Designing and Assessing Supportability in DOD Weapon Systems:

A Guide to Increased Reliability and Reduced Logistics Footprint

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ACQUISITION,
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MEMORANDUM FOR THE ACQUISITION COMMUNITY

SUBJECT: *Designing and Assessing Supportability in DOD Weapon Systems: A Guide to Increased Reliability and Reduced Logistics Footprint*

In the past year, dramatic changes have been instituted through revision of the Department's acquisition and requirements, now capabilities, generation regulations. A key concept echoed in these new documents is Total Life Cycle Systems Management (TLCSM). The program manager and his staff now have responsibility for a system from cradle to grave.

The *Supportability Guide* is both timely and discerning. It examines the life cycle logistics activities now required of the PM, in the new regulatory environment. It puts the PM's decision-making responsibilities for systems supportability into the appropriate systems engineering context. And it stresses the recurring, life cycle role of the PM to translate and refine the user's desired capabilities into actionable, contractible, and measurable system performance and supportability requirements.

I commend the authors, Mr. Lou Kratz, Assistant Deputy Undersecretary of Defense (Logistics, Plans and Programs) and his staff, for their insight into the new acquisition reality and into the impact of TLCSM on the PM's responsibilities. His ability to strip away jargon in favor of sound, clearly written and timely advice will clearly benefit the Acquisition Community. This Guide should be a 'must read' for all program management professionals.

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EXECUTIVE SUMMARY

The challenges facing today's program manager (PM) have increased dramatically. The 2001 Quadrennial Defense Review (QDR) described the need to reduce the logistics footprint, improve our global mobility, and increase reliability of DoD weapon systems. The new DoD 5000.1 and 5000.2 are oriented toward achieving these objectives while also reducing the time required for development and deployment of needed warfighter capability through implementation of evolutionary acquisition strategies and spiral development processes.

Another fundamental change in DoD policy is the designation of the weapon system PM as the life cycle manager [Total Life Cycle Systems Management (TLCSM)], responsible not only for effective and timely acquisition of the system, but also for service as the primary manager and single point of accountability for sustainment of a weapon system throughout its life cycle.

This guide provides a template for PMs when assigned or responsible activities to use in defining and assessing their program activities to meet QDR objectives and DoD policy requirements throughout the weapon system life cycle. Emphasis is placed on designing for increased reliability and reduced logistics footprint and on providing for effective product support through performance-based logistics (PBL) strategies.

The guide uses the Defense Acquisition Management Framework and a systems engineering process to define the appropriate activities and required outputs throughout a weapon system's life cycle to include those related to sustainment of fielded systems. A System Operational Effectiveness (SOE) framework is included that shows the linkage between overall operational effectiveness and weapon system and product support performance.

With today's use of evolutionary acquisition, there is a diminution of the sequential, chronologically phased sequence of design, development, deployment and sustainment activities. With an incremental block development approach, the PM may be involved in one or more of these activities simultaneously. The PM also has to contend with the increasing emphasis on system of systems concepts and network centric warfare. Clearly, there is a need for facilitating guidance to assist the PM with the increasing complexities of that role.

This guide provides a reference for PMs and their teams to design in and then assess the effectiveness of their TLCSM responsibilities in implementing PBL strategies anywhere along the system's life cycle.

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1. DEFENSE ACQUISITION MANAGEMENT FRAMEWORK AND A GUIDE TO INCREASED RELIABILITY AND REDUCED LOGISTICS FOOTPRINT

Revised policy with specific relevance to supportability is found in DoD Directive 5000.1 (Defense Acquisition System) and DoD Instruction 5000.2 (Operation of the Defense Acquisition System). This policy provides a clear rationale for the design and assessment of supportability in DoD weapon systems throughout the life cycle. The policy clearly establishes that:

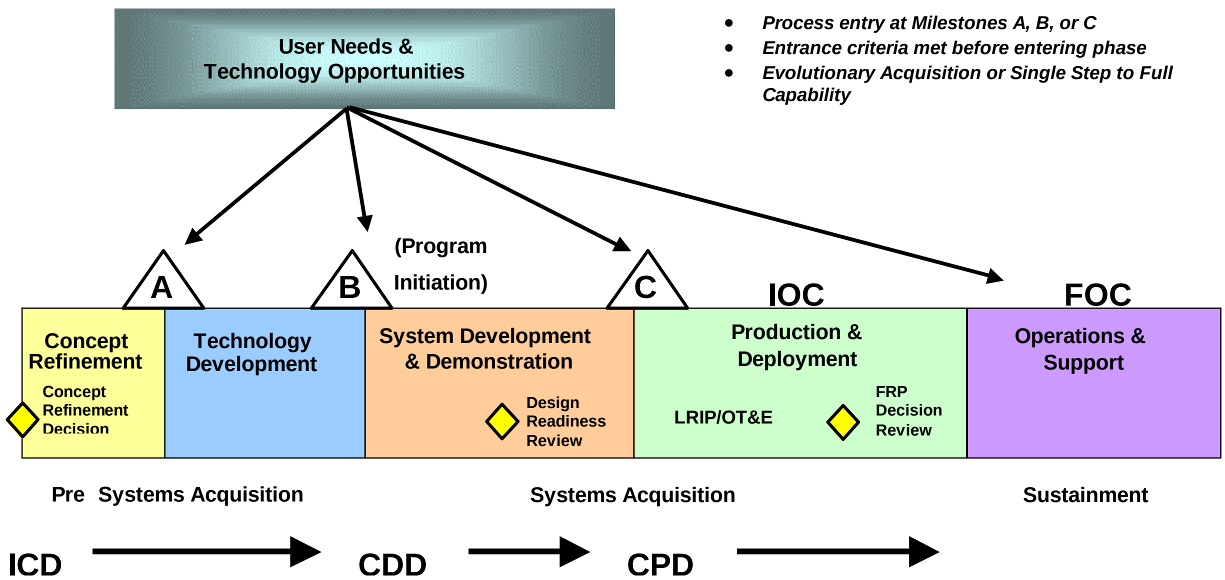
- **The PM is the single point of accountability:** Each PM is charged with the accomplishment of program objectives for the total life cycle, including sustainment.
- **Evolutionary acquisition:** This is DoD's preferred strategy for satisfying operational needs. Spiral development and incremental development are the two basic approaches for achieving evolutionary acquisition.
- **Supportability and Sustainment as key elements of performance:** Supportability and sustainment are essential components of battlefield effectiveness. If a weapon system is not supportable and sustainable, it cannot be considered as an effective warfighting capability.
- **Performance-based strategies:** For the acquisition and sustainment of products and services, performance-based strategies will be considered and used whenever practical. This approach applies to new procurements, major modifications and upgrades, as well as to re-procurements.
- **Performance Based Logistics (PBL) strategies:** PBL is the preferred support strategy within the Department of Defense whenever practical, and PMs are to work directly with users to develop and implement PBL agreements.
- **Increased reliability and reduced logistics footprint:** PMs must ensure the application of a robust systems engineering process to provide for reliable systems with reduced logistics footprint and total ownership cost (TOC).
- **Continuing reviews of sustainment strategies:** Reviews must be conducted at defined intervals throughout the life cycle to identify needed revisions and corrections, and to allow for timely improvements in these strategies to meet performance requirements.

