of all of the subordinate projects. The ILSPs of the subordinate projects should be consistent with the program-level ILSP and address the specific approaches to be employed by the individual project. It is left to the discretion of the program LCLS manager and the project LCLS managers to include the level of detail that is appropriate for them.

Depending on the relative roles and responsibilities of the Government's program and project offices and respective contractor organizations, it may be appropriate or necessary for the contractor organizations to develop ILSPs as well.

### **3.2.1 Maintenance Concept and Planning**

#### **Maintenance Concept**

The objective of the maintenance concept is to define an approach to system maintenance that will provide required system availability while controlling life cycle costs. The maintenance concept must be compatible with the mission profile or other operational requirements and constraints and is subject to such resource constraints as cost, crew time available for maintenance, mass/volume allocated for tools, spares, etc.

The maintenance concept is usually identified during Pre-Phase A development so that an estimate of the life cycle costs can be made during project formulation. It is especially important that the maintenance concept be defined at the earliest stages of development of hardware system designs and operational concepts. For systems where maintenance will be a significant activity and cost driver, early consideration can allow adjustment of hardware design to facilitate maintenance, optimize requirements for spares, and reduce total life cycle cost.

#### **Maintenance Planning**

Maintenance planning is the process of applying the maintenance concept to each hardware item and associated processes when making implementation decisions for the lifetime of the system. Maintenance planning applies the maintenance concept and decisional processes to define the level at which each item is maintained, how it is maintained, and the resources required to maintain it.

#### **Maintenance Plan**

The Maintenance Plan documents the results of the maintenance planning effort. The Maintenance Plan and underlying maintenance concept should encompass all program life cycle

phases and address all applicable mission phases including development and test, ground operations, launch, in-space and destination surface operations, and post-flight turnaround. It defines acceptable levels of repair, what tasks will be performed, how those tasks will be conducted, the resources that are required, and the organization responsible for the various associated activities. Acquisition of support resources must be based on the Maintenance Plan. The supportability tasks included in maintenance planning identify the mission criticality of parts, authorized maintenance levels, and estimates of replacement rates and of part failures. A Level of Repair Analysis (LORA) should be conducted to determine the best value support policy for an item (considering all resources including cost, mass, volume, and crew time available for maintenance) and to help identify the appropriate time to make, repair, or discard the hardware item.

In simple programs the Maintenance Plan is often included as an appendix to the ILSP. In complex programs the Maintenance Plan is usually issued as a separate document and referred to in the ILSP. There is the potential to introduce document control issues if the Maintenance Plan is included in the ILSP – as changes to the Maintenance Plan will result in a reissue of the ILSP whether or not there was a logistics impact resulting from the change.

### **3.2.2 Design Interface**

#### **Design Interface Planning**

The Design Interface element of LCLS is the process through which LCLS experts engage with hardware system designers to make the system supportable for the least possible resource demand. Resource demands include financial cost, support personnel time, quantity of spares, mass of spares, volume of spares, etc. It is unlikely that all resource demands can be minimized so those that are most tightly constrained or limited should be focused upon. For example, during ground operations the time required by ground personnel to support the flight vehicle system or the total financial cost of support activities might be far more important than the mass/weight of spares or their geometric volume. On the other hand, for in-space maintenance and repair operations, it may be more important to minimize the total mass and volume of spares - accepting that total financial cost may be of less importance. For maintenance of ground systems, driving considerations might be total sustainment cost or minimization of repair time if launch opportunities are severely time-constrained.

In general, the life cycle logistics expert should strive to influence the design to facilitate maintenance, repair, and other support activities as much as possible. Ease of access to components for maintenance is critical. However, since it may not be possible to place all components for optimal access, those that are most likely to require attention (either because of frequent routine servicing requirements or inherent reliability that suggests a greater frequency of failure) should be prioritized for ease of access. Experience also suggests that it is desirable to design hardware in a way so that those specific components that are most likely to fail (such as bearings, valves, electronics subunits) can be replaced so that it is not necessary to replace a larger assembly. Another factor to consider is the testability of a system - that is, the ability to obtain information from the system to identify the specific items that have failed. Good testability can significantly increase the efficiency of repair operations by avoiding a trial-and-error approach to fault isolation.



Design interface is the relationship of logistics-related design parameters of the system to its projected or actual support resource requirements. These design parameters are expressed in operational terms rather than as inherent values and specifically relate to system requirements and support costs of the system. Programs such as "design for testability" and "design for discard" must be considered during system design.

The primary items that need to be considered as part of design interface include:

- Reliability requirements
- Maintainability requirements
- Standardization requirements
- Interoperability requirements
- Safety requirements
- Security requirements
- Usability requirements
- Environmental and hazardous materials requirements

### **3.2.3 Supply Support**

#### **Supply Support Concept**

The objective of the Supply Support Concept is to define an approach to the identification, procurement, and management of initial and replenishment spare and repair parts. The Supply Support Concept is based on the approved maintenance concept and identifies the strategy of how required material will be acquired, who will provide the material, and where inventory will be held. These strategies can range from acquisition through the Prime Contractor, Direct Vendor Delivery from vendors, the use of Third Party Logistics providers, etc.

Two primary objectives of supply support are to ensure that end items are delivered in a satisfactory state of readiness and to maintain readiness by fulfilling material replenishment requirements throughout the life cycle of the end item. Achieving these objectives is based on an appropriate Supply Chain Management strategy. In order to ensure supportability throughout the life cycle, NASA must have knowledge of all suppliers in the supply chain and be able to identify risks to the supply chain.

Decisions affecting spares and the supply chain must be made very early in the life cycle of a system. As the program evolves, the project-level Government LCLS manager must issue provisioning technical documentation guidance, consistent with the system's maintenance and support concepts, via the contract to ensure that project unique materials are promptly ordered and that the supply chain is responsive to NASA's requirements. The project-level Government LCLS manager must also ensure that follow-on spare and repair parts are obtained in a cost-effective manner. An effort should be made during design to minimize the use of proprietary materials and processes whenever possible. The project-level Government LCLS manager should obtain technical data, drawings, tools, etc. through contractual requirements, to enable competition among contractors for follow-on logistics support. In this way, the project can enhance the effectiveness of the supply chain throughout the system's life cycle. Relying entirely on the original prime contractor for follow-on support material entails risks in the areas

of cost and availability of needed spare and repair parts, especially during the post-production support period.

For single-use systems that are in a continuing production run, such as launch vehicles, the total pool of equipment should be considered. At any time, there will be a number of components in existence from the next vehicle in production to components that have been delivered for use in a production vehicle but not yet installed. Failures could occur at any point in production, and the use of production components for replacement on the vehicle closer to launch should be considered to avoid excessive spare component procurement.

The Supply Support Concept is documented in the ILSP. The ILSP should address the following:

- The supply support concept and the strategies used to ensure effective support to the end item and responsiveness of the supply chain.
- The factors, risks and assumptions on which the supply support concept is based.
- How any anticipated commercial item acquisitions will affect the supply support system.
- Any unique supply requirements that are being considered.
- Any Government Furnished Material (GFM) that will be used.
- The plan to include training, support and test equipment in the supply support system.
- Implementation of space-based inventory management system architecture and element-to-element inventory management system compatibility. Compatibility with the appropriate NASA logistics and inventory management system should also be addressed.

### **Initial Provisioning** \*

Provisioning is the process of determining the range and depth of spares and repair parts and support and test equipment required to operate and maintain the end item for an initial period of service. The basic contract should define an initial provisioning period. This period must be specified in the major systems contract and be defined in terms of some significant event in the program cycle, e.g., assembly complete plus 2 years of continuous operation of four successful flights. The period should cover test and evaluation, plus a short period of operation, so that sufficient operational experience can be gained with the system to provide a basis for adjusting spares stock levels and fully competitive acquisition of follow-on spare parts. However, this may not be possible for production runs that are relatively short and when the program would incur manufacturing restart or requalification costs. Provisioning methodologies will be determined by the individual projects.

Initial provisioning should be accomplished by the development contractor during the original phase of a major system program. A requirement covering procedures for the conduct of initial provisioning should be included in the synopsis and solicitation, with the contractor's obligations to perform initial provisioning set forth as a separately priced line item. Regardless of the type of program, all provisioning should be accomplished before the manufacturing lines are closed in

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\* Much of the content from this section and the following sections on Replenishment, Life of Type Buys, SAIP, and Breakout draw extensively on content from the former NPR 5900.1, NASA Spare Parts Acquisition, which has been cancelled.

order to not incur manufacturing restart costs. Life of type buys would apply as well. On programs with short development production schedules, an SAIP process (discussed more fully below) should be considered.

The product of initial provisioning assessments should include a list of proposed spare parts and related quantities needed to support the major system during the initial provisioning period. The recommended sparing strategy and schedules shall also be included. The list provides the basis for an assessment of the potential for breakout (describe below) and competition on re-procurement items. For each item, there shall be a unit price and identification of the OEM. Whenever possible, the specific spare parts and quantities proposed should be based upon probabilistic analyses using parameters such as predicted/designed consumption rates, any empirical data available, engineering estimates of predicted use of the spare parts, and the overall probability of sufficiency (POS) assumed. POS is the probability that the spare parts will be available when needed.

The contractor submits the list of proposed spare parts and related quantities to NASA and participates in an initial provisioning conference in which NASA evaluates the contractor's recommendations and the data upon which they are based and makes initial purchase and inventory-stocking decisions. The contractor makes recommendations only. The decisions (a) on how to procure, (b) to purchase or not purchase an individual item suggested by the contractor as a spare part, and (c) on the quantity of each item to be purchased are made solely by NASA. For human spaceflight programs, the project-level Government LCLS Manager must consider spares for system development and testing, ground processing, prelaunch test and check-out, launch support, and In-Flight Maintenance (including support of systems on destination surfaces). Program managers or their designated Life Cycle Logistics Support Managers should process recommendations on spares make decisions on purchases in a timely manner in order to minimize procurement costs and to ensure that spare parts are available in time to support the need.

To provide a vehicle for ordering spare parts during this period, the contract should include a separate line item, obligating the contractor to provide any parts identified during initial provisioning and ordered by the Government. Unless otherwise justified, prices shall be negotiated before the contractor begins work on an individual order. If possible, each order should be on a firm fixed-price basis with individual items separately priced. If experience can be gained with the operational system, the items selected as spare parts and the quantities needed may change. Individual item pricing will facilitate making these changes and provide a pricing history for later purchases.

Program managers or their designated Life Cycle Logistics Support Managers should screen for parts availability from Government sources and obtain parts from those sources if available at a lower cost, provided that traceability standards can be maintained. To the maximum extent practicable, follow-on spares procurement should be purchased directly from the actual manufacturer, i.e., lowest-tier subcontractor, or from other qualified manufacturers to eliminate the layers of support costs at each tier (see discussion of "breakout" below).

It may be cost effective to use existing prime or subcontractor personnel and processes to effect such procurements. Purchase requirements shall be consolidated upon completion of NASA decisions on the contractor's provisioning recommendations.

## **Replenishment**

Replenishment begins prior to the conclusion of the initial provisioning period, i.e., when demand and usage patterns are becoming clearer. Requirements for replacement of parts used but not reordered during the initial provisioning period are considered replenishment requirements. Spares replenishment then continues throughout the life of the system. The key is to stock the right parts in the right quantities at the appropriate location(s). These factors seldom remain static during the system's useful life. Early in the initial provisioning period, NASA typically orders spare parts exclusively from the major systems contractor. As experience is gained, however, opportunities to break out items for competitive acquisition may become apparent. Before ordering spare parts under the major systems contract, the contracting office should examine the alternate sources.

Replenishment may be accomplished by NASA or by a prime or support contractor. Any purchases of spare parts for replenishment, whether accomplished by NASA or a contractor, shall be separate from the major system development contract and shall comply independently with the requirements for full and open competition. The decision should be based on the lowest overall cost to NASA in a full-cost environment, including consideration of such factors as major system contractor total-system responsibility, inventory-stocking costs, overhead charges, and Government contract administration costs. In any case, NASA retains the final overall responsibility for replenishment, and program managers must ensure that periodic reviews and oversight are conducted and ensure that there is timely, efficient program support. The requirements for effective management and financial reporting of program stock, as specified in NPR 4100.1, NASA Materials Inventory Management Manual, may apply. This inventory control may be achieved by the use of NASA's supply management system.

## **Life of Type Buys**

Life of type buy decisions will be driven by several factors. Hardware obsolescence notice can drive the decision to procure what is needed while stock/capability is still available. Limited production runs due to unique one-of-a-kind development programs, can drive the cost of trying to keep the vendor's production line open for limited spare buys at later dates.

Cost tradeoffs should be made on life of type buys based on such factors as the quantity required to support the life of the program, production schedules, cost for spares, keeping production lines open, retooling, and potential obsolescence.

## **Spares Acquisition Integrated with Production (SAIP)**

SAIP is a process whereby the Government combines spare parts orders with planned production. This approach is particularly effective when applied to limited initial production runs. Rather than extending a contract for the sole purpose of producing very low quantities of spares buying spares along with the initial production run may be more cost effective.

SAIP implementation is best applied to major programs that have distinct acquisition phases. Program managers should have the contractor provide development schedules and identify spares order decision dates to implement SAIP buy orders. On programs that combine acquisition phases, SAIP shall be implemented on items that are more mature and pose less risk of design changes. On items that still pose a risk of change, SAIP should be deferred until the design matures and implemented before production lines close.

### **Breakout**

Breakout means the purchase of spare parts, either by the Government or a contractor, directly from the original equipment manufacturer (OEM) or another source close to the original manufacturer. The goal of breakout is to eliminate any added costs that can be incurred because of subcontractor tiers, when no value added or enhancements are made. Breakout is best used on re-procurements or replenishing initial spare stock levels to the probability of sufficiency as determined from history

Breakout should be an ongoing consideration throughout the program or project life cycle. Program and project managers shall include breakout as a part of their logistics planning and analyses requirements. Individual breakout decisions shall be based on the results of the logistic support analysis required by NPD 7500.1, Program and Project Logistics Policy, or an economic analysis for non-program hardware that shall take into account the following considerations:

- a. Design stability of the items of supply to be acquired.
- b. Availability of drawings, technical data, hardware and software documentation, production process, test and quality specifications, tools, test equipment, and materials required to ensure competition.
- c. Potential benefits of the competition compared to the cost to re-procure from the original source of supply.
- d. Liability assumed by the Government.

Breakout shall be explicitly recognized in the structuring of major systems contracts. Contract provisions shall require prime contractors to identify actual hardware manufacturers and to furnish data for evaluating breakout benefits. Decisions to retain the original source of supply for the life of a program or project due to proprietary processes, quality considerations, safety, or cost will be documented for future audits.