1.1. The Guide Framework: Defense Acquisition Management Framework and Systems Engineering and Design Maturation Processes

This guide presents the Defense Acquisition Management Framework coupled with the systems engineering and design maturation processes as a management framework. As shown in Fig. 1.1, the DoD 5000 series defines a flexible System Acquisition/Life Cycle Model that includes life cycle phases and decision points. The guide provides a methodology to integrate a structured systems engineering process within the life cycle model framework. This integrated process can be applied in various contexts - to new system development programs, to modifications of fielded systems, and to the reengineering of product support approaches for fielded systems.

This guide is designed for use by PMs or activity charged with responsibility for weapon systems programs. The term PM, as used here, refers to the entire, integrated program office team, including program office personnel, other government personnel, and industry.

The purpose of the guide is to provide methodologies for integrating sustainment objectives into performance objectives to achieve the most capable and life cycle cost effective systems possible in both the short- and long-terms. Using information in this guide, the PM team will be able to select and integrate their approach, strategies, and tools to achieve the objectives of increased reliability and reduced logistics footprint and fulfill their TLCSM responsibility.



ICD: Initial Capabilities Document
CDD: Capabilities Development Document
CPD: Capabilities Production Document
IOC: Initial Operating Capability
FOC: Full Operating Capability
LRIP: Low-Rate Initial Production
OT&E: Operational Test and Evaluation
FRP: Full Rate Production

Figure 1.1. DOD 5000 Defense Acquisition Management Framework.

1.2. DoD System Life Cycle Phases

As displayed in Figure 1.1, the DoD 5000 series segregates the system life cycle into phases:

- Pre-systems acquisition: Accomplished in Concept Refinement and Technology Development Phases
- Systems acquisition: Consisting of a System Development and Demonstration Phase and a Production and Deployment Phase.
- Sustainment activities: Accomplished in the Operations and Support Phase.

As a function of a number of factors, an individual program can enter the DoD acquisition management framework during any of these three phases. Each phase has defined entrance criteria that are based on the definition and validation of needed capabilities, technology maturity, system design maturation, and funding. Major decision points mark the entrance into succeeding phases, with specific decision points tailored on a program-by-program basis.

1.3. System Operational Effectiveness (SOE)

The concept of SOE is used in this guide to explain the dependency and interplay between system performance, availability (reliability, maintainability, and supportability), process efficiency (system operations, maintenance, and logistics support), and system life cycle cost. This overarching perspective provides a context for the “trade space” available to a PM along with the articulation of the overall objective of maximizing the operational effectiveness of weapon systems. SOE requires proactive, coordinated involvement of organizations and individuals from the requirements, acquisition, logistics and user communities, along with industry. This applies equally to new weapon systems as well as to major modifications and opportunistic upgrading of existing, fielded systems. In all cases, full stakeholder participation is required in activities related to ‘designing for support,’ ‘designing the support,’ and ‘supporting the design.’

1.3.1. Pre-Acquisition Activities

As early as possible, and before a formal program is established, identify actions necessary to achieve significant increases in reliability and reductions in logistics footprint. Accordingly, this guide identifies efforts recommended as part of the technology maturation process prior to and during the Concept Refinement and Technology Development phases. While considered pre-acquisition, these efforts are critical to achieving improved system sustainment.

The pre-acquisition activities are focused on identifying an affordable, militarily useful capability where needed technologies have been demonstrated in a relevant environment. This includes the demonstration of key supportability related characteristics of the end item as well as new technologies required to reduce logistics footprint and cost-effectively support the system.

A key output of pre-acquisition efforts is the documentation of program capability requirements that should balance capability, life cycle cost, and supportability. The initial acquisition strategy, including the high-level product support strategy, must also be defined. The pre-acquisition timeframe offers the most leverage for positive impact on system supportability and sustainment, and for establishing a competitive product support strategy that will achieve maximum SOE.

1.3.2. System Acquisition Activities

During the System Development and Demonstration phase, there are two primary logistics-related objectives:

- Influence design for supportability
- Design and develop the support system

During Production and Deployment phase the emphasis is on implementing the product support capability to meet established war fighting capabilities.

1.3.3. Sustainment Activities

To support PMs in carrying out their life cycle responsibility, the guide also identifies evaluation and refinement activities needed to ensure that the system, including the support system, continues to meet warfigher requirements within resource constraints.

1.4. Assessment of Supportability Throughout the Acquisition Life Cycle

Referring to the DOD 5000 Defense Acquisition Management Framework, Section 3 of this guide discusses the objectives, activities, and expected outcomes for each phase. PMs can use the guide to assess the adequacy of their logistics-related activities and outcomes in addressing TLCSM responsibilities and objectives.

In performing these functions, related strategies and tools must be integrated. These could include the following, among others:

- Integrated Product and Process Development (IPPD)
- Cost as an Independent Variable (CAIV)
- Open Systems
- Joint Technical Architecture (JTA)
- Performance Based Acquisition (PBA)
- PBL, etc.

Implementation of IPPD and CAIV provide a development environment and information with which decisions can be made from a life cycle view. Open Systems and JTA call for system/technical architectures and interface standards that provide for ease of upgrade and modification that reduce long-term costs. PBA and PBL provide strategies for buying equipment and services against stated performance requirements, thus allowing the service provider the opportunity to offer innovative, cost-effective solutions. Each of these functions must be effectively integrated in order to maximize results.

1.5. Logistics-Related Activities for Each Phase

The discussions in Sections 2 and 3 addresses the logistics-related activities in each phase of a development program, whether it is a major new system, a modification to a fielded system, or a redesign of a product support system. For any program involving development, many of the same major systems engineering activities apply: defining requirements, allocation of requirements, design synthesis, system analysis, and validation/verification. Given this linkage to the fundamental systems engineering process, the PM can tailor activities discussed in Section 2 and Section 3 to assess adequacy of progress and planning at various program stages, regardless of life cycle phase.

2. SYSTEM DESIGN THROUGH APPLICATION OF THE SOE CONCEPT

The TLCSM approach increases the significance of design for system reliability, maintainability, manufacturability, and supportability. The inherent objective of the TLSCM is to enhance warfighter capability through improved SOE of new and fielded weapon systems.

SOE is the composite of performance, availability, process efficiency, and total ownership cost. The objectives of the SOE concept can best be achieved through influencing early design and architecture and through focusing on System Design for Operational Effectiveness (SDOE). Reliability, reduced logistics footprint, and reduced system life cycle cost/total cost of ownership (TOC) are most effectively achieved through inclusion from the very beginning of a program – starting with the definition of required capabilities. The SOE concept provides a framework within which trade studies can be conducted in a proactive manner.

Linkage Between Performance and Sustainment

Warfighter performance objectives drive sustainment objectives, which drive the performance-based support strategy. In turn, performance agreements document support requirements and objectives. As illustrated in Figure 2.1, the link between performance and sustainment is critical, and must be considered throughout the early program design activities.