In rare cases, it may be possible to use initial spare parts to develop technical data for use in future spares replenishment by reverse engineering. While legal, the practice of reverse engineering can be difficult and costly and should be used only when other alternatives are not feasible

NASA personnel should identify, as early as possible in the development cycle, the technical data, and the attendant rights thereto that NASA needs to acquire. Such identification will facilitate the making and implementation of breakout decisions. The following specific actions should be taken:

- (a) Establishment of separate contract line items for technical data, normally broken down in terms of the subsystem, assembly, or subassembly to which the data relates and to individual parts and components. Also, to the extent feasible, the breakdown should include the pricing of such data if related to designs and developments first produced under the contract.
- (b) Identification by the contractor of any technical data that, if delivered, will be with limitations or restrictions on NASA's right to use it, or have others use it, for manufacture or re-procurement purposes.
- (c) Establishment of delivery schedules and/or options for delivery on a phased basis keyed to component design stability.
- (d) Establishment of procedures for inspection of technical data needed for breakout, both for technical completeness and accuracy, as well as for any unauthorized limitations or restrictions on its availability for use for manufacture or re-procurement. Where Government expertise does not exist, a verification contract may be awarded to a manufacturing or production engineering firm with related experience.
- (e) Requirements that the contractor correct any deficiencies in the technical data regarding its completeness and accuracy and revise the technical data regarding any engineering changes made during contract performance that affect the form, fit, and function of any spare part designated for breakout.
- (f) Contractual provisions and procedures to correct in a timely manner, and without cost to the Government, any unauthorized restrictions on the right to use the technical data for manufacture and/or re-procurement.

### **3.2.4 Support and Test Equipment**

#### **Support Equipment Planning**

Systems or other items of equipment normally require the use of additional equipment to support operations or maintenance. Any item of equipment required to support operation or maintenance is categorized as support equipment. The support equipment can be a special item designed for only one specific use, or it can be items that have multiple uses. The support equipment planning process should encompass all program life-cycle phases and address all applicable mission phases including development and test, ground processing including assembly and checkout, prelaunch, launch, in-space and destination surface operations, and post-flight turnaround. The following list is a summary of some of the different types of support equipment:

#### **Ground Support Equipment (GSE)**

GSE is non-flight equipment with a physical and/or functional interface with the flight hardware that is routinely required for the handling, servicing, inspection, testing, maintenance, alignment, adjustment checkout, vehicle assembly, repair, and overhaul of flight hardware.

#### **Ground Support Systems (GSS)**

GSS is non-flight infrastructure and equipment that provided functional and /or physical support to GSE. It does not physically interface with flight hardware but it may supply commodities, power, or data that eventually reaches flight hardware after it has been conditioned or controlled by GSE.

### **Flight Support Equipment (FSE)**

Flight Support Equipment (FSE) is returnable hardware that provides the interface between the LRU/ORU or Shop Replaceable Unit (SRU) and the carrier. FSE supports loads during all applicable phases of flight and provides thermal conditioning for launch, landing and in-space operations, as required. For external hardware, FSE is compatible with EVA. For external items that are robotically compatible, the FSE is also robotically compatible such that translation, storage, removal and replacement can be conducted end-to-end without EVA intervention.

### **Orbital Support Equipment (OSE)**

OSE is similar to FSE, except that OSE remains on orbit.

### **Flight Crew Equipment (FCE)**

FCE consists of all crew-related equipment and includes space suits, extravehicular life support equipment, food, bioinstrumentation, personal communications equipment, photographic equipment, miscellaneous mission operational aids, and tools.

### **Surface Support Equipment (SSE)**

SSE is equipment used on destination lunar, asteroid, and planetary surfaces to provide support for setup and sustainment of the surface infrastructure (habitats, production facilities, manufacturing equipment, maintenance facilities, power stations, communications, transportation, and launch and landing sites, etc.). SSE is equipment required for handling, servicing, inspection, testing, maintenance, alignment, adjustment checkout, repair, and overhaul. SSE is analogous to other types of support equipment that is designed specifically for use in the particular surface environment. For the design of this equipment key environmental variables include atmospheric pressure (or lack thereof) and gravitational acceleration.

### **Test, Measurement, and Diagnostic Equipment (TMDE)**

TMDE is any system or device used on the ground, in flight, or on a destination surface to evaluate the operational condition of an end item or subsystem thereof to identify and/or isolate any actual or potential malfunction. This TMDE includes diagnostic and prognostic equipment; semiautomatic and Automatic Test Equipment (ATE) to include Test Program Sets (TPSs) (with issued software); and calibration test or measurement equipment. (Note: When the term TMDE is used, it refers to both TMDE-GP and TMDE-SP.)

### **Test, Measurement, and Diagnostic Equipment - General Purpose (TMDE - GP)**

TMDE-GP is any TMDE that can be used to support multiple end items or systems without requiring modification. Addition of external special accessories, plug-in assemblies, logic probes, and attenuators (or TPSs for ATE) are not considered modifications.

### **Test, Measurement, and Diagnostic Equipment - Special Purpose (TMDE-SP)**

TMDE-SP is any TMDE designed specifically for support of and functionally restricted to one end item or system. To use this TMDE for support of another end item or system would necessitate modifications to the TMDE. Addition of external special accessories, plug-in assemblies, logic probes, attenuators (or TPS for ATE) are not considered modifications.

### **Automatic/Automated Test Equipment (ATE)**

ATE is any TMDE that performs a predetermined program to test functional or static parameters, to evaluate the degree of performance degradation, or to perform fault isolation of unit malfunctions. As a minimum, ATE must be able to sequentially perform testing/measurements, compare the measurements to predetermined values or ranges, and based on the results of this comparison, branch to other tests without manual intervention. ATE is usually external to the prime device.

### **Test Program Set (TPS)**

The TPS is the combination of interface devices, software test programs (such as those residing in logic storage media or in permanent digital memory), and documentation that together allows the ATE operator to perform the testing/diagnostic action on the Unit Under Test (UUT).

### **Built-In Test Equipment (BITE)**

BITE is any identifiable device that is a part of the supported end item and is used for testing that supported end item.

### **Calibration Equipment**

Calibration Equipment consists of measurement standards and TMDE used in performance of calibration.



The number of different tools and support equipment required for test, maintenance, assembly, servicing, handling, etc. should be kept to a minimum. Commonality should be stressed and multi-application tools should be used wherever possible. TMDE-GP should be utilized versus TMDE-SP, whenever possible.

Support equipment factors may impact commercial item acquisitions (e.g., new calibration standards and procedures for related test equipment may not be available when a commercial end item is deployed). Additionally, rapid deployment of a commercial end item may necessitate the procurement of commercial support equipment or the need for interim contractor support.

### **3.2.5 Manpower, Personnel, and Training**

#### **Manpower and Personnel Analysis**

Manpower and personnel analysis is the process conducted to identify and acquire personnel with the skills required to support the system over its planned lifetime. Training includes the students, courses, instructors, equipment, facilities, curricula, and all other materials required to train personnel to support a system including individual and crew training; new equipment training; initial, formal and on-the-job training including any certifications, if required; and logistics support planning for training equipment. Because Manpower, Personnel and Training (MPT) costs are usually a major driver of support costs, planning for this element must begin at program initiation. Acquisition logistics efforts should strive to minimize the quantity and skill levels of manpower and personnel required to support the system over its planned lifetime.

Training of flight crews for In-Flight Maintenance (IFM) is managed by NASA's Mission Operations Directorate (MOD). Materials used during this training utilize source material developed during the logistics development process. This training may be performed in NASA training facilities, at other NASA facilities utilizing flight hardware, or at contractor facilities utilizing flight or training hardware.

System-specific training required for ground personnel should be defined by the project in collaboration with the ground processing organizations and documented in the projects' ILSPs. The contractors' role in the training of ground personnel should also be defined in the projects' ILSPs and should address the following specific topics:

- Safety
- Skills or knowledge to be trained and any required certifications
- Recommended necessary duration of training
- Training facilities required
- Training equipment or devices required
- Training program content
- Training program implementation
- Other resources required

Additional details of the implementation and performance of functions by the contractor should be included in the contractors' ILSPs.

## **Support of Training Equipment and Devices (TE&D)**

Training Equipment and Devices (TE&D) are model replicas of the end item (system) devoted to the training and instruction of personnel. Because the conduct of training frequently results in increased maintenance requirements (due to constant use from students performing operating and maintenance tasks), the project office may need to adjust the quantity of spare parts and other supply support normally provided.

The ILSP should address the following, as applicable:

- The procurement of data and documentation necessary to support and maintain TE&D.
- Identification of the spare parts and Configuration Management considerations that may impact the TE&D acquisition strategy.
- Identification of spares, repair parts and consumables required for the TE&D.
- Include discussion of tradeoffs and the impact on the acquisition strategy and the overall support structure (e.g., the decision to use [or not use] commercial hardware/software).

## **Contractor/Factory Training**

Contractor or factory training encompasses training that is provided by a contractor in the operation, maintenance, or activation of a system, equipment, or training device. It can be conducted at a contractor site or Government facility by contractor or other personnel. Factory training can be either initial or follow-on training, or both.

The ILSP should address the following:

- Whether ground and crew training for system maintenance will be required at the factory.
- Any constraints related to its development and implementation.
- Date, course title, description, developing organization, course developer, and trainee population.
- When identifying the trainee population, indicate if the training is designed for operators, operators/maintainers, (indicate level of training: Organizational, Intermediate, or Depot-Level maintainers), team training, Government and/or contractor personnel.
- Whether training is for basic skills, skill progression, or other types of training.
- The rationale for the training of Government personnel (including flight crew) at facilities other than Government facilities.

## **On-Board Maintenance Training**

On-Board Maintenance Training is provided to flight crews during a mission when necessary to support the performance of specific tasks that may be particularly complex or which require capabilities beyond those acquired by the crewmembers during pre-mission training. On-Board Maintenance Training may include Computer Based Training (CBT), Interactive Courseware (IC), and embedded training.

The ILSP should address the following:

- The philosophy, relative scope and benefits of on-board maintenance training capability during a mission.
- The type of training provided, such as:
  - Proficiency training
  - Maintenance training
  - Other on-board maintenance training packages and the location where the identified training will be accomplished.

### **3.2.6 Technical Data**

#### **Types of Technical Data and Documentation (TD&D)**

TD&D is recorded information, regardless of form or characteristic, of a scientific or technical nature. There are five categories of technical data:

1. Configuration Documentation (i.e., to include engineering drawings, interface requirements and control documents)
2. Technical Procedures
3. Items Identification Data
4. Technical Reports
5. Other (imagery and video of hardware during fabrication and assembly, Problem Reporting, Analysis, and Corrective Action [PRACA]-type data acquired during testing, etc.)

The Supportability Analysis should include a detailed review of TD&D requirements and options for long-term support of NASA Program requirements.

The ILSP should address the following:

- The system to store TD&D and access/transfer plans for NASA.
- Documentation of technical data management planning.
- The acquisition strategy, and associated drivers, for technical manuals and engineering drawings.
- Compatibility of contractor data with existing Government data systems.
- The process to mitigate/minimize proprietary data rights.

The technical data planning process should encompass all program life cycle phases and address all applicable mission phases including development and test, ground processing including assembly and checkout, prelaunch, launch, recovery, in-space and surface destination operations, and post-flight turnaround.

#### **Data Rights**

It is especially important to ensure that the Government has data rights to the delivered system. Data rights are a broad field that includes full data rights, limited data rights, intellectual property

rights, proprietary information rights, copyrights, and trade secrets. Without full or limited data rights to drawings and software procured for use in a system, NASA may not have the right to transfer the drawings, software and associated documentation to other Government agencies or other contractors to ensure the effectiveness of the supply chain for life-cycle support. If the contractor who developed the system considers the design techniques and algorithms in the software to be trade secrets or proprietary, they will not want the information to be released to competitors. The LCLS manager must determine if it will be necessary to release this information to another Government agency or contractor for support purposes during the life cycle of the system. If so, the Government must have either:

1. Full data rights which allow the Government to do anything with the drawings and algorithms, or
2. Limited data rights authorizing release of the drawings and algorithms for support purposes only.

### **Technical Data and Documentation (TD&D) Requirements for Commercial Equipment**

In most cases, there is no longer a requirement to develop NASA-unique TD&D for commercial equipment. Commercial manuals should be used if feasible and if they satisfy the requirements of the program/project. The alternative is the commitment of spending considerable time and money converting the manuals. In the past, a major data problem has been the incomplete identification of data requirements and the lack of emphasis on procedures that ensure legible, complete and correct TD&D.

The ILSP should address the following:

- Procedures for Technical Data & Documentation (TD&D) procurement including development of Data Requirement Description (DRD) language for application to agreements and contracts.
- Roles and responsibilities of activities/contractors participating in the development of TD&D.
- Risks and mitigations associated with the acquisition, timely delivery, and quality of TD&D.

### **Validation/Verification of TD&D**

The validation process evaluates TD&D for technical accuracy, adequacy, comprehensibility, and usability. The validation is normally conducted at the development/test facility or operational site and involves the performance of operating and maintenance procedures, including test, checkout, calibration, alignment, removal, installation and disassembly. TD&D verification is performed by the Government to ensure that the TD&D is adequate to support the operation and maintenance of the end item. The verification is conducted using personnel with skill levels equivalent to those of the target operators or maintainers.

The ILSP should address the following:

- The plan for TD&D review, validation and verification.

- The validation process and provisions to ensure the validation method permits the performance of tasks in an environment that closely duplicates (or simulates) operational conditions.

### **3.2.7 Logistics Information Management**

Logistics information is critical in all phases of life cycle management. The effective management of this information is vital to supporting knowledge-based logistics decisions throughout the life cycle. The content and format requirements for logistics information must be identified early in the life cycle.

Initial logistics data is derived from the results of the various Logistics Support Analyses (LSAs). In the case of an acquisition program utilizing a contractor, this requirement can be levied on the contractor; however, in the case of Government Furnished Equipment (GFE) developed in-house by NASA (or any other government agency) NASA will be required to develop/obtain this data. Additional logistics data will accrue during the life cycle of the program or project. Examples include lifetime or cycles to failure of specific hardware items, information about failure modes that are experienced, and time (and other resources) required for preventive and corrective maintenance. Regardless of the original source of the data, NASA must maintain this data in a compatible format throughout the equipment life cycle.