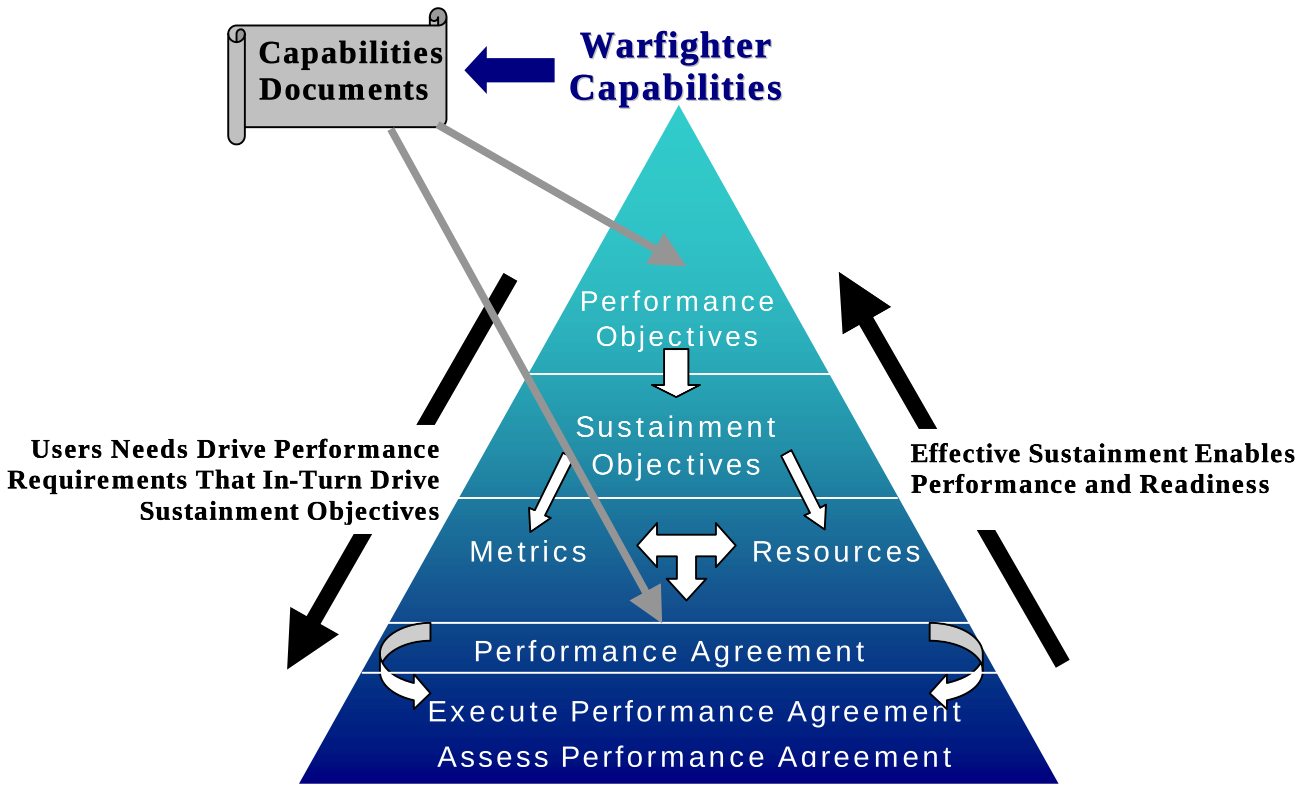


Figure 2.1. Linkage Between System Performance and Sustainment Objectives

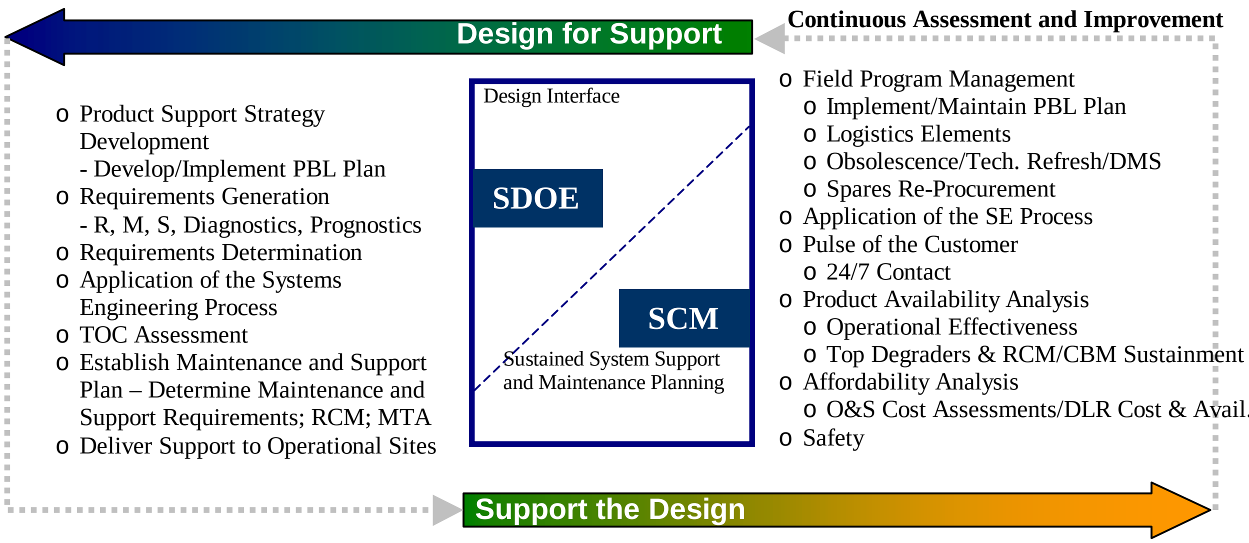
2.1. System Operational Effectiveness: 'Design for Support' and 'Support the Design'

Designing for optimal SOE requires balance between System Effectiveness and System Life Cycle Cost as shown in Figure 2.3. The emphasis is not only on the reliability and maintainability of the prime mission system or equipment to execute mission capability ('Design for Support'), but also on human factors engineering along the cost-effective responsiveness and relevance of the support system and infrastructure ('Support the Design'). As shown in Figure 2.2, the key here is to integrate smoothly the DOD 5000 Defense Acquisition Management

Framework (including its defined phases and milestones), together with the systems engineering and design maturation processes. The intent of this guide is to provide PMs with a common basis of understanding from which to tailor specific aspects of their program.

2.2. System Operational Effectiveness: Balancing Variables and Making Tradeoffs

SOE provides a working model that PMs can use to balance the inherent design features of a system against the processes used for system sustainment. This balance allows for achievement of the desired mission capability, while reducing the TOC and logistics footprint.



The concept reflected in this figure is applied in an iterative manner, particularly for evolutionary acquisition and spiral development.

SDOE – System Design for Operational Effectiveness

SCM – Supply Chain Management

FIGURE 2.2. 'Design for Support' and then 'Support the Design'

Weapon system operational effectiveness derives from a number of component factors that can be described in a hierarchical model, as shown in Figure 2.3.

As can be seen in the SOE concept, numerous trade-offs between system performance, availability, process efficiency, human factors, and cost are needed to maximize weapon systems operational effectiveness. To support such trade-offs, the 'cause-and-effect' relationships must be made explicit between design decisions and system operations and support, as shown in Figure 2.4. Achieving weapon system supportability is an iterative process of designing in system performance and supportability to achieve warfighter capability. Consistent with the DoD 5000 guidance, closer integration between acquisition and product support systems requires an SOE concept to achieve DoD's objectives.

Maximizing operational effectiveness requires proper attention and balance among all the factors included in the SOE model. For example, disproportionate allocation of resources and attention to one area, i.e. performance, can lead to imbalance in others, i.e. process efficiency ~ logistics, and to unaffordable TOCs. Just as the structural integrity of a modern office building relies on comprehensive planning, architectural design documents, and attention to the details of building and subsystem infrastructure, so does the modern weapon system rely on similar attention to corresponding levels of detail.

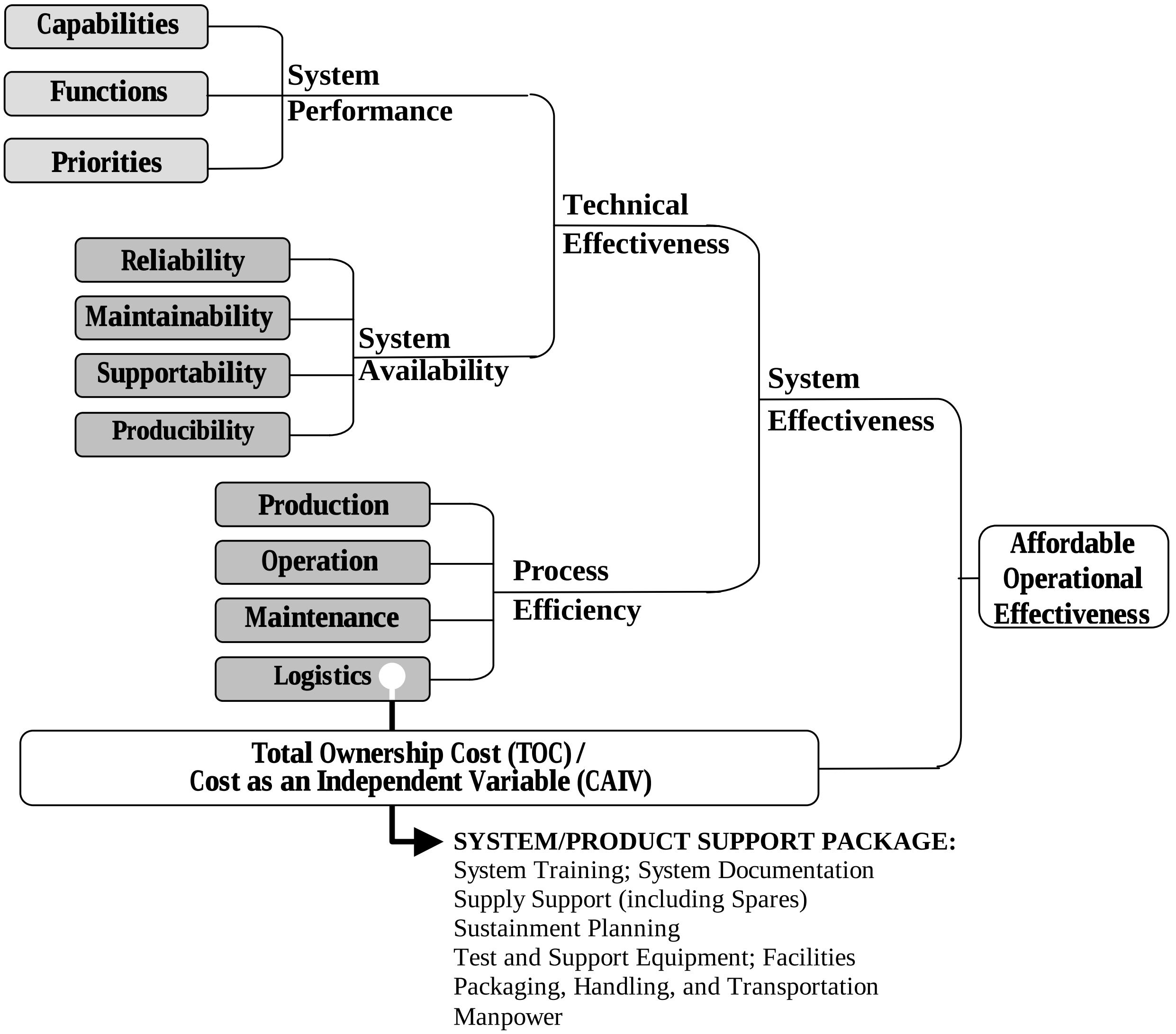


FIGURE 2.3. System Operational Effectiveness (SOE). [Verma and Gallois, 2001]*

This section addresses each of these model components and sub-components, describing their planning requirements, time-phase criticality, and relationship to overall operational effectiveness. Topics in this section include:

- System performance
- System availability
- Process efficiency
- System ownership and CAIV
- Operational effectiveness

* Verma, D. and B. Gallois, *Graduate Program in System Design and Operational Effectiveness (SDOE): Interface Between Developers/Providers and Users/Consumers*, International Conference on Engineering Design (ICED 2001), Glasgow, UK, August 2001.

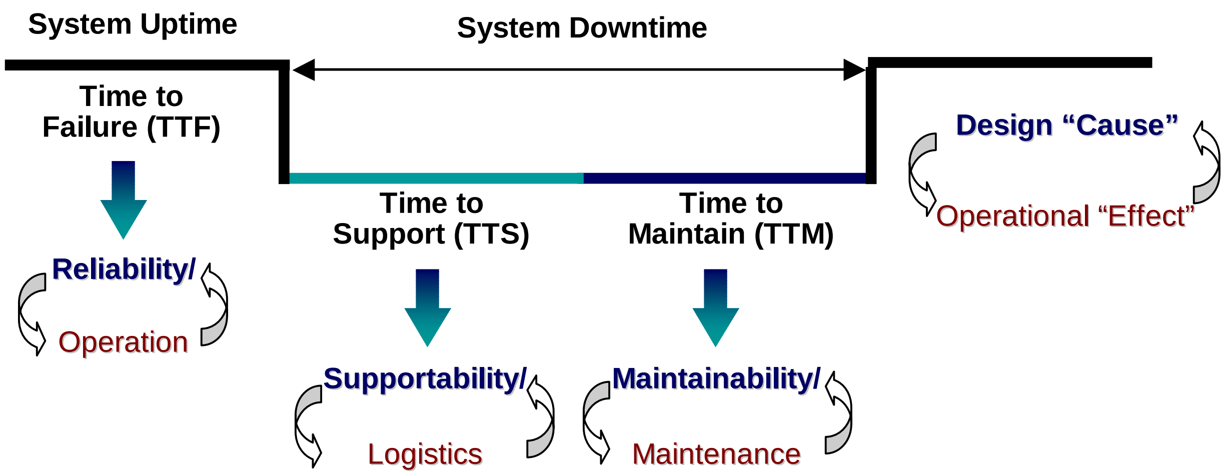


FIGURE 2.4. Cause and Effect between Design Decisions and Operational Effects.

2.2.1. System Performance

System performance is realized through designed-in system ***capabilities*** and ***functions***. In this context, the term ***capabilities*** refers to the various desired performance attributes and measures of the system, such as maximum speed, range, altitude, or weapons delivery accuracy. The term ***functions*** refers to the desired mission capabilities and mission scenarios that the system must be capable of executing in an operational environment. For example, an aircraft may have the capability to fly at Mach 2.0, but its ability to function at that speed in a real-world mission is dependent upon many other factors, among them not being down for repairs. Therefore, factors of reliability, durability, maintainability - overall sustainment - are inherent in achieving optimum system functionality.

Desired capabilities are determined by ***priorities. Priorities*** reflect the stakeholder value system that drive the inevitable tradeoffs that the system design must undergo, balancing performance, availability, operations and support, and TOCs. The level of operational effectiveness achievable is predicated upon the allocation of resources towards these priorities.

Performance cannot be considered separate from the other elements of operational effectiveness – they are inextricably linked. The system capabilities and functions represent the desired mission capabilities as a total package, together with the sustainment objectives and the desired logistics footprint reductions. As discussed in the following paragraph, in the current operational and budgetary context, priorities must be complemented with an emphasis on system availability -- Reliability, Maintainability, Supportability (RMS), and producibility.