The ILSP should address the following:

- The content and format of required logistics data.
- The original source of the data.
- Management of the data - e.g. where it will be stored, how it and access to it will be controlled, who will compile it, who will have access to it

### **3.2.8 Packaging, Handling, Storage, and Transportation (PHS&T)**

Packaging, Handling, Storage and Transportation (PHS&T) planning must include all phases of end-item life cycle. This includes:

- Shipment from the Original Equipment Manufacturer (OEM).
- Operations at intermediate and final assembly locations.
- Packaging, handling and storage at the launch site and at test facilities.
- Launch (including requirements for Flight Support Equipment [FSE]).
- In-space handling and stowage (with special attention to interfaces for the crew, robotics, and support equipment).
- Handling on destination surfaces.
- Launch from destination surfaces.
- Reentry and landing.
- Shipping from landing site to launch site.
- Shipping from landing site to depot facilities for repair and refurbishment.

- Shipping from depots.

The ILSP should address:

- The plan for ensuring that PHS&T aspects of logistics operations are considered and integrated into engineering design and support subsystem design efforts.
- The interaction with the design process is to ensure that end items can be handled with standard equipment and that the need for special handling and support equipment is minimized.
- Specific requirements for responsibilities, surveillance, approvals, facility and equipment and personnel certifications, and procedural aspects of the PHS&T functions for Program Critical Hardware (PCH).
- Specific requirements for transportation manager training for required DOT and Hazardous Shipping Certifications.

The PHS&T section must address all aspects of PHS&T that are the direct responsibility of the hardware developer and must define information, and the plan for providing that information, needed by other organizations that have responsibility for PHS&T operations during various phases of the life cycle. Examples include but are not limited to:

- Physical contact constraints
- Load limits
- Shock and vibration constraints
- Environmental constraints (i.e., temperature, humidity, etc.)
- Contamination control
- Commodity requirements and interfaces (i.e., power, purge gases, etc.)
- Required DOT permits for hazardous and oversized loads.
- Other safety documentation

The PHS&T planning and budgeting process should encompass all program life cycle phases and address all applicable mission phases including development and test, ground processing including assembly and checkout, prelaunch, launch, recovery, in-space and surface destination operations, and post-flight turnaround.

### **3.2.9 Facilities**

The role of facilities in Supportability activities must be considered. This includes facilities for storage, supportability activities associated with assembly and checkout as well as prelaunch processing, and depot repair.

The ILSP should address the following:

- Facilities necessary to enable the performance of supportability functions.
- Specific requirements that facilities must meet to properly enable supportability functions (e.g., lighting, clean room conditions, temperature, humidity, and utilities such as electrical power and pressurized gasses).

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- Need for auxiliary equipment such as forklifts and cranes.
- Certification processes and requirements (including OEM facilities that are supporting post-production repair activities).

## 4. Life Cycle Logistics Support: Tightly Coupled Programs

### 4.1 Life Cycle Logistics Support Roles and Responsibilities<sup>3</sup>

The Program Manager (PM) is responsible for acquisition and support of the program's systems throughout the program's life cycle. The PM is also responsible for providing the needed LCLS capability to maintain the availability, supportability, and operational capability of a system. Emphasis is placed on increasing reliability and reducing the logistics footprint utilizing Systems Engineering concepts and providing for effective Product Support. Early in the design process, the PM must consider the relationship of supportability requirements to other trade-space requirements such as mass, safety, and mission success. Potential supportability requirements are discussed in Appendix B.

Ultimate responsibility for LCLS rests with the Program Manager. The LCLS functions, described in subsequent sections of this document, are executed by the Program's Life Cycle Logistics Support Manager. The Program Manager may choose to serve in this role if circumstances warrant (e.g. a small program with insufficient funding to support a dedicated LCLS Manager) or may designate a dedicated individual to perform this function. Hereafter in this document the term Life Cycle Logistics Support Manager (LCLS Manager) will be used to designate whoever performs this role.

The LCLS Manager may establish a staff of LCLS specialists to perform the various LCLS functions. The composition of this LCLS team and the required capabilities of the individual team members are determined by the LCLS Manager. The size of this team and the required team member capabilities may change over the course of the program.

In most programs the prime contractor will also have a counterpart LCLS team (as will subcontractors). The contractor LCLS teams will execute functions defined in the contract. Therefore, it is critical that the Program LCLS team participates in defining those specific contract requirements to ensure that expected functions are performed by the contractors and that necessary LCLS-specific deliverable products are developed by the contractors.

The Project Manager's LCLS responsibilities are analogous to those of the Program Manager but deal specifically with the needs of the Project. As such, emphasis is placed on meeting the project's specific support and sustainment needs in a manner that is consistent with the approach established for the overall program. At the same time, the various subordinate projects within a program should play in integral, collaborative role in defining the overall program LCLS concepts and approaches. Similarly, the Project Manager may directly oversee the project's LCLS activities or may delegate the execution of these activities to a dedicated LCLS Manager.

The purposes of LCLS are to (1) reduce life cycle costs by integrating support considerations into system and component design; (2) develop support requirements that are consistently related to readiness objectives, to design, and to each other; (3) acquire the required support; and (4)

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<sup>3</sup> Much of this content is derived from CxP 70064 *Constellation Program Supportability Plan*, and from *Boeing International Space Station (ISS) Spares Management & Logistics Work Instruction for New Hardware Design/Development* (Initial Release, March 2012).



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provide the required support during the operational phase at minimum life cycle cost. In order to ensure that the purpose of LCLS is achieved in large complex programs, Programs and subordinate Projects have specific, though interrelated, LCLS functions. The table below provides one example of how those roles might be distributed. The specific distribution of roles and responsibilities must be determined uniquely for each Program and its subordinate Projects.

	<b>Program</b>	<b>Project</b>
Supportability Concept Development	Develops Supportability concepts and strategy -- documented in the Supportability Plan	Contributes to development of Supportability concepts and strategy
	Reviews and validates Project supportability concepts documented in Project Integrated Logistics Support Plans	Develops Project concepts consistent with Program Supportability concepts -- documented in Project Integrated Logistics Support Plans
Supportability Requirements	Develops and manages requirements for Program requirements documents; flows down to Project	Reviews and critiques Program requirements
	Reviews System Requirements Document (SRD) requirements to ensure consistency of the SRD requirements with the overall program requirements	Develops Project requirements that satisfy Program requirements and allocates requirements to contractor
	Defines and manages the Program verification requirements. Performs analysis to ensure compliance with Project requirements	Performs verification of Project requirements
Supportability Documentation	Develop supportability documentation. Provides supportability-related inputs to Level II program documentation such as operations concepts and Safety, Reliability, and Quality Assurance (SR&QA) requirements	Develops Project Supportability documentation (e.g., ILSP, LSA Reports)
	Reviews Project ILSP for consistency with Program Supportability Plan, concepts, and strategy	Ensures Project and lower level (as appropriate) ILSP is consistent with Program Supportability Plan, concepts, and strategy
Supportability Data	Ensures consistency, as appropriate, and establishes the scope, contents, format, and guidelines of the LSA and LSA Reports, when applicable. Documented in appendix to Program Supportability Plan. Agrees to Project unique tailoring as appropriate	Participates in the establishment of the scope, contents, format, and guidelines of LSA and LSA Reports and develops the LSA and LSA Reports per established guidelines and standards, when applicable. Proposes Project unique tailoring
	Ensures access to supportability data and information and Logistics Support Analysis Record (LSAR) data via Program data architecture system. These deliveries may include imagery, CAD models, and drawings. Supportability plan will address delivery of this source data. Program will review Data Requirements Documents (DRDs) for inclusion of this source data	Incorporates supportability data and information into Project information management systems and provides supportability information via Program data architecture system (Includes the source data deliverables in the DRDs)

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	<b>Program</b>	<b>Project</b>
	Participates in LSAR reviews, when applicable. Produces an integrated schedule of reviews. Ensures consistency of scope, format, and style of LSAR content for maximum consistency with end user product format	Hosts and supports LSAR reviews; responds to reviewer comments and implements agreed-to changes; delivers corrected LSAR within agreed-upon time. Reviews are expected to occur at PDR, CDR, and L-18 months for first launch of a system. Collects, maintains and confirms closure of reviewer comments
Design Reviews	Participates in Project design reviews	Leads supportability participation in Project design reviews
	Assesses Project designs for consistency with Program design policy for supportability, maintainability, and operability	Assesses the system design to ensure that supportability, maintainability, and operability requirements are realized
Provisioning of Spares and Inventory	Establishes processes and guidelines for provisioning of spares, Program considerations of vendor stability, and resulting needs for initial lifetime buy vs. incremental procurement	Participates in the establishment of processes and guidelines for provisioning of spares, Program considerations of vendor stability, and resulting needs for initial lifetime buy vs. incremental procurement. Leads provisioning strategy for Project spares and unique support equipment procurement. Leads Provisioning Conference.
	Defines Program LRU/ORU selection guidelines including failure rates, criticality, packaging, and configuration	Participates in definition of LRU/ORU selection guidelines. Implements the Program LRU/ORU selection criteria to provide program consistency for design of maintainable items
	Manages obsolescence for Program common hardware items	Manages obsolescence for Project unique hardware
	Defines common Source Maintenance and Recoverability (SM&R) code schema to designate reparability and location of repair of hardware items	Participates in development of SM&R code schema and implement SM&R code schema
	Develops and implements inventory management system including program-provided GFE within Program Supply Chain	Contributes to development and implementation of inventory management system

## 4.2 LCLS Program Functions

The following sections provide an overview of the responsibilities and functions of Program-level logistics support organizations and Project-level logistics support organizations during the Formulation and Implementation Phases of tightly coupled programs<sup>4</sup>. The program phases and milestones that are mentioned are depicted graphically in Figure 4.X.

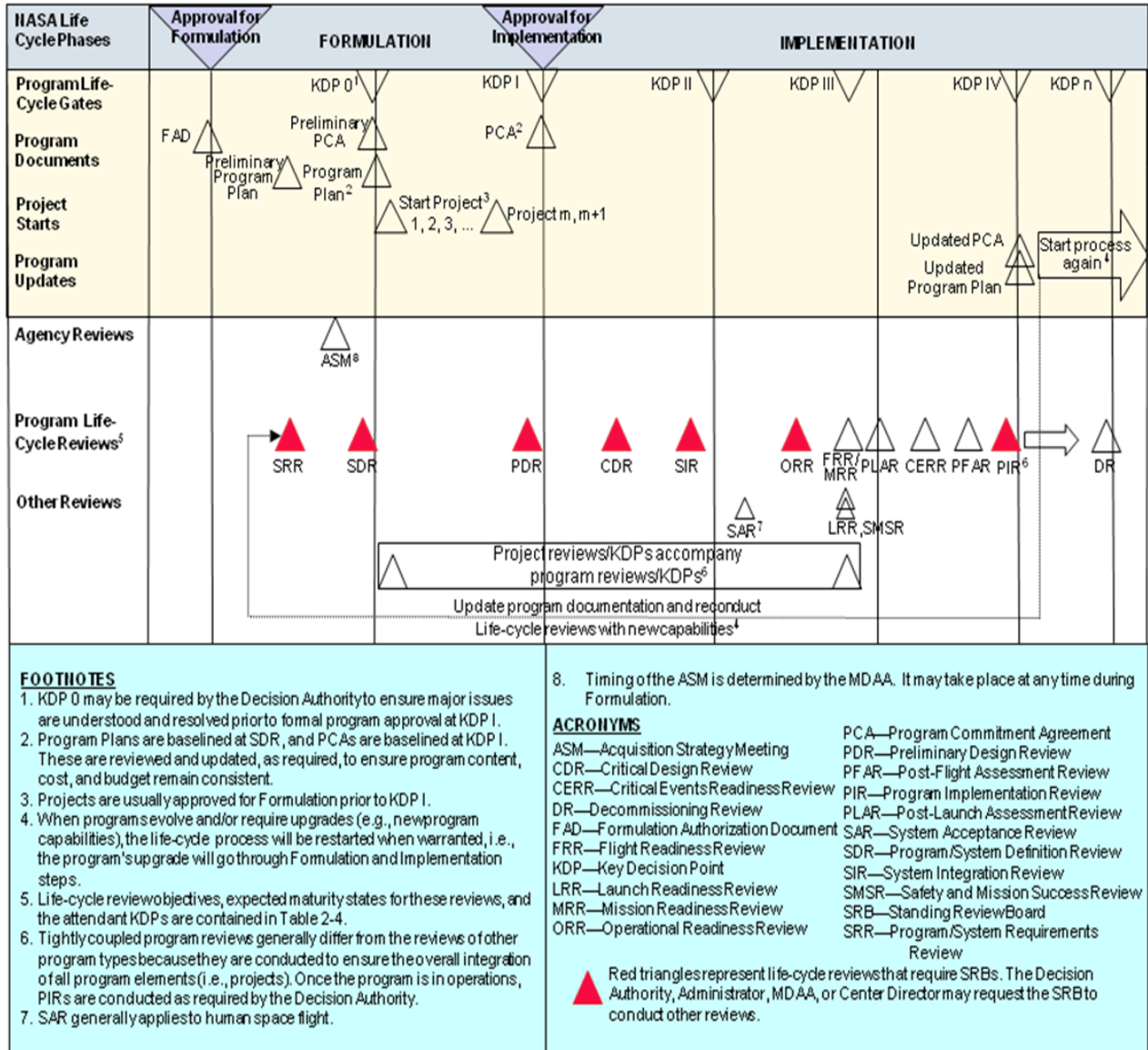


Figure 4.X. NASA Tightly Coupled Program Life Cycle (from NPR 7120.5E, Figure 2-3)

<sup>4</sup> Per Appendix A of NPR 7120.5E, "tightly coupled programs" are "Programs with multiple projects that execute portions of a mission(s). No single project is capable of implementing a complete mission. Typically, multiple NASA Centers contribute to the program. Individual projects may be managed at different Centers. The program may also include other agency or international partner contributions."

### 4.2.1 Formulation Phase

**Program Support Objectives.** At the earliest stages of a Program the Program's LCLS team should define the Program's life cycle support objectives. These objectives may include:

- Minimizing total life cycle support cost
- Achieving specified operational availability levels
- Supporting specified launch schedules
- Supporting the attainment of specified values of crew safety and mission success

The LCLS team must work with Program Management, Systems Engineering, Design Engineering, Safety, Reliability, and Operations to understand the Program's needs and objectives and to make sure that these other functional organizations understand that LCLS plays an integral role in achieving these objectives.

**Program Support Concept.** Almost simultaneously with the definition of the LCLS objectives, the LCLS team must begin development of the support concept that will allow the achievement of these objectives. The support concept must be consistent with the Concept of Operations. In fact, in many cases the support concept will be an integral part of the Concept of Operations. As a result, the LCLS team must work closely with other disciplines in the development of these concepts. Without external constraints this would be a simple matter. However, there are always constraints that must be accommodated. Some constraints are absolute and fixed. Others may be negotiable and adjustable through various trade-offs. The LCLS team must develop a support concept that is achievable within the boundaries established by the constraints. However, they should freely challenge constraints that are identified to determine whether they are truly fixed or adjustable. Examples of relevant constraints include:

- Budget limitations
- Inherent system reliability and redundancy
- Mass and volume capacity for in-flight spares and other logistics-related equipment and supplies
- Crew time available to perform life cycle support functions
- Crew capabilities
- Resupply opportunities
- Failed hardware return opportunities
- Other operational concepts

In addition to the primary focus on achieving the program objectives and support objectives, the support concept should also define the relative roles of Government personnel and contractor personnel in the execution of the concept. The appropriate assignment of roles may be different for various projects within a program. The Program LCLS team should define the role assignments at the Program level and what role assignments are acceptable - or what role assignments are not acceptable - at the Project level. With this guidance, the individual projects can select the approach that best meets their needs. It should be noted that these roles may shift over the course of the life cycle. If this is anticipated, it should be captured in the definition of the support concept.

**Program Support Requirements.** Once a support concept is defined, the LCLS team must develop technical requirements and programmatic requirements that will ensure that the system is designed so that it can be supported according to the support concept and that the infrastructure necessary to support the system will be established. Development of the technical requirements is, effectively, the beginning of the Design Interface element. These requirements must be developed collaboratively with the other functional areas to ensure that related and supporting requirements are compatible and that no conflicting requirements are introduced. These requirements must be developed by the time of the System Requirements Review (SRR).

The Program-level LCLS team is responsible for the process of allocating support requirements to subordinate projects for inclusion in their requirements sets. In the allocation process the Program-level LCLS team determines which Program-level support requirements are applicable to each project and, working collaboratively with the Project-specific LCLS teams, crafts applicable requirements statements specific to each project. In cases where a Program requirement specifies a summary quantity (e.g. total in-flight spares mass) that must be divided or distributed among two or more projects, the Program-level LCLS team leads the process of distribution in collaboration with the relevant projects.

From the SRR to the PDR, the LCLS team must work closely with the design team to make sure that the system hardware detailed design complies with the LCLS-related technical requirements that were baselined at the SRR. Additionally, the LCLS team must work closely with the designers to find design solutions that facilitate system maintenance in all operational environments (both during a mission and before launch) and consider total life cycle cost. A range of potential design solutions may be compliant with requirements but some might be more desirable than others. For example although a specific design may meet the technical performance requirements established for the specific system it may result in significantly greater life cycle support costs than alternative designs.

**Program Support Integration.** In Programs that include multiple projects the Program-level LCLS team plays a critical role in coordinating with all projects to make sure that the Projects develop support concepts and requirements that do not conflict with each other and that the total resources required for complying with the concepts and requirements do not exceed those available to the Program as a whole.

The Program-level LCLS team also coordinates common needs and activities of LCLS functions and LCLS teams across the program. This includes:

- Working with projects to define roles and responsibilities at points of functional intersection<sup>5</sup>
- Developing a common LCN scheme for use by all projects
- Establishing tools and mechanisms to enable the implementation of commonality across designs from different projects
- Facilitating common or consolidated procurements
- Facilitating the establishment of common or consolidated support facilities and other capabilities

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<sup>4</sup>This refers to periods when hardware from two projects are physically integrated or when hardware from one project is located at another project's primary geographic location.

**Program Integrated Logistics Support Plan.** During the period from SRR to PDR the LCLS team must develop the Program's Integrated Logistics Support Plan (ILSP) as discussed in Section 3. This document will be baselined at, or before, PDR. The ILSP defines the LCLS strategy that will be utilized in implementing the LCLS concept to meet LCLS objectives. The ILSP defines how the Program will address each of the LCLS elements through each phase of the Program. This should include the technical approaches as well as organizational aspects. Organizational aspects address the relative role of Program and Project LCLS organizations and the relative roles of Government and contractor LCLS teams. The ILSP is updated at subsequent Program milestones as appropriate.

#### 4.2.2 Implementation Phase

During the Implementation phase of a tightly-coupled program the Program-level LCLS team provides information to the Program Manager on the status of overall LCLS efforts across the program. This includes:

- Schedule and budget status of all LCLS activities.
- Projected life cycle sustainment costs (e.g. spares, repairs, manpower).
- LCLS-related risks to the Program such as unanticipated costs, supplier/vendor viability issues, and increases in mass or volume requirements for flight spares to meet availability requirements.

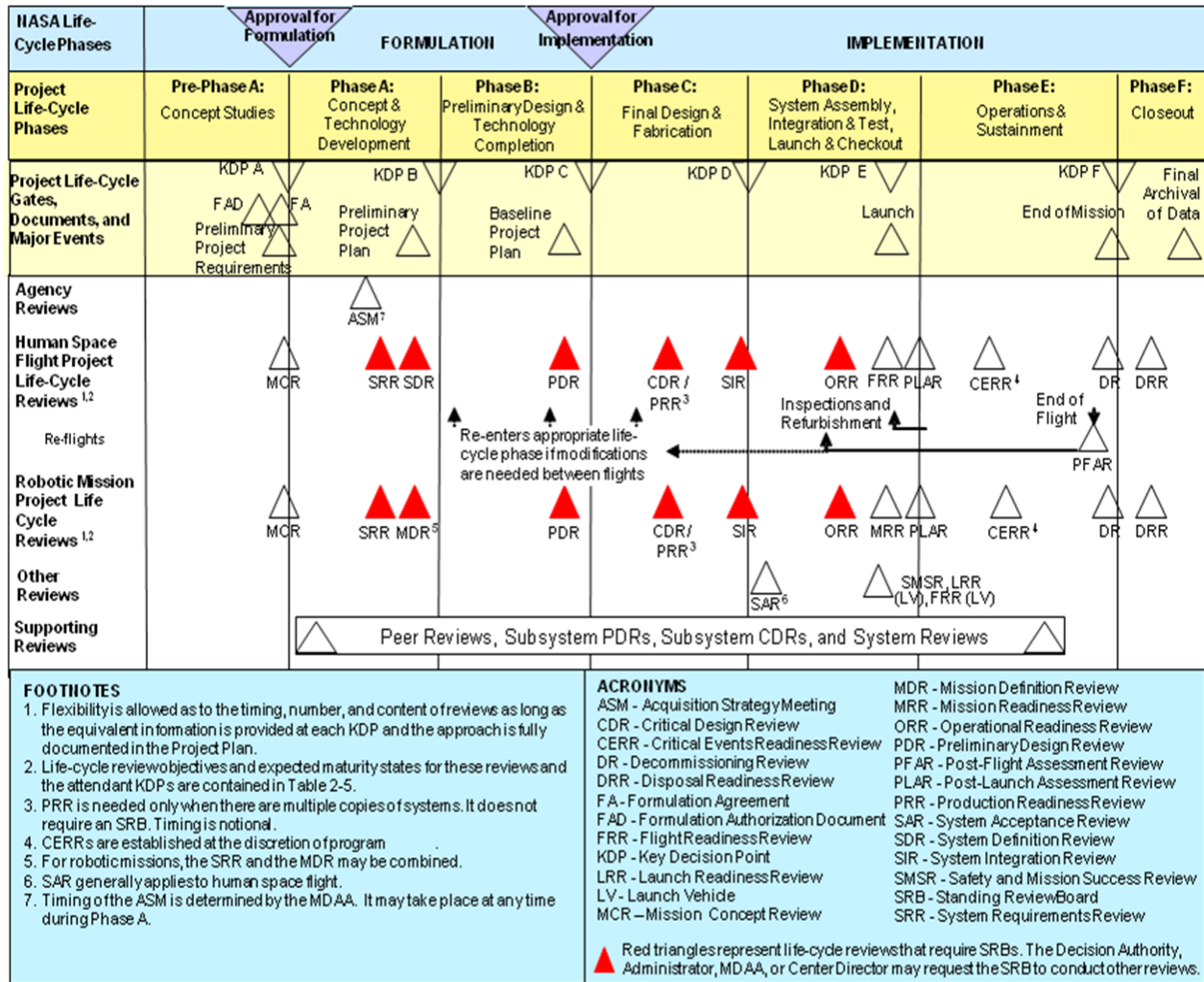
The Program-level LCLS team performs an overall integration function to ensure that all Project LCLS team activities are consistent with the Program's LCLS objectives and implementation and with other Project LCLS efforts. At the same time, it is not necessary for the Program-level team to serve as an intermediary in all Project-to-Project LCLS activities - although they should maintain awareness of these interactions. Additionally, the Program-level LCLS team establishes and maintains LCLS infrastructure used by all of the Projects - such as LCLS data management systems, common depot repair facilities, and other facilities and capabilities that may be used by multiple Projects.

During the course of a Program it may become necessary to update operational concepts and associated system support concepts. The Program-level LCLS team updates the Program support concept as necessary when conditions require.

The Program-level LCLS team ensures that processes are in place to monitor contractor viability throughout the supply chain. The processes should be implemented at the level at which Government contracts are established (i.e. at the Program level or the Project level). The relative roles of the Government and prime contractors in supply chain monitoring processes may vary depending upon the capabilities of the prime contractors. Therefore this function may be executed differently for the various subordinate projects. The topic of allocation of roles and responsibilities between the Government and the contractors in this area is addressed in much greater detail in Appendix X (*this app is the LMI report*).

### 4.3 Project Functions

The figure below is for individual projects.



NASA Project Life Cycle (NPR 7120.5E, Figure 2-5)

#### 4.3.1 Formulation Phase

##### 4.3.1.1 Pre-Phase A: Concept Studies

##### 4.3.1.1.1 Technical Activities

**LCLS Strategy.** Develop a preliminary LCLS strategy for each life cycle phase, consistent with the Program support concept, to serve as the basis for estimating life cycle costs associated with LCLS, development of schedule baselines, and to serve as the basis for developing

associated programmatic and technical requirements. This preliminary support strategy may be documented in the MCR briefing package.

The support concept should be defined such that it complements the overall mission architecture and Concept of Operations (ConOps). It should consider both ground operations and flight operations. Fundamental issues to consider for in-flight support include mission duration, system fault tolerance, inherent reliability, mass and volume capacity for spares, resupply opportunities, and crew time constraints. Additional considerations include defining appropriate levels of maintenance for in-flight operations and the potential benefits of system hardware commonality for reducing total spares requirements.

The LCLS team must develop a concept that is achievable within the boundaries established by existing constraints. Examples of relevant constraints include:

- Budget limitations
- Inherent system reliability and redundancy
- Mass and volume capacity for in-flight spares and other logistics-related equipment and supplies
- Crew time limitations
- Crew capabilities
- Resupply opportunities
- Failed hardware return opportunities
- Other operational concepts

Ground operations considerations should include both direct support of flight hardware and support of launch systems and other associated ground facilities. In the former case, the potential for flight hardware repair and refurbishment will lead to decisions about where these operations would be performed (e.g. at the launch pad, in hardware integration facilities, or in depot-level repair facilities - either on-site or remote) and whether they are performed directly by Government personnel or by contractors.

**Requirements Development.** Requirements development begins in Pre-Phase A after Authorization to Proceed (ATP) and continues through the System Requirement Review (SRR) in Phase A. The LCLS goals during this phase are to influence the design for supportability through logistics requirements definition.

The LCLS team develops preliminary LCLS requirements to be included in project management requirements and technical requirements. The support requirements must be developed in the context of the support concept and the larger Concept of Operations. Requirements may include life cycle cost, operational availability, constraints on in-flight spares mass and volume, design to specific accessibility demands, design to specific sets of tools and other support equipment that will be available, or others specific to the needs of the project. The objective of the requirements is to ensure that the hardware systems are designed so the support concept can be implemented. All support requirements should be clearly related to the achievement of program and project objectives and minimization of life cycle cost.

Minimizing LCC must be one of the primary objectives during development of requirements and during review of the concept of operations, specifications, drawings and other documents. These



documents will be canvassed to identify cost drivers for further scrutiny. Supportability cost drivers will be identified to the project team and the appropriate function (e.g. design engineering) so these cost drivers can be addressed and eliminated or at least minimized. Trade studies will be monitored and the LCLS team will use a tailored LCC tool (Refer to Appendix X, ) to assess trade options and identify the most supportable option with the lowest life cycle cost.

The LCLS team begins initial supportability assessments, ensures that supportability requirements and recommendations are considered in initial design activities, and that supportability constraints are addressed. The LCLS team continuously reviews the hardware architecture as it develops to identify and refine the maintenance concept for each hardware item.

Not all parameters will be known at this early stage of project development so assumptions must be made and documented. Initial results will provide a Figure-of-Merit comparison between trade options and identify an anticipated life cycle cost for each option. Logistics recommendations will be presented to the project team so they can be addressed. Significant supportability LCC concerns should be identified as project risk - resulting in their inclusion on a watch list - and a risk mitigation plan developed. This process will be repeated throughout the design cycle as the design matures and may result in periodic re-assessment of the LCC to refine the relative figure-of-merit cost of each option.

### **4.3.1.1.2 Milestone Reviews**

**Mission Concept Review (MCR).** At the time of the MCR initial LCLS concepts should be available for review by all interested program participants. The LCLS team should also participate in the review of other plan and concepts that are available to ensure that there are not conflicts and that all concepts are consistent and supportive.

### **4.3.1.1.3 Organizational Activities**

An important aspect of the support concept is definition of the roles and responsibilities of the participating parties. These parties may include government organizations (e.g. the Program Office, Project Office, line organizations of NASA field centers), the development contractor(s), and sustaining operations contractors - if applicable. It is also important to keep in mind that the roles of the participants may change and evolve over the course of the program/project life cycle.

Early definition of these roles and responsibilities throughout the life cycle is important since the associated costs can be a significant component of the total life cycle sustainment cost. During the Concept Studies Phase the LCLS management should define expectations for contractor involvement since this can be a significant factor in contractors' proposals and the total projected Project cost.

#### 4.3.1.2 Phase A: Concept and Technology Development

##### 4.3.1.2.1 *Technical Activities*

**Requirements Development.** The process of defining end item support requirements and operational constraints continues as the design evolves. Project LCLS personnel should work closely with the corresponding Program LCLS personnel to ensure appropriate flowdown through the allocation process of LCLS requirements to the project. The logistics requirements for a particular system or piece(s) of hardware are significantly influenced by the system design (particularly the inherent reliability and maintainability of the design) and by the maintenance concept (e.g., repair by component replacement, repair in-situ, off-equipment repair in a depot facility, etc.). The appropriate trade-off decisions can be most effectively made early during concept development and design. Development of requirements should be completed by the SRR. Examples of LCLS requirements are included in Appendix B.

The LCLS team should maintain continuous awareness of all requirements as they are developed and matured since many requirements that are not "owned" by the LCLS team may have a significant influence on the LCLS concept and LCLS requirements. The LCLS team should actively engage with other discipline teams to address potential conflicts and impacts to arrive at a set of requirements that provides the best overall solution for the program or project.