2.2.2. System Availability

The DOD 5000 Defense Acquisition Management Framework provides a framework with which to ensure that desired performance capabilities are achieved. The intense review of Key Performance Parameters (KPPs), performance testing, and appropriate oversight all works to facilitate that objective. The pressures on PMs to meet program objectives of cost, performance, supportability, and schedule, reflect the Department’s emphasis on system technical effectiveness or capability.

The components of ***system availability*** are defined to include: ***RMS and producibility,*** defined as follows:

- **Reliability:** The ability of a system to perform as designed in an operational environment over time without failure.
- **Maintainability:** The ability of a system to be repaired and restored to service when maintenance is conducted by personnel using specified skill levels and prescribed procedures and resources.
- **Supportability:** The inherent quality of a system - including design, technical support data, and maintenance procedures - to facilitate detection, isolation, and timely repair/replacement of system anomalies. This includes factors such as diagnostics, prognostics, real-time maintenance data collection, 'design for support' and 'support the design' aspects, corrosion protection and mitigation, reduced logistics footprint, and other factors that contribute to optimum environment for developing and sustaining a stable, operational system.
- **Producibility.** The degree to which "Design for Manufacturing" concepts have been used to influence system and product design to facilitate timely, affordable, and optimum-quality manufacture, assembly, and delivery of system to the field. Producibility is closely linked to other elements of availability and to costs. Items that feature design for manufacturability are also normally easier to maintain, have better accessibility features, and have lower life cycle costs.

The components of system availability cannot be 'added on' after the design and development phase. System availability components of RMS are, by nature, inherent 'designed in' qualities, and, correspondingly, must be accorded the highest priority during the system design and development process.

Emphasis on RMS and producibility during design, development, and sustainment is guided by a concise understanding of concept of operations, system missions, mission profiles, and capabilities. Such understanding is invaluable to understanding the rationale behind functional and performance priorities. In turn, this rationale paves the way for decisions about necessary trade-offs between system performance, availability, and system cost, with impact on the cost effectiveness of system operation, maintenance, and logistics support. The focus on RMS must be complemented by emphasis on system manufacturing and assembly, both critical factors related to the production and manufacturing, and to the sustainment cost of complex systems.

Following is a discussion of each of the factors of system availability.

Reliability

Together with system performance, functions, and capabilities, a primary focus during design and architecture development is on system ***reliability***. This requires an understanding of the mission and operational capabilities, mission profiles, and operational environment(s). It is the system capabilities definition activity that offers the first and most significant opportunity to positively influence a system from the perspective of reliability. Trade-offs among 'Time to Failure,' system performance, and system life cycle cost are necessary to ensure the correct balance and to maximize system technical effectiveness. Subsequent to capabilities definition, as system design and development process (for new and upgraded/fielded programs) progress to the system architecture formulation phase, factors of system reliability become even more important. Options that must be considered and implemented to enhance system reliability include:

- Derating (defined as purposeful over-design to allow a safety margin)
- Redundancy and Ease of reconfiguration

The primary objective is to minimize the risk of failure within the defined availability, cost, schedule, weight, power, and volume constraints**.** While conducted such analyses, trade-offs must be conducted and dependencies must be explored with system maintainability and supportability. Such a focus will play a significant role in minimizing the necessary logistics footprint, while maximizing system survivability and availability.

Maintainability

The emphasis on system ***maintainability*** has the objective of reducing system 'time and cost to maintain.' In other words, maintainability engineering can be defined as the composite of activities, methods, and practices used to influence the system design in order to minimize necessary system maintenance requirements and associated costs for both preventive and corrective maintenance. Maintainability should be a designed-in capability and not an add-on option. Great maintenance procedures cannot overcome poor system and equipment maintainability. From a design influence perspective, timely focus is required on issues pertaining to physical accessibility, performance monitoring and fault localization, built-in-test implementation (coverage and efficiency), false alarms, failure diagnostics and system prognostics. In simple terms the intent is to reduce the time it takes for a properly trained maintainer to isolate the failure and fix it. Intrinsic factors contributing to maintainability are:

- Modularity: Packaging of components such that they can be repaired via 'remove and replace' action vs. on-board repair.
- Interoperability: The ability of components to be compatible with standard interface protocols to facilitate rapid repair and component enhancement/upgrade through 'black box' technology using common interfaces. Physical interfaces can be designed such that mating between components can only happen correctly.
- Diagnostics: Applicable and effective on-board monitoring/recording devices and software, e.g. built-in test (BIT), that provide enhanced capability for fault detection and isolation, thus optimizing the time to repair. Emphasis must also be on accuracy and minimization of false alarms.
- Prognostics: Applicable and effective on-board monitoring/recording devices and software, e.g. BIT, that monitor various components and indicate out of range conditions, imminent failure probability, and similar proactive maintenance optimization actions.
- Fail Safe: In the event of a failure, systems should be designed to revert to a safe mode or state to avoid additional damage and secondary failures.
- Access: The designed-in structural assurance that components requiring more frequent monitoring, checkout, and maintenance can be easily accessed. This is especially important in Low Observable (LO) platforms. Maintenance points should be directly visible and accessible to maintainers. Access for corrosion inspection and mitigation also needs to be provided.

Maintenance task analysis methods and tools provide a detailed understanding of necessary requirements of logistics support to sustain required system effectiveness levels.

Supportability

A similar emphasis is also necessary on system ***supportability*** or the 'time and cost to support.' This parameter refers to the time and cost necessary to provision for, and make available, the necessary elements of logistic support during system operations to facilitate system maintenance. The primary objective of 'design for system supportability' is to positively impact and reduce the requirements for the various elements of logistics support during the system operations and maintenance phase. Accordingly, the focus is on addressing issues pertaining to: a) Commonality (physical, functional, and operational); b) Modularity (physical and functional); c) Standardization (system elements and parts, test and support equipment); d) Diminishing Manufacturing Sources and Material Shortages (DMS and MS); and e) Technology maturity and refreshment, Commercial Off The Shelf (COTS) technology maturity, open system standards, proprietary issues, single source items.