##### 4.3.1.2.2 *Milestone Reviews*

Two milestone reviews occur during Phase A. These are the System Requirements Review (SRR) and the System Definition Review (SDR). These reviews and the role of the LCLS team in the reviews are discussed in the following sections.

**System Requirements Review (SRR).** The objective of this review is to ascertain the adequacy of the project's system requirements - including LCLS requirements. In addition, the LCLS team should perform an overall assessment of the project from the LCLS perspective.

Specific life cycle logistics success criteria to be considered at SRR:

1. Have requirements for reliability, availability, commonality, maintainability, transportability, and standardization been identified?
2. Are the requirements verifiable?
3. Have Logistics / Supportability and non-Logistics Requirements Been Accepted by the Project / Design?
4. Have Trade Studies / Analyses Included Supportability Requirements / Constraints?

5. Has crew time for maintenance been predicted / identified?
6. Have opportunities to reduce logistics resource footprint been identified?
7. Has system life cycle cost been estimated and have opportunities to reduce it been identified?

**System Definition Review (SDR).** The primary product provided by the LCLS for the SDR is the Preliminary ILSP. This document should be as complete as possible to allow all interested parties to review and comment on initial LCLS concepts and plans. It is of very limited value if it consists only of section titles and generic content. This is only a preliminary version so it should be expected that it will change significantly before it is baselined during the period leading up to the PDR.

The LCLS team should actively participate in the SDR process - beyond just providing the preliminary ILSP. They should closely monitor concepts for system design as they develop to ensure that the support concept remains valid and that no unsupportable system concepts are introduced. Ideally, any issues will be identified and resolved during the daily course of business. Any remaining unresolved issues must be raised during the SDR comment and resolution process.

#### **4.3.1.2.3. Organizational Activities**

**LCLS Team.** During this phase the LCLS manager should define the staffing requirements for the LCLS team. This includes defining functions to be performed by the team, the number of personnel required to perform these functions, and the schedule for when the personnel must be available. Staffing needs may change over the life of a project.

**Contractor Interface.** During this phase the LCLS relationship with the primary contractors should be clearly defined and implemented through contractual mechanisms. The roles, responsibilities, and functions of the contractors during the design, development, and operational periods of the project should be clearly defined. All data and other deliverables (both content and delivery schedule) required by the Government LCLS team from the contractors should be identified in detail and defined in the contract.

### **4.3.1.3 Phase B: Preliminary Design & Technology Completion**

#### **4.3.1.3.1 Technical Activities**

The design development phase begins after SDR and continues through successive design reviews until the final design is accepted for production. The goal of the LCLS effort is to complete supportability assessments and assure that supportability recommendations / solutions are considered and implemented into the design. The LCLS team will begin this process by having a thorough understanding of the specification requirements and helping the Project Team to ensure the requirements are consistent with the Concept of Operations. The LCLS team will review the hardware architecture as it matures and develop or refine the maintenance concept for each hardware item. As the Project progresses, the LCLS team will use the maintenance concept as the basis for development of plans and outputs that optimize supportability of the Project hardware at the least life cycle cost.

**ILSP.** The ILSP should be finalized and formally baselined by PDR. During this phase the project LCLS team begins execution of the activities defined in the ILSP. Even prior to the official baselining of the ILSP, it is necessary that activities defined therein be initiated.

**Design Support - Influencing Design to Reduce Life Cycle Cost.** The LCLS team will continue to assess cost drivers as the design is refined. Several iterations of the Life Cycle Cost (LCC) assessment will be performed during the design phases of the projects. LCC assessments can also be used to support design trades. LCC results will be updated as required during development phases.

Additionally, the processes used to identify candidates for in-flight Organizational-level maintenance and in-flight Intermediate-level maintenance (discussed further in following paragraphs) generate outputs that can identify opportunities for hardware redesign that may result in reduced cost for spares and reduced mass and volume demand for in-flight spares.

As the system design is maturing the LCLS team must maintain continuous awareness of the system architecture and the components of which it is comprised. The LCLS team should engage with the designers when they identify situations where design modifications or alternative design solutions could enhance the supportability of the system and reduce total life cycle cost.

**Maintenance Concept and Planning.** For flight systems the LCLS team should begin identifying the preferred maintenance approach for each hardware item. Is the item an ORU and, thus, must be removed and replaced in its entirety? Is there an opportunity to repair the item during the mission - thus creating an opportunity for Intermediate-level maintenance? Must maintenance actions be performed in situ? Examples would be replacement of connectors and repair of structure. Examples of the processes used to identify candidates for in-flight Organizational-level maintenance and in-flight Intermediate-level maintenance are included in Appendix ZZZZ. Consideration must also be given to requirements for preventive maintenance actions and servicing activities. All of these possibilities lead to determination and acquisition of required spares and replacement parts, materials, tools, support and test equipment, and maintenance procedures.

For hardware items that fail during a mission, consideration should be given to whether it is possible and desirable to return them to the ground for repair and reuse. This is an unlikely possibility for missions other than Earth-orbital missions. However, when this is an option, plans must be defined for performing the repairs after the return of the failed items. Will this be done in a Government facility or will it be done in the facility of the OEM that produced the item? In either case, advance planning is required to establish the capability.

The following are the key factors that need to be addressed in developing a Preliminary Hardware Ground Maintenance Approach and Recommendation:

- ORU/LRU Cost
- Historical Cost to repair for same or similar HW (if applicable)
- Repair frequency estimates for same or similar equipment (MTBF estimates if available)
- Remaining life of the program or project (baselined and extended Program life durations being considered)
- Lifetime Buy of Spares (cost)

- Level of HW failure Testing and Diagnosing required/desired:
  - ORU Level
  - Sub-ORU
  - Component Level
- Level of HW repair required/desired:
  - ORU Level
  - Sub-ORU
  - Component Level
- Depots/OEMs that can perform the work
- Skills required to perform Ground Repairs
- Procedures required to perform Ground Repair (cost)
- Certifications Required to perform Ground Repair (certification process and cost)
- Available Test Equipment and Tooling
- Special Test Equipment (STE) or Tooling required (including identifying the cost of equipment not available)
- List of material(s) required to support Ground Repairs

Additional analyses and trade studies to be completed include:

- Trade of Lifetime Spare buy vs. Estimated Cost to Repair for Program life (Repair costs to include cost of STE, Retention Contract, estimated Repair costs for ORUs, parts and SRU inventory, OEM/Depot Certification, Transfer of equipment, estimated TT&E costs and any other relevant repair costs).
- Repair and Retention Cost Trades for OEMs/Depots which could perform the work (Repair costs to include cost of STE, Retention Contract, estimated Repair costs for ORUs, parts and SRU inventory, OEM/Depot Certification, Transfer of equipment, estimated TT&E costs and any other relevant repair costs).

**Supply Support.** During this phase the LCLS team should determine their approach to acquisition of spares - the Supply Support element of LCLS. Will they purchase sufficient spares produced in conjunction with initial production (Spares Acquisition with Initial Production - or SAIP) to meet the projects needs for the duration of its service life or will they acquire spares throughout the life of the project. If the former, how will they deal with possible redesign of items for which they have already procured spares? How will they respond if failure rates are greater than expected and additional spares are needed in the future? These are the types of issues that must be considered and for which a clearly articulated strategy must be developed. Various potential provisioning strategies are detailed in section 3.2.3.

**Packaging, Handling, Storage and Transportation (PHS&T).** The LCLS team should begin developing a PHS&T plan to support project hardware. Factors to consider include schedule constraints, potential transportation modes, and cost.

The LCLS team should also begin performing a detailed PHS&T assessment of project hardware. Each item that will be shipped or stored should individually undergo a PHS&T assessment. The objective of the PHS&T process is to protect hardware items from damage and/or deterioration due to shock, vibration, thermal, vacuum, and other environmental conditions under nominal transportation and ground storage conditions. This assessment must consider transportation constraints arising from inherent characteristics of the hardware such as

size, mass, sensitivity to environmental factors (e.g. shock, vibration, temperature) and hazardous materials. An example of a PHS&T checklist is provided in Appendix F.

**Logistics Information Management.** The LCLS team must establish the processes and capabilities that will be necessary to manage and control the various LCLS functions that will be implemented. This includes management of large quantities of information and data about the hardware that is necessary to enable execution of the planned logistics-related functions.

#### **4.3.1.3.2 Milestone Reviews**

**Preliminary Design Review (PDR).** The PDR demonstrates that the preliminary design meets all system requirements with acceptable risk, within cost and schedule constraints, and establishes the basis for proceeding with detailed design. It confirms that the correct design option has been selected, interfaces have been identified, and verification methods have been described. Full baseline cost and schedules, as well as risk assessments, management systems, and metrics are presented. The LCLS team plays an active role in the PDR.

Typical LCLS-related PDR success criteria include affirmative answers to the following exit questions:

- Can the preliminary design, as disclosed, satisfy the draft logistics / supportability requirements?
- Have all opportunities for minimizing total life cycle cost been implemented?
- Have long-lead items and key supply chain elements been identified?

The LCLS team provides the outputs listed below for the PDR. The intent is for the Project Team to review these outputs and accept them as part of the Project planning baseline. At this Phase, these outputs are consistent with the level of detail in the hardware design. They should have enough detail so that the Project Team has a good understanding of how the hardware will be supported, and the size / cost of the infrastructure that will be required.

- Recommended Design Changes / Considerations
- Preliminary Maintenance Concept
- Preliminary Levels Of Repair
- Life Cycle Cost (LCC) Update
- Preliminary Hardware Ground Maintenance Approach Options and Recommendations
- Performance Schedule
- Initial Functional Availability Assessment
- Initial Spare Parts List
- Initial PHS&T Requirements and Plans

Supportability-related data needed for development of LCLS outputs include:

- Design Safety
  - Hazard Analyses
  - Failure Modes Effects Analysis (FMEA)

- Margins of safety between functional requirements and design provisions.
- Design Reliability
  - Sources of failure rate data including predicted failure rates and duty cycles.
  - Reliability prediction methods.
  - Parts or components that have a critical life limit or require special consideration.
- Design Maintainability
  - Preventive maintenance schedules.
  - Accessibility, testability, and ease of maintenance.
  - Provisions for diagnosing cause of failure and means for localizing the failure.
  - Degree to which the system has been optimized from a maintenance and maintainability viewpoint in order to ensure that the system is supportable utilizing the approved maintenance concept.
- System Availability / Supportability requirements
- Assessment of adequacy of allocations (e.g., mass and volume for spares, tools, and test equipment; crew time required to perform maintenance, etc.) to meet availability / supportability requirements and provide an operational margin to deal with unanticipated failures while ensuring crew safety and mission success.

#### **4.3.1.3.3      *Organizational Activities***

**LCLS Team Collaboration.** During Phase B the Government LCLS team and the contractor(s) LCLS teams should maintain a collaborative relationship. However, it is important that the Government team respects the need for the contractor team to implement the responsibilities defined in their contract without interference.

**Supplier Viability Monitoring.** An important issue to be addressed is the process for monitoring supplier viability to provide early awareness of supplier problems that could pose a threat to the project. A variety of approaches are possible. The choice of the preferred approach will largely be based on the maturity and capabilities of the primary contractor. This is detailed further in Appendix A.

#### **4.3.1.4          Phase C: Final Design & Fabrication**

##### **4.3.1.4.1      *Technical Activities***

Much of the technical activity during this phase is a continuation of that begun in previous phases. As the system's hardware design matures, new items are incorporated into the design and previously identified items become better understood and associated data and information is more complete.

**Maintenance Concept and Planning.** The LCLS team will refine the maintenance concept and repair levels as more data become available and as the design becomes more defined. The documented initial maintenance concept / repair levels will be updated. Also, the Preliminary Hardware Ground Maintenance Approach and Recommendation will be updated as new, more detailed information becomes available. This assessment will compare the OEMs / Depots capable of performing the required repair work (and address technical capabilities and projected costs); and, the Recommendation will identify the OEM/Depot selected for the repair work and

shall be the result of engaging participants with a vested interest (“stakeholders”) in a series of collaborative working group meetings.

**Logistics Support Analysis.** Logistics Support Analysis is initiated as early as possible in the design / development cycle and documented in the Logistics Support Analysis Record (LSAR). The process is iterative and the fidelity is consistent with the maturity of the design and release of the source data available. The methodology for performing the analysis is defined in:

AeroSpace and Defense Industries Association of Europe (ASD) S3000L,  
International Procedure Specification for Logistics Support Analysis (available at <http://www.asd-stan.org/s3000L.html>).

The specifications for documenting the LSA in the LSAR are contained in:

Government Electronics Industry Association (GEIA) GEIA-STD-0007, Logistics Product Data (available at <https://standards.nasa.gov>).

**Illustrated Parts Breakdown (IPB) Drawings.** Once the hardware designs are completed and the Maintenance Task Analysis has been completed as part of the LSA, IPBs can be prepared. The IPBs are isometric drawings that illustrate components and key interfaces relevant to maintenance procedures. Generally, these will be produced by the contractor organization - and thus must be specified as a required deliverable.

#### **4.3.1.4.2 Milestone Reviews**

**Critical Design Review (CDR).** The CDR is the only milestone review during this phase. The LCLS team provides the products listed below for the CDR. It is intended that the Project Team will review these and accept them as part of the Project planning baseline. These outputs are consistent with the level of detail in the hardware design. They should have enough detail so that the Project Team has a full understanding of how the hardware will be supported, and the size / cost of the infrastructure that will be required.

- Maintenance Concept / Plan (Update from PDR)
- Life Cycle Cost (LCC) (Update from PDR)
- Levels Of Repair (Update from PDR)
- Hardware Ground Maintenance Approach / Plan (Update from PDR)
- Functional Availability Assessment (Update from PDR)
- Indentured Parts List
- PHS&T requirements and plans (Update from PDR)
- Pre-production On-Orbit Supportability Data (LSAR/IPB)
- Support Equipment Requirements
- Facility Requirements
- Initial Sparing Assessment
- Initial Obsolescence Assessments

Typical CDR success criteria include affirmative answers to the following exit questions:

- Does the design provide the lowest supportability cost?



- Has an integrated logistics assessment been identified and implemented?
- Are long-lead procurement plans in place and has the supply chain been assessed?
- Has LSA documentation been updated to reflect the most current engineering
- Is the Level of Repair Analysis (LORA) complete or is an update required?

### **4.3.1.4.3 Organizational Activities**

The LCLS team should ensure that processes are in place for acquisition of spares and other materials, that plans for depot maintenance operations are defined and implemented, that all deliverables required from the contractor(s) are on schedule and of adequate quality. Team members should begin shifting their focus from development activities to operations. They should be working closely with their contractor counterparts to ensure that they are prepared to transition to the operational phase of the project.

### **4.3.1.5 Pre-Delivery Phase (Through DD250) (Phase D)**

The primary objective of the Pre-Delivery Phase is to finalize and complete assembly, integration, test; closeout documentation; verify that project requirements have been met; and deliver production units. The contractor LCLS team may be required to support the system during these processes. An additional logistics objective of this phase is to ensure logistics elements are in place to support end-items (establish interim support provisions, as necessary).

**Physical Configuration Audit (PCA).** During this phase, the Physical Configuration Audit (PCA) is completed. The PCA is a technical examination of the designated system design configuration to verify that the physical, “as is” product conforms to all the technical documentation that describes it. The PCA is typically conducted on the first production article. After successful completion of the physical evaluation of the product design, the product baseline is frozen and all subsequent product changes should be incorporated only through the formal change board process. The PCA involves a detailed evaluation of the product technical documentation, engineering drawings, specifications, and parts listings that are utilized in the operation and logistical support of the product to verify that these documents accurately describe the “as is” product.

**LCLS Output for the Pre-Delivery Phase (DD250).** The LCLS team provides the updated / final outputs listed below prior to DD250. The intent is for the Project Team to review these outputs, and after review accept these as part of the Project completion baseline. At this Phase, these outputs support manufacturing and operations. Post DD-250 infrastructure should be fully defined, and in place to the extent necessary to support initial activation and sustaining operations.

- Maintenance Concept / Plan (Update from CDR)
- Hardware Ground Maintenance Baseline / Plan (Update from CDR)
- Functional Availability Assessment (Update from CDR)
- Parts List (Update from CDR)
- Final PHS&T requirements and plans (Update from CDR)
- Obsolescence Assessments (Update from CDR)

- Requirements Closure
- Baselined LSAR / IPB & Validation Records

**Conduct LSAR / IPB Reviews.** The LCLS team reviews the LSAR and IPB provided by the contractor to ensure that the products meet the quality standards of the end user. This review is performed in conjunction with the NASA and contractor Subject Matter Experts (SME) within the contractor and/or NASA Engineering systems team, Safety, and subcontractor organizations.

**Finalize LSAR / IPB Documentation.** The finalization of the LSAR / IPB documentation is contingent on two major factors; 1) The release of required source data (drawings, imagery, test reports, fitchecks, etc) where initial analyses can be completed, and 2) The review and acceptance of the products by the NASA customer. The NASA customer accepts the maintenance data, which is the combination of the LSAR and IPB, by signing a Validation record. All participants in the external review sign the Validation record, which defines the ORUs and / or SRUs with their applicable maintenance tasks along with the IPB. The Validation Record can be signed with comments (open issues) so that the TD&D can be delivered to MOD for immediate utilization (source data for SODF development).

**Finalize Imagery.** Available imagery is referenced within the LSAR as part of the RD&D. The imagery is documented and referenced to specific maintenance tasks in order to provide the crewmembers performing maintenance on-orbit any information that may help during those activities. Specific images are collected and maintained by the ISS program Imagery Working Group (IWG).

**Finalize PHS&T Planning.** The initial PHS&T document is evaluated for updates at CDR-30 days and submitted for final integration into the Logistics Supportability Analysis Record.

**Finalize On-Orbit Maintenance Plan.** The LCLS team performs on-orbit maintenance planning and manifesting in coordination with traffic models. This is in support of preventive maintenance and limited life requirements, resupply of consumable hardware, and return or disposal of hardware.

**Baseline Hardware Ground Maintenance Approach.** The Product Support Depot Maintenance and Repair (DM&R) function is responsible for developing the Baseline Hardware (HW) Ground Maintenance Approach and Recommendation. This final HW Ground Maintenance Approach and Recommendation will be complete and comprehensive. The Recommendation shall be the result of engaging participants with a vested interest (“stakeholders”) in a series of collaborative working group meetings. The Recommendation shall also identify forward work to be completed if there are any “open items”, and contain a list of mutually agreed upon and “accepted” action items and completion dates.

**Baseline Sparing Assessment.** Determine the range and depth of spares needed to support the confidence levels defined in the Functional Availability Assessment. In addition, the Repair Level Analysis (RLA) results and the development of the maintenance concept are used to determine what level of sparing is required to support repairable vs. non-repairable philosophy.

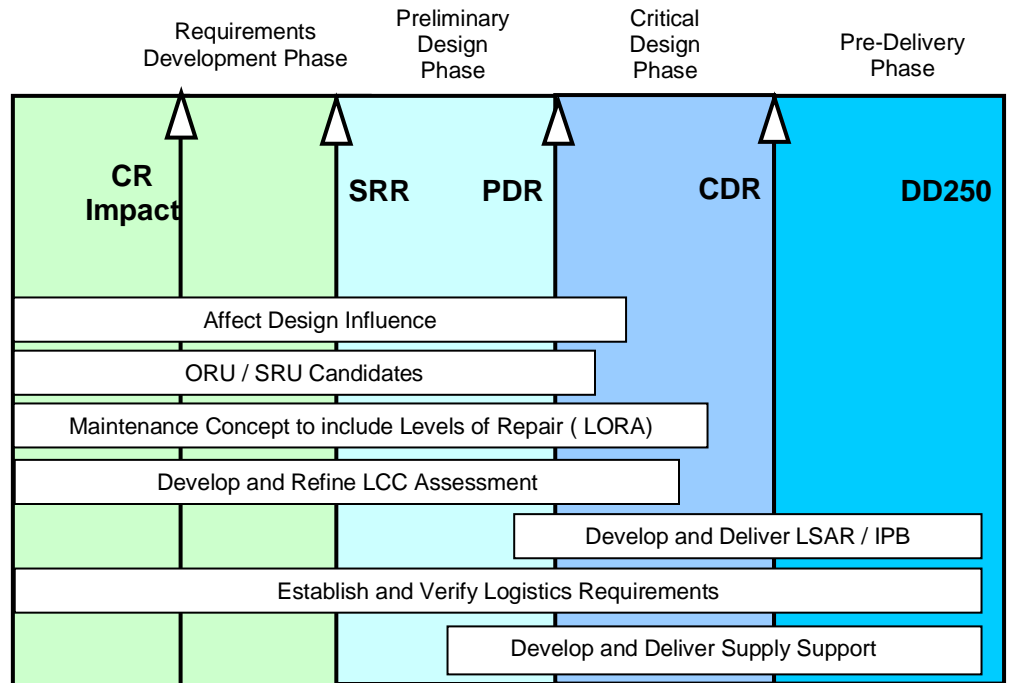
**Develop Indentured Parts List (IPL).** The development of an Indentured Parts List (IPL) is needed to breakdown the various levels of indenture which supports in the determination of what

parts are mapped to what sub-assembly. To the extent possible, the source control drawings for all parts will be broken down to the lowest possible level, identifying the true manufacturers' generic part number. This will enable the Program to promptly identify obsolescence concerns, as well provide a record of single source suppliers.

**Update Obsolescence Screening.** Once developed, the IPL will be loaded into the obsolescence database and the data screened for any issues. A comprehensive obsolescence assessment will be performed with a goal of identifying any parts that have become obsolete during the design and build of the hardware. Additionally, parts that are nearing the end of their life cycle will be identified.

**Update Functional Availability Assessment.** If there have been any changes to reliability data, spares data, or function or ORU confidence or POS target, then repeat simulations outlined in section 8.8 as needed to update results.

### Hardware Development Phases and Product Support Activities



TASK SUMMARY OUTPUT	Requirements Development Phase	Preliminary Design Phase	Critical Design Phase	Pre- Delivery Phase
Set of Requirements	X			
Trade Study Findings	X			
LCC Assessment	X	X	X	
Recommended Design Changes/Considerations	X	X	X	
Functional Availability Targets / Assessments		X	X	X
RIDS/RID Closures	X	X	X	X
Maintenance Concept	X	X	X	
Repair Levels		X	X	
Ground Hardware Maint. Approach/Plan		X	X	X
Performance Schedule		X	X	
Parts List/IPL		X	X	X
PHS&T		X	X	X
Pre-Production On-Orbit Supportability Data			X	X
Support Equip. Requirements			X	X
Facilities Requirements			X	X
Sparing Assessments			X	X
Obsolescence Assessments			X	X
Requirements Closure				X
LSAR/IPB & Validation Records				X

**Figure 4-1 – Hardware Development Phases and Product Support Activities.**

(Logistics Outputs are in no particular order)

#### 4.3.1.6 Phase E: Operations & Sustainment

During the Operations and Sustainment Phase the LCLS team implements the processes defined in the ILSP. Key activities include ongoing supply support efforts, overseeing depot maintenance operations, integrating with other project organizations to manifest spares for on-orbit systems, supporting in-flight maintenance, gathering performance data on operational systems to enable refined projections of logistics support resource needs, and implementing the ILS process for new hardware and systems.

**4.3.1.7 Phase F: Closeout**

When a project comes to the end of its life cycle, the LCLS team must support decommissioning and property disposal activities. Participation by the LCLS team is essential to ensuring that the proper disposal sequence is followed to be sure that items are not disposed of prematurely. The team can also be instrumental in helping to identify potential alternative uses for project hardware by other programs and projects.

## APPENDIX A: Supplier Viability Risk Management<sup>6</sup>

**NASA Role in Supplier Risk Management.** NASA has a mixture of programs that are managed by either NASA or a prime contractor. It is inevitable that NASA and its various prime contractors will have different approaches to supplier risk management and even different capabilities. Further, NASA’s primes may have supply management programs at different stages of development.

As such, NASA has three basic program structures:

- Programs led by a prime contractor with a well-developed supplier management program, which we will define as a “mature prime”
- Programs led by a prime contractor without a well-developed supplier management program, which we will define as a “novice prime”
- Programs led by NASA.

Being classified as “mature” does not mean a contractor has been in existence for a long time or has experience with large number of contracts. The classification is solely defined by the development and reliability of the contractor’s supplier management program.

The three basic program structures are important, because the approach to managing supplier viability and risk changes depends on the structure, as shown in Figure 3-1.

**Figure A-1. Risk Management by Program Management Type**

	<b>Mature Prime</b>	<b>Novice Prime</b>	<b>NASA Prime</b>
<b>NASA Role</b>	<i>Monitor</i>	<i>Mentor</i>	<i>Manage</i>
<b>Risk Management Responsibility</b>	<i>Prime</i>	<i>Prime</i>	<i>NASA</i>
<b>Level of NASA Involvement</b>	<i>Low</i>	<i>Moderate</i>	<i>High</i>

A prime contractor has responsibility for supplier risk, since it holds the supplier contracts. The contractor may operate its own supplier risk management processes, but it must be able to provide NASA with the specific reports and metrics it requires. When the prime contractor is a novice prime (i.e., the contractor does not have a well-developed supplier management program), NASA should take more control over the monitoring of supplier viability to supplement the

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<sup>6</sup> The material in this Appendix is adapted directly from LMI Report NS106TI, *Strategies for Mitigating NASA's Supplier Viability Risk*, produced under contract.

prime contractor's capabilities. Naturally, if NASA is the prime integrator for a program, then NASA must take full responsibility for supplier viability management.

**Depth of Risk Mitigation.** A common concern for a supplier risk management program is determining how deeply to monitor and mitigate supplier risk within the supply chain. Maximum risk mitigation would lead programs to engage with suppliers as deeply as possible within the supply chain; however, constraints stemming from privity of contract and program office resources will limit the feasible depth of engagement.

The challenge is that critical suppliers may be two, three, or more tiers into the supply chain, and NASA and its prime contractors may not have the ability to influence suppliers at that level. In addition, the number of suppliers can grow exponentially at each succeeding tier within the supply chain, thus creating severe workload limitations.

These limitations make it imperative for NASA to prioritize suppliers based on their criticality. Risk management resources should be focused on suppliers of critical items, where a disruption in the supply can significantly impact the program.

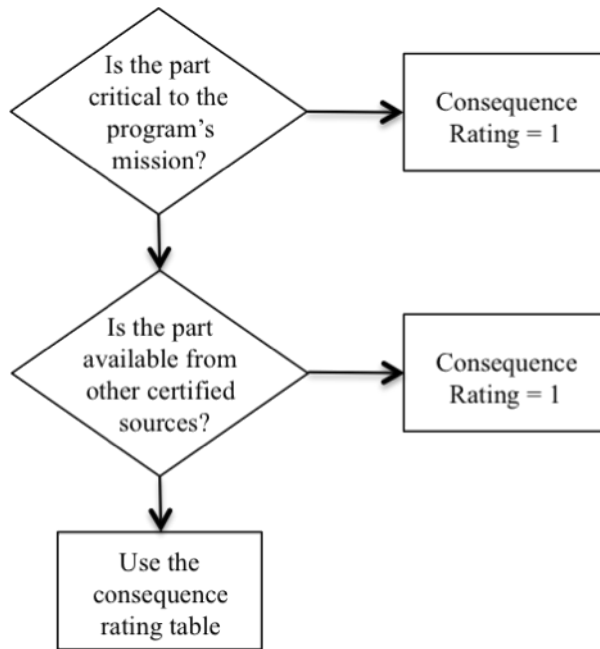
Management of suppliers deeper in the supply chain should be consistent with the overall risk management program in terms of monitoring and mitigation methods, as well as the responsibilities for engaging the suppliers. NASA should consider the risk management expertise available within the supply chain and work with prime and sub-tier suppliers to ensure that risk is sufficiently managed without duplication of effort.

**Methodology for Risk Quantification and Mitigation.** Supplier viability risk can be defined in terms of "consequence" and "likelihood". Risk consequence measures the effect of a particular risk. In the case of supplier viability, risk consequence is synonymous with the impact of a supplier's failure on a program. The consequence is directly related to the criticality of the items provided by the supplier to the program's mission. In general, if the loss of supply for an item will affect the success of the mission, then the item is critical.

Supplier risk consequences can be assessed based on a decision tree, which considers the criticality of the part being supplied and the number of certified suppliers that can provide that part. This decision tree is shown in Figure 4-1.

If a supplier is not critical or has multiple sources, then its consequence rating is 1. If the supplier is critical, then we use a metric that consists of the number of days of supply for the item that NASA has in its inventory, divided by the amount of time (in days) needed to certify and start receiving the same product from a new supplier. For items with significant technical complexity, the time to certify and start production with a new supplier should be multiplied by 1.2 to reflect uncertainty involved in complex production.

*Figure A-2. Consequence Rating Decision Tree*



If a supplier is not critical or has multiple sources, then its consequence rating is 1. If the supplier is critical, then a "criticality index" metric is used that consists of the number of days of supply for the item that are in inventory, divided by the amount of time (in days) needed to certify and start receiving the same product from a new supplier. For items with significant technical complexity, the time to certify and start production with a new supplier should be multiplied by 1.2 to reflect un-certainty involved in complex production.