The architecture definition phase presents the best opportunity to influence system design from this perspective. The objective of this influence is to reduce the requirements (time and cost) to procure and make available the various elements of logistics support. The emphasis should be on increased reliability and decreased logistics footprint.

Supportability influence during design addresses logistics support elements, to include:

- System training and training devices
- System documentation/technical data
- Supply support (including spares)
- Sustainment planning
- Corrosion prevention and mitigation planning
- Test and support equipment, to include embedded system test and diagnostics
- Facilities
- Packaging, Handling, Storage, and Transportation (PHS&T)
- Manpower and personnel requirements

Tasks Associated with RMS: To implement effectively the critical objectives of system availability, specific tasks must be performed related to each of the RMS components. Selected tasks are shown in Table1.

Producibility

Emphasis on producibility can have a direct impact on RMS as well as life cycle cost. Many techniques are available to address manufacturability during design. Ease of manufacturing and repeatability in the process, along with concepts like process control and six sigma approaches, application of variability reduction analysis using Taguchi and Design for Experiments (DoE) techniques, as well as material characterization analysis and statistical process control, are essential elements to realizing affordable, reliable, and supportable design.

2.2.3. Process Efficiency

Process efficiency reflects how well the system can be produced, operated and maintained, and to what degree have the logistics infrastructure and footprint been reduced to provide an agile, deployable, and operationally effective system.

Table 1. System Availability: Key and Selected Tasks Associated with RMS

Reliability	Maintainability	Supportability
• Concept of Operation Definition/Mission Profile/Design • Reference Mission Definition • Reliability Requirements Analysis and Allocation • Reliability Modeling and Analysis • Reliability Prediction • Failure Mode, Effects, and Criticality Analysis • Fault Tree Analysis • Reliability Demonstration • Continual Reliability Assessment of Fielded Systems	• System Maintenance Concept Definition • Failure Diagnosis/Embedded Diagnostics /BIT/Prognostics Requirements Definition • Maintainability Modeling and Analysis • High Level Maintenance and Repair Philosophy Development • Maintainability Requirements Analysis & Allocation • Maintainability Prediction • Reliability Centered Maintenance Analysis • Human Factors/Accessibility Analysis • Maintainability Demonstration • Continuous Maintainability Assessment of Fielded Systems • Corrosion Prevention and Mitigation Analysis	• Support Concept of Operations Definition • System Analysis from Commonality Perspective • System Component Interchangeability Analysis • Compliance with Open Systems Analysis • Analysis of Vendors from Maturity & Stability Perspective • Technology Analysis from a Proprietary and Maturity Perspective • Application of Multi-Media Techniques, Information and Instructional Technology • Obsolescence Management and Technology Refreshment Analysis • Supportability Demonstration • Continuous Supportability Assessment of Fielded Systems • Corrosion Control

Achieving process efficiency requires early and continuing emphasis on producibility, maintenance and the various elements of logistic support. These include supply chain management and resource demand forecasting, system training, system documentation, test and support equipment, maintenance planning, packaging and handling, transportation and warehousing, and facilities.

Process efficiency is enhanced by:

- Application of optimization methods to reduce necessary capital investment within the system support infrastructure, e.g., spares optimization and personnel allocation optimization.
- Application of process design, re-engineering, and control to enhance efficiency of the system/product production process.
- Application of process improvement-oriented technologies, e.g., asset visibility and tracking technologies, e-commerce and supply chain management, failure diagnostics and prognostics, and multi-media technologies for documentation and training.
- Development of innovative concepts such as opportunistic maintenance and maintenance-free operating periods (MFOP).
- Development of innovative contractual and management structures such as PBL.

2.2.4. Technical Effectiveness

Technical effectiveness reflects the inherent balance between system performance and system availability. These two aspects of the system must be designed-in synergistically and with full knowledge of the expected system missions in the context of a proposed system maintenance concept. Performance and sustainment objectives must be defined in explicit, quantitative terms to facilitate this trade off and the correlating selection and assessment of product and process technologies.

2.2.5. System Effectiveness.

System effectiveness reflects the balance achieved between the technical effectiveness and the process efficiency of the system. In this context, process efficiency is constituted by the system operational, maintenance, and logistics processes. System effectiveness reflects a holistic view of the real mission capability delivered to the field.

2.2.6. System Ownership Cost/Cost-As-An-Independent Variable

The final piece in the overall SOE model pertains to cost effectiveness. Certainly, the overriding objective should be to maximize the system effectiveness from the perspective of the warfighter. Given a resource-constrained environment, however, trade-offs are inevitable among performance, availability, process efficiency, and cost. The PM must think in both the short- and long-terms. Short-term pressures to achieve system performance and schedule imperatives are very real, and cannot be ignored. In any program, there will always be financial constraints and unforeseen financial contingencies. The PM must address these issues using the SOE model – balancing consideration of performance, cost, schedule, system availability, and process efficiency components. Ultimately, over the system life cycle, balancing this composite of long-term objectives will clearly provide greater benefit to the warfighter and to DoD.

2.2.7. Operational Effectiveness

As PMs execute the critical components of the SOE model, including RMS and overall process efficiency, the driving factors for achieving overall ***operational effectiveness*** become proper balance and coordination of ***system effectiveness*** and ***system ownership cost***. Operational effectiveness reflects the overall balance between the real capability delivered to the field and the total cost to deliver and then to sustain this capability over it's useful, operational life.

2.3. The SOE Model and the Defense Acquisition Management Framework

The SOE model has applications throughout the entire Defense Acquisition Management Framework for all new acquisitions, modifications of existing systems, and improvements to fielded systems.

Fundamental to DoD's approach to providing for warfigher capabilities is evolutionary acquisition. Evolutionary acquisition is the preferred DoD strategy for rapid acquisition of mature technology for the user. An evolutionary approach delivers capability in increments, recognizing, up front, the need for future capability improvements. The objective is to balance needs and available capability with resources, and to put capability into the hands of the user quickly. The success of the strategy depends on consistent and continuous definition of needed capabilities, and the maturation of technologies that lead to disciplined development and production of systems that provide increasing capability towards a material concept.