The consequence rating for suppliers—on a 1-to-5 scale—is based on the schema defined in Table A-1. The rating represents the severity (or impact) of a supplier's loss of viability.

***Table A-1. Risk Consequence Rating Scheme***



<b>Consequence Rating</b>	<b>Qualitative consequence rating definition</b>	<b>Criticality index*</b>
1 (Low)	<ul style="list-style-type: none"> <li>• Minor cost increase that can be absorbed within budget</li> <li>• Minor schedule variance with no milestone impacts</li> <li>• Minimal reduction in technical performance</li> </ul>	>1.5
2 (Minor)	<ul style="list-style-type: none"> <li>• Cost exceeds budget, but sufficient funds available</li> <li>• Schedule slip, no major delivery impact</li> <li>• Minimal reduction in technical performance</li> </ul>	1.2 to 1.5
3 (Moderate)	<ul style="list-style-type: none"> <li>• Cost exceeds budget and funding increase may be necessary</li> <li>• Significant schedule slip that is partially recoverable at program level</li> <li>• Some operational requirements may not be met</li> </ul>	1.0 to 1.2
4 (Significant)	<ul style="list-style-type: none"> <li>• Cost exceeds budget and funding increase is necessary</li> <li>• Significant slip in schedule and delivery likely to be impacted</li> <li>• Mission success questionable</li> </ul>	0.8 to 1.0
5 (Severe)	<ul style="list-style-type: none"> <li>• Large funding increase necessary</li> <li>• Major impact to schedule</li> <li>• Mission success unattainable</li> </ul>	<0.8

\* Inventory (in days) /certification time (in days)

Risk likelihood is defined as the probability or frequency that a risk may occur. In terms of supplier viability, risk likelihood represents the level of certainty that a supplier will experience a loss of viability. Likelihood is based on the set of metrics that are defined in Table A-2

**Table A-2. Metrics for Assessing Risk Likelihood**

Metric	Definition
Regulatory burden	A qualitative assessment of suppliers operating in a highly regulated industry or working with highly regulated materials and products. Companies subject to multiple regulations are more at risk of disruptions caused by regulatory changes.
Supplier margin	The net profit of the supplier. Companies with higher profit margin are less likely to experience financial failures.
M&A postulated	A qualitative assessment of the potential for a supplier to be involved in a merger or acquisition. Corporate priorities can change after a merger or acquisition, impacting the service to NASA.
Percentage of off-shore suppliers	The portion of suppliers used that are foreign in origin. Foreign companies are less likely to have readily available financial data and are a higher risk due to cultural differences in sharing risk exposure information.
Percentage of small business suppliers	The portion of suppliers that are small businesses. Small businesses tend to have a lower tolerance for financial problems and are more likely to experience a financial failure.

Because the Altman Z-score is a proven predictor of financial failures, it is recommended to begin the supplier assessment with a Z-score calculation and assigning likelihood points based on the results, as shown in Table A-3.

**Table A-3. Z-Score Likelihood Points**

Supplier type	Z-score	Likelihood points
Public company	>2.99	0
	1.81 - 2.99	5
	<1.81	10
Private company	>2.90	0
	1.23 - 2.90	5
	<1.23	10

Suppliers can receive likelihood points of 0, 5, or 10 points based on their Z-score. If a supplier receives 10 points based solely on its Z-score, then the supplier is considered high risk, and no further evaluation is necessary. If a supplier receives a 0 or 5 based on their Z-score, it is still necessary to assess that supplier against the other metrics in Table A-2.

If the financial data required for the Z-score calculation is unavailable, such as for a private company, assign at least 5 likelihood points for the Z-score metric. To anticipate the event when a supplier is unable to or will not provide the financial data necessary for the Z-score calculation, introduce a contract requirement for the supplier to provide the data. If the supplier cannot provide the data or is un-willing to agree to the contract term, NASA can purchase financial reports from financial monitoring companies, many of which provide reports on private firms. As an example, Dun and Bradstreet maintains “Private Company Insight Reports” that offer key

company data for more than 250,000 U.S. private companies, including financial data for up to 3 years.

The Z-score for public companies is calculated per the following equation:

$$Z = 3.3 (EBIT/Total Assets) + 1.2(Net Working Capital/Total Assets) + \\ 1.0 (Sales/ Total Assets) + 0.6 (Market Value of Equity/Book Value of Debt) + \\ 1.4 (Accumulated Retained Earnings/Total Assets)$$

where, Z is the Z-score for the company and EBIT is earnings before taxes.

The Z-score for private companies is calculated per the following equation:

$$Z = 0.717 (Net Working Capital/Total Assets) + \\ 0.847 (Accumulated Retained Earnings/Total Assets) + 3.107 (EBIT/Total Assets) + \\ 0.420 (Book Value of Equity/Total Liabilities) + 0.998 (Sales/Total Assets)$$

Likelihood points are assigned to the remaining metrics based on low and high-risk criteria. If a supplier has a low risk for a particular metric, it receives 0 points for that metric; if a supplier has a high risk for the metric, it receives the corresponding points, as shown in Table A-4.

**Table A-4. Additional Metric Likelihood Points**

<b>Metric</b>	<b>Risk level</b>	<b>Risk criteria</b>	<b>Likelihood points</b>
Program budget / schedule	Low	At or below budget, on time or ahead of schedule	0
	High	>10% over budget or behind schedule	1
Percentage of business with NASA	Low	<50%	0
	High	>50%	3
Regulatory burden	Low	No	0
	High	Yes	3
Supplier margin	Low	>5%	0
	High	<5%	3
M&A postulated	Low	No	0
	High	Yes	1
Percentage of off-shore suppliers	Low	<10%	0
	High	>10%	1
Percentage of small business suppliers	Low	<25%	0
	High	>25%	1

Once points are determined for each of the nine metrics, the sum of the points for a supplier then becomes its total likelihood rating. This rating is converted into a 1-to-5 score using the scale in Table A-5. The score represents the likelihood a supplier will encounter a viability risk.

**Table A-5. Risk Likelihood Rating Scheme**

<b>Risk level</b>	<b>Qualitative likelihood rating definition</b>	<b>Likelihood rating</b>
Nearly certain = 5	Most always encountered; practically unavoidable event	Risk score of 10 or more
Highly likely = 4	Expected to occur; typically occurs in efforts of a similar nature	Risk score of 6 to 9
Possible = 3	Even likelihood of occurrence; often encountered in similar efforts	Risk score of 4 to 5
Unlikely = 2	Hypothetically possible, but uncommon in programs of similar type	Risk score of 2 to 3
Very unlikely = 1	Rarely encountered; standard practices will effectively avoid event	Risk score of 0 to 1

The risk consequence rating scheme in Table A-1 and risk likelihood rating in Table A-5 are intended to be a starting point for NASA's risk assessment of its suppliers. This study did not

include a review of NASA programs to ensure that the ranges are appropriate for NASA's suppliers. With additional analysis, the criteria provided can be tuned to allow an appropriate distribution of the suppliers into the various risk levels for consequence and likelihood.

**Risk Matrix.** Consequence and likelihood together can be used to identify the risk each supplier presents to the program. Using the 1-to-5 ratings for consequence and likelihood, the risk of a particular supplier can be plotted on the matrix shown in Figure A-2.

The matrix can be used to visualize the risks for individual suppliers in relation to one another, prioritize the order in which each is addressed, and plan ways to mitigate each risk. Based on its placement in the matrix, a supplier is determined to have a low, medium, or high risk of failure. Suppliers that fall into the green range are considered low risk; suppliers that fall into the yellow range are considered a moderate risk; and suppliers that fall into the red range are considered a high risk. However, note that a supplier with a low consequence rating will always be a low risk - no matter how likely the risk is to occur. For this reason, we calculate a supplier's consequence rating first and can eliminate the likelihood rating calculations for suppliers in this category.

*Figure A-2. Supplier Risk Matrix*

(1,5)	(2,5)	(3,5)	(4,5)	(5,5)
(1,4)	(2,4)	(3,4)	(4,4)	(5,4)
(1,3)	(2,3)	(3,3)	(4,3)	(5,3)
(1,2)	(2,2)	(3,2)	(4,2)	(5,2)
(1,1)	(2,1)	(3,1)	(4,1)	(5,1)

For suppliers in the "high risk" category (red) corrective action should be implemented and monitoring should be increased. Supplier monitoring should be increased for those suppliers in the "medium risk" category (yellow). No specific action is necessary for suppliers in the "low risk" category (green).

## **APPENDIX B: Example Requirements**

Sample logistics-related requirements from several NASA programs appear below. The designation (e.g. ISS.X or CxP.X) are used to indicate the program of origin for the purposes of this document and are not the designations used in the original source requirements documents.

### **ISS Program (excerpted from SSP 41000 and SSP 50520)**

#### **ISS.1.1 On-Orbit Maintenance**

The Hardware X shall be maintained on-orbit utilizing corrective, in situ, or intermediate maintenance.

##### **ISS.1.1.1.1 Corrective Maintenance**

On-orbit HARDWARE X corrective maintenance shall be performed by removal and replacement or by in-situ maintenance.

##### **ISS.1.1.1.2 In situ Maintenance**

When on-orbit removal and replacement is not applicable, HARDWARE X functionality shall be restored by in-situ maintenance.

##### **ISS.1.1.1.3 ORU Intermediate Maintenance**

The HARDWARE X equipment designated for on-orbit intermediate maintenance shall be packaged for the removal and replacement of Shop Repairable Units (SRU) and for other approved off-equipment repairs.

#### **ISS.1.1.2 Access for On-Orbit Maintenance (non-Logistics)**

The installation of HARDWARE X components shall not prohibit access to all IVA locations requiring on-orbit maintenance as specified in SSP 5005, paragraph 11.2.3.6.

##### **ISS.1.1.2.1 Access for On-Orbit Inspection**

The installation of HARDWARE X components shall not prohibit access for the inspection of equipment located in the unpressurized environment and requiring on-orbit maintenance without the removal of other equipment. Removal or opening of protective covers is permissible.

### **Constellation Program**

These requirements are excerpted from the Constellation Architecture Requirements Document (CARD), CxP-70000. This was the Program-level requirements document. The subordinate

programs each had their own requirements documents that contained flow-down requirements in response to the CARD requirements. Note: Some of these requirements may not immediately appear to be LCLS-related requirements (e.g. turnaround requirements). However, they are important constraining requirements that would drive subordinate requirements dealing directly with the LCLS infrastructure (e.g. flight rates), maintenance environment (i.e. on the launch pad or in an integration facility), and hardware maintainability design requirements.

**CA5511-PO** The nominal flight rate of CLV to ISS shall be 5 per year with a maximum rate of 6 per year.

**CA5512-PO** The nominal CLV Lunar flight rate shall be 2 per year with a maximum rate of 3 per year.

**CA5525-PO** The EVA System shall accommodate flight rates necessary to sustain the ISS and human exploration programs, as stated in the System Flight Rate Table.

**CA5539-PO** Ground Systems shall provide the capacity to operate the missions as defined in the Systems Flight Rate table for ISS and human exploration programs.

**CA0492-PO** The CEV shall be capable of conducting a lunar mission within 26 (TBR-001-003) days following a missed lunar injection opportunity.

**CA4100-PO** The CLV shall be capable of conducting a lunar mission within 26 (TBR-001-003) days following a missed lunar injection opportunity.

**CA0060-HQ** The CEV shall remain docked to the ISS for up to 210 days.

**CA0123-PO** The Constellation Architecture system shall have an 88% (TBR-001-021) probability of launch per crew launch attempt, starting at "LCC Call to Station" and ending at close of day-of-launch window.

**CA0178-PO** The CEV shall have a launch availability of no less than 98% (TBR-001-041) per launch attempt, starting at (TBD-001-505) hours for "LCC Call to Station" and ending at close of day-of-launch window.

**CA1066-PO** The CLV shall have a launch availability of no less than 98% (TBR-001-041) per crew launch attempt, starting at "LCC Call to Station" and ending at close of day-of-launch window.

**CA3064-PO** Ground Systems shall have a launch availability of no less than (TBD-001-563)% per crew launch attempt, starting at "LCC Call to Station" and ending at close of day of launch window.

**CA0550-PO** The Constellation Architecture shall be maintainable during each design reference mission within the limits of the maintenance resources shown in the Maintenance Resources table.

**CA5710-PO** The Constellation Architecture shall provide the infrastructure to maintain systems through their operational life cycles.

**CA5182-PO** The EVA Systems flight hardware shall not require planned refurbishment or repair during a single ISS mission.

**CA5184-PO** The EVA Systems flight hardware shall be designed to allow for in flight maintenance, including replacement and repair of major end items.

**CA5495-PO** The CEV shall sustain in-space operations using only onboard equipment and spares without resupply or support from personnel other than the crew.



## APPENDIX C: Example DRDs

### Data Requirement Description (Based on JSC-STD-123)

**1a. DRD Title:** Parts Obsolescence Monitoring

**1b. Data Type:** 3

**2. Date of Current Version:** -1/01/04

**3a. DRD No.:** F-LM-04

**3b. RFP/Contract No.:** NAS 15-1000

**4. Use:** Obsolescence reporting and Single Source Supplier Analysis (SSSA) alerts the ISS Program that production is concluding for a specific part, and provides the identification of single source suppliers and plans methods to be used to provide for the continued support of the ISS through its operational life.

**5. DRD Category:** Technical

**6. References (SOW, Clause, etc.):** Statement of Work (SOW); paragraphs 3.3.8.5.3

**7. Interrelationships (e.g. with other DRDs):** None

**8. Preparation Information:** The contractor shall prepare the DRD as follows:

**SCOPE:** Parts Obsolescence Monitoring shall consist of Parts Obsolescence and Single Source Supplier Analysis (SSSA).

**Parts Obsolescence Monitoring:** The contractor shall identify and resolve hardware and component obsolescence issues and loss of failure analysis, production and repair capabilities in compliance with Program management and control requirements. Loss of capabilities includes, but is not limited to, loss of skills or a supplier going out of business. The contractor shall deliver parts provisioning data for all repairable parts and parts containing EEE parts to support management of parts obsolescence. The contractor shall obtain government approval for hardware changes as required by NSTS 07700 and SSP 41170.

The contractor shall compile a list of their sole source, single source (where requalification may be required) "production" suppliers for essential consumable industrial materials, parts, components, systems, and critical facilities and perform an analysis of those suppliers to identify areas of concern relative to supporting the program mission. This analysis and plan shall address consumables, hardware (including flight hardware), and expendable items requiring recurring procurement over the Station's life. This analysis shall encompass all subcontractors regardless of tier. The contractor shall perform an analysis of those single source suppliers to identify area of concern relative to supporting program mission. The Contractor shall prioritize the analysis to ensure that any subcontractors / suppliers that are leaving the program near term are addressed first, with the remaining scheduled based on their contract completion dates. The contractor

shall identify those subcontractors / suppliers which have already completed their production requirements.

**CONTENT:** The SSSA shall consist of the following:

A list of single source suppliers (includes all subcontractors regardless of tier).

The items that the single source suppliers provide.

Identify any risks associated with proprietary processes, environmental issues and foreign ownership of the resultant suppliers outside the continental United States.

Provide recommendations to protect the items from production stoppages and ensure availability of materials, consumables and facilities.

This report shall document items that have been previously identified as obsolete and the actions taken to ensure support for the life of the program (i.e. life of type procurements).

**FORMAT:** Parts obsolescence and SSA content submittal shall be submitted in a format supported by the electronic library or as otherwise agreed to by NASA and the contractor.

**9. OPR:**

**10. FIRST SUBMISSION DATE:**

Frequency of submission: Quarterly Report

Additional Submissions: (blank)

**11. MAINTENANCE:** Shall be maintained and updated electronically

**12. COPIES/DISTRIBUTION:**

1 original/record (hard copy): Program Data Management

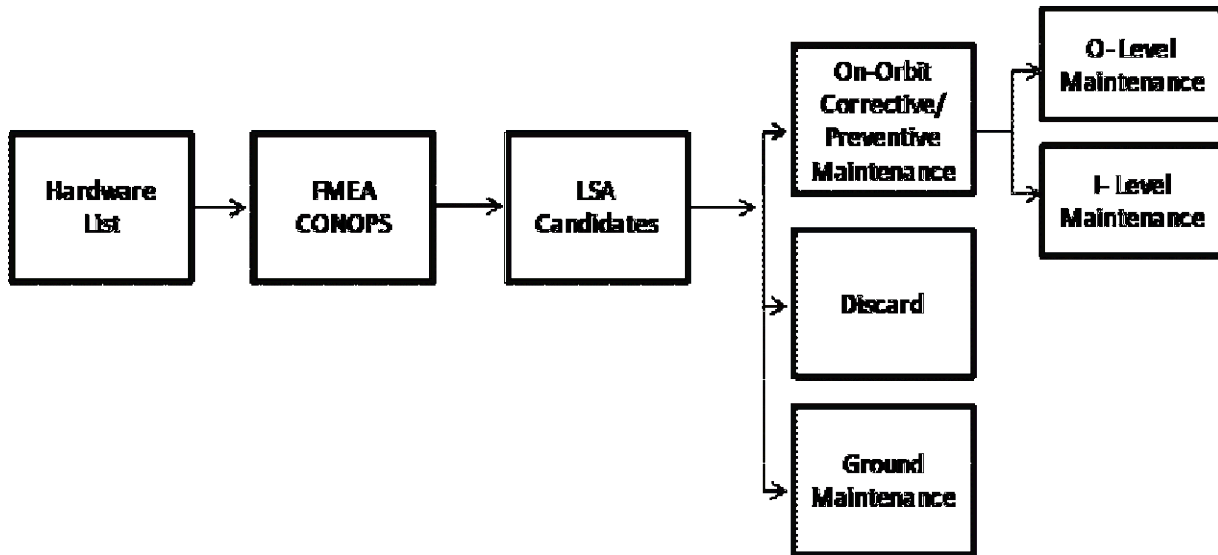
1 electronic copy: to a Program authorized repository

**13. REMARKS:** None



## Appendix D: Maintenance Level Identification Processes<sup>7</sup>

The LCLS team will provide an initial assessment of the maintenance concept based on the hardware design and the Concept of Operations. The maintenance concept starts with an LSA Candidates List that is developed from an initial hardware list and analyzed against the Concept of Operations and Failure Mode and Effects Analyses. The LSA candidates list is composed of any hardware that requires operational logistics support. Ground maintenance / repair and / or discard candidates will also be identified and documented.



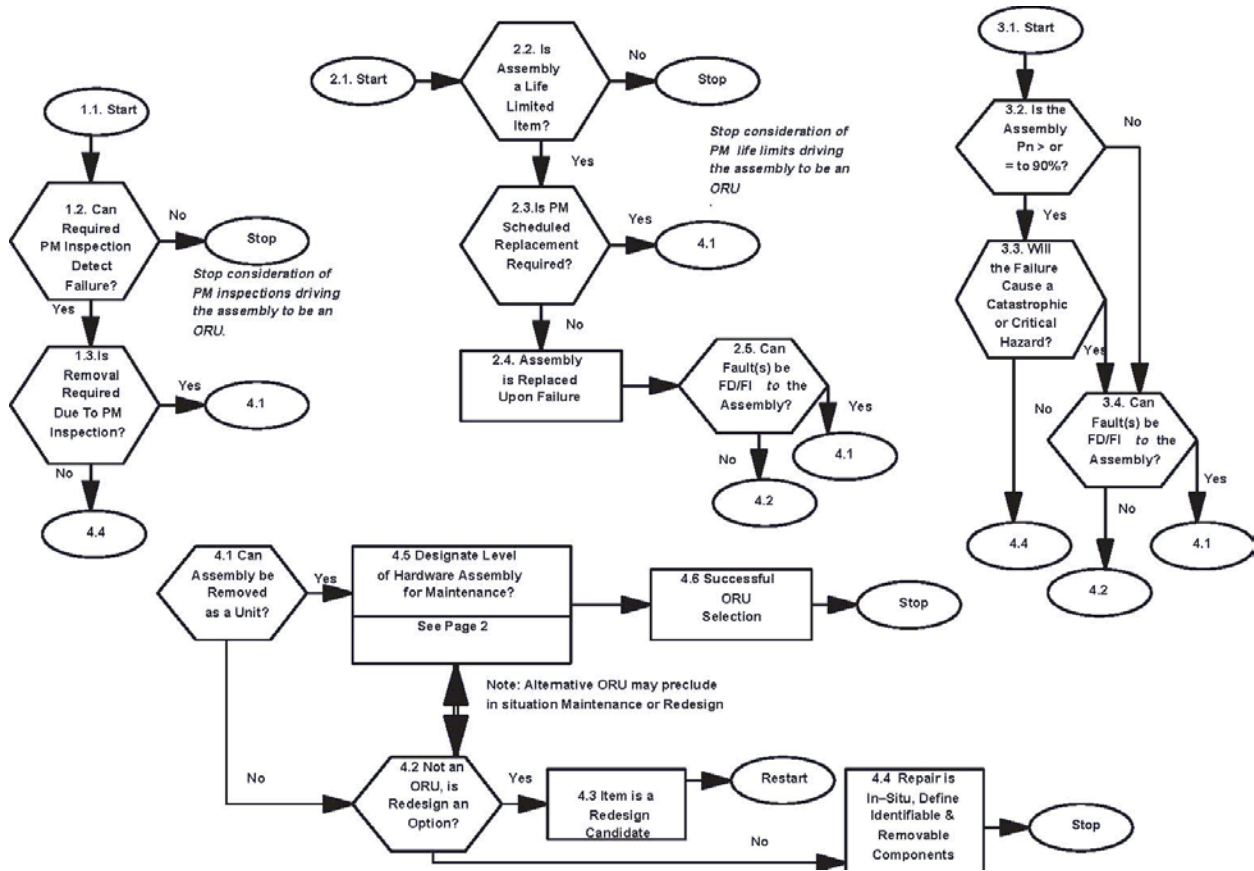
**Figure D-1. Flight Hardware Maintenance Concept / Repair Level Initial Definition**

### **On-Orbit Maintenance Level (Organizational / Intermediate)**

As data become available, the LCLS team will select the hardware from the LSA Candidates list and perform an analysis using the ORU Selection Criteria. Figure D-2 depicts the ORU Selection process. The I-Level Maintenance ORU Selection Process is depicted in Figure D-3.

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<sup>7</sup> adapted from *Boeing International Space Station (ISS) Spares Management & Logistics Work Instruction for New Hardware Design/Development* (Initial Release, March 2012).



- \* Assembly Grouping Rationale:
- Resupply & Return Weight & Volume
  - Fault Detection & Isolation Complexity
  - High Interchangeability of Components
  - High Tool or Equipment Commonality
  - Critical Human Factors
  - Annual Man Hours Factors

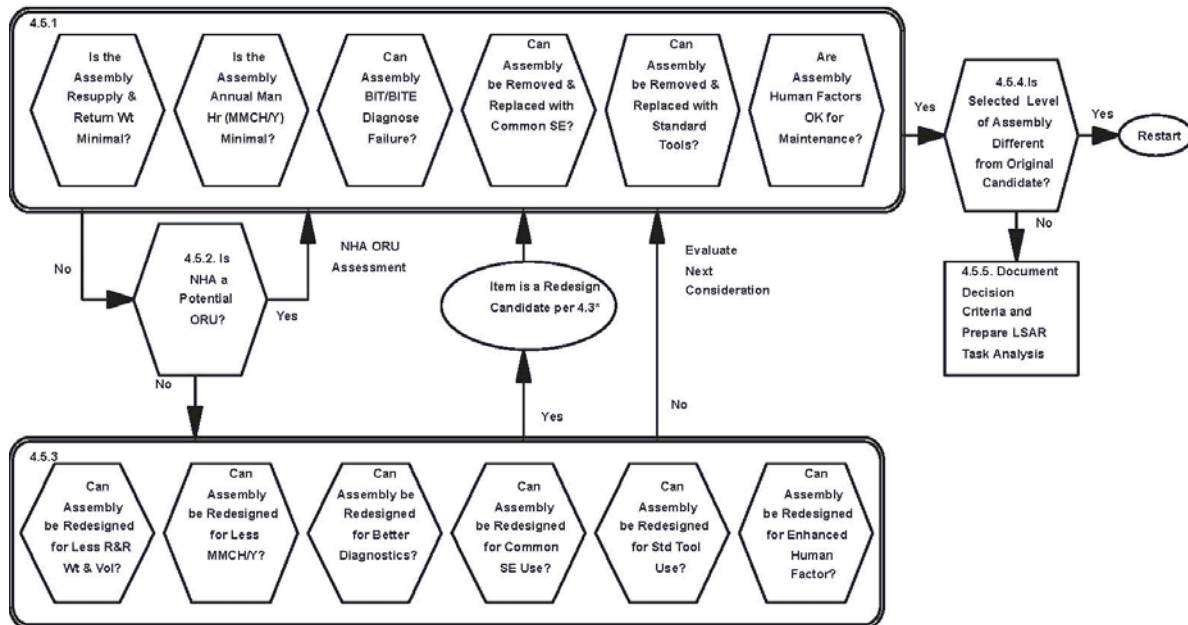
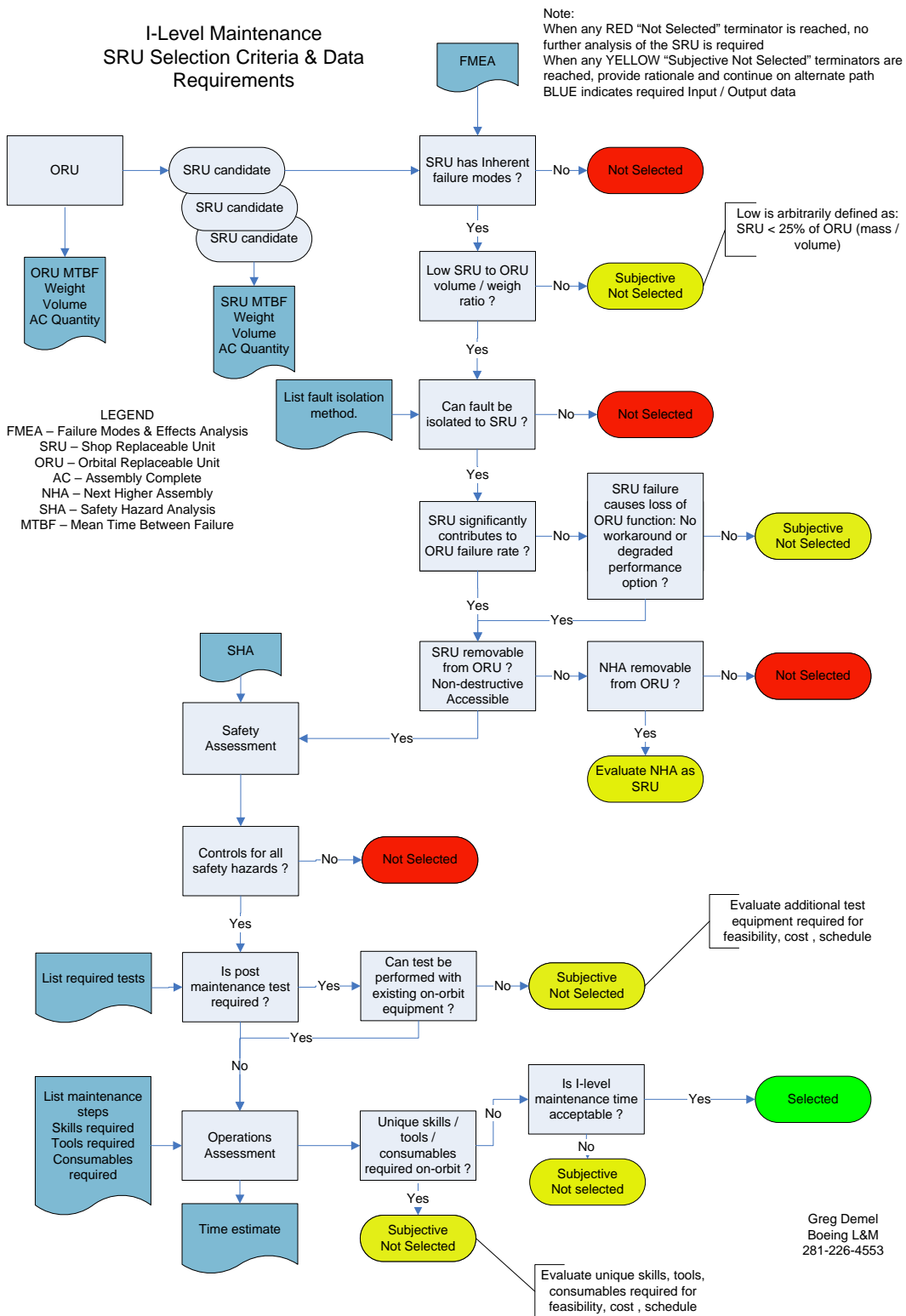


Figure D-2. Organizational (O) - Level Maintenance ORU Selection Process



**Figure D-3. Intermediate (I) - Level Maintenance ORU Selection Process**