There are two basic approaches to evolutionary acquisition:

1. **Incremental or Block Development**: In this approach, ultimate functionality can be defined at the beginning of the program, with the content of each deployable increment[1] determined by the maturation of key technologies.

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[1] In this context, an "increment" is a militarily useful and supportable operational capability that can be effectively developed, produced or acquired, deployed, and sustained.

2. **Spiral Development**: In this approach, ultimate functionality cannot be defined at the beginning of the program, but only by the maturation of the technologies, matched with the evolving needs of the user. As increments are developed, towards the full and ultimate functionality, they provide the user with capability.

Figure 2.5 illustrates these concepts.

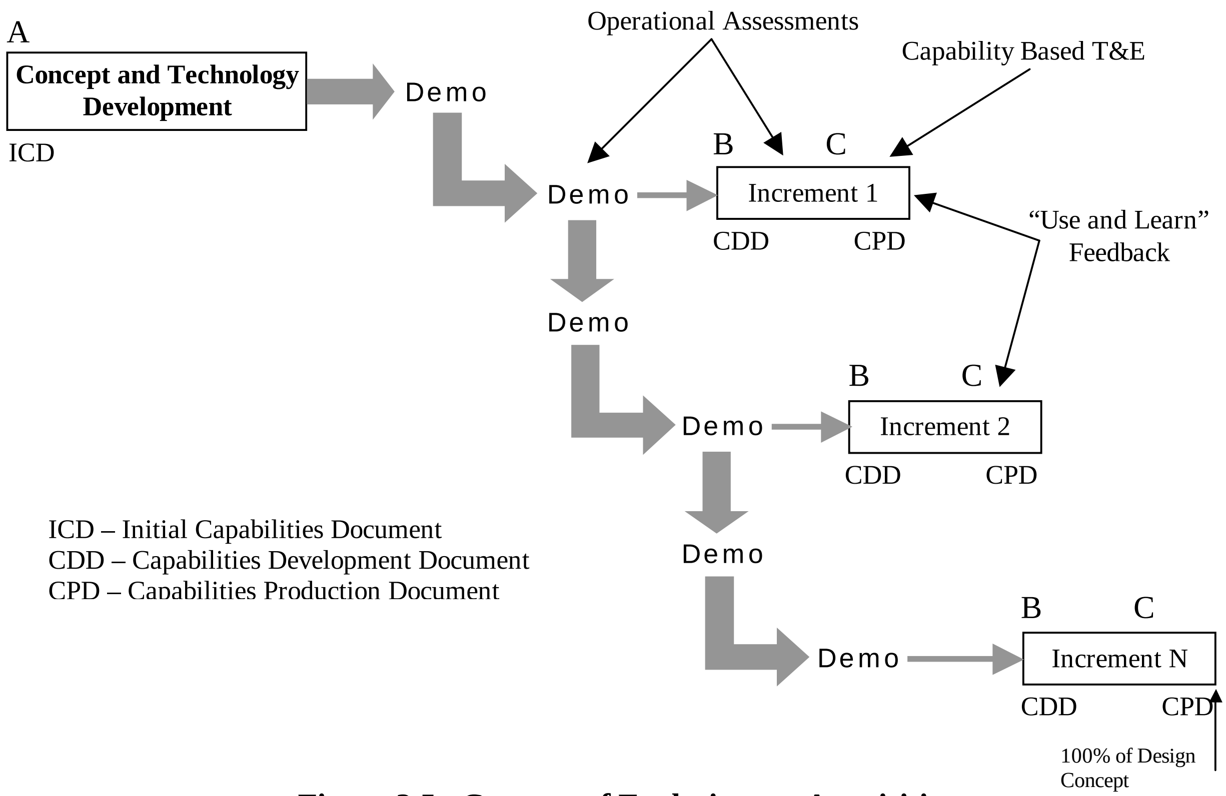


Figure 2.5. Concept of Evolutionary Acquisition.

Challenges and Benefits of Evolutionary Acquisition

Evolutionary acquisition presents new challenges, and potential benefits, to the PM in both acquisition and sustainment activities. The obvious challenge is the potential cost and configuration control problems that can arise with multiple configurations of end-items as well as the support system. This must be addressed early in development and evolution of the acquisition strategy. If planned correctly, this can provide the PM the opportunity to observe and evolve the success of tentative support strategies.

Especially when dealing with a new technology, one of the important aspects of building a successful performance-based support strategy is development of a cost baseline from which to negotiate a meaningful performance contract or set of performance agreements. Evolutionary acquisition provides opportunity, during system development, to collect cost and maintenance data on a smaller scale than is possible in single step to full capability acquisition programs.

This can result in an additional benefit by providing for the creation of a partnership environment between the support provider, the user, and the PM, thus potentially providing for a win-win support relationship and strategy. This kind of partnership between the PM team and the user is most critical for the development and sustainment of a rapid deployment and product support strategy for all configurations of fielded systems.

3. SUPPORTABILITY ASSESSMENT THROUGHOUT THE LIFE CYCLE

3.1. Introduction

Section 3 provides a synopsis of key supportability assessment activities and outputs related to effective TLCSM and PBL implementation within the structure of the Defense Acquisition Management Framework. This discussion provides information on how to maximize SOE through a disciplined program of supportability assessment throughout the life cycle - from program conception, through implementation and deployment. Assessments must accompany, and be aligned with, traditional major milestones in a program. Included is a framework for PMs when assigned or responsible activities to align assessment of their weapon system programs and the associated supportability and sustainment strategies with the life cycle milestones.

In addition to regular milestone checkpoints, the Services in conjunction with the users shall conduct continuing reviews of sustainment strategies, utilizing comparisons of performance expectation as defined in performance agreements against actual performance measures. To ensure long-term success of selected strategy, these reviews can occur at the Pre-Initial Operating Capability Supportability Review after production approval, and the Post-Deployment Supportability Review after deployment. In this context, the services should establish a process for Independent Logistics Assessments (ILA).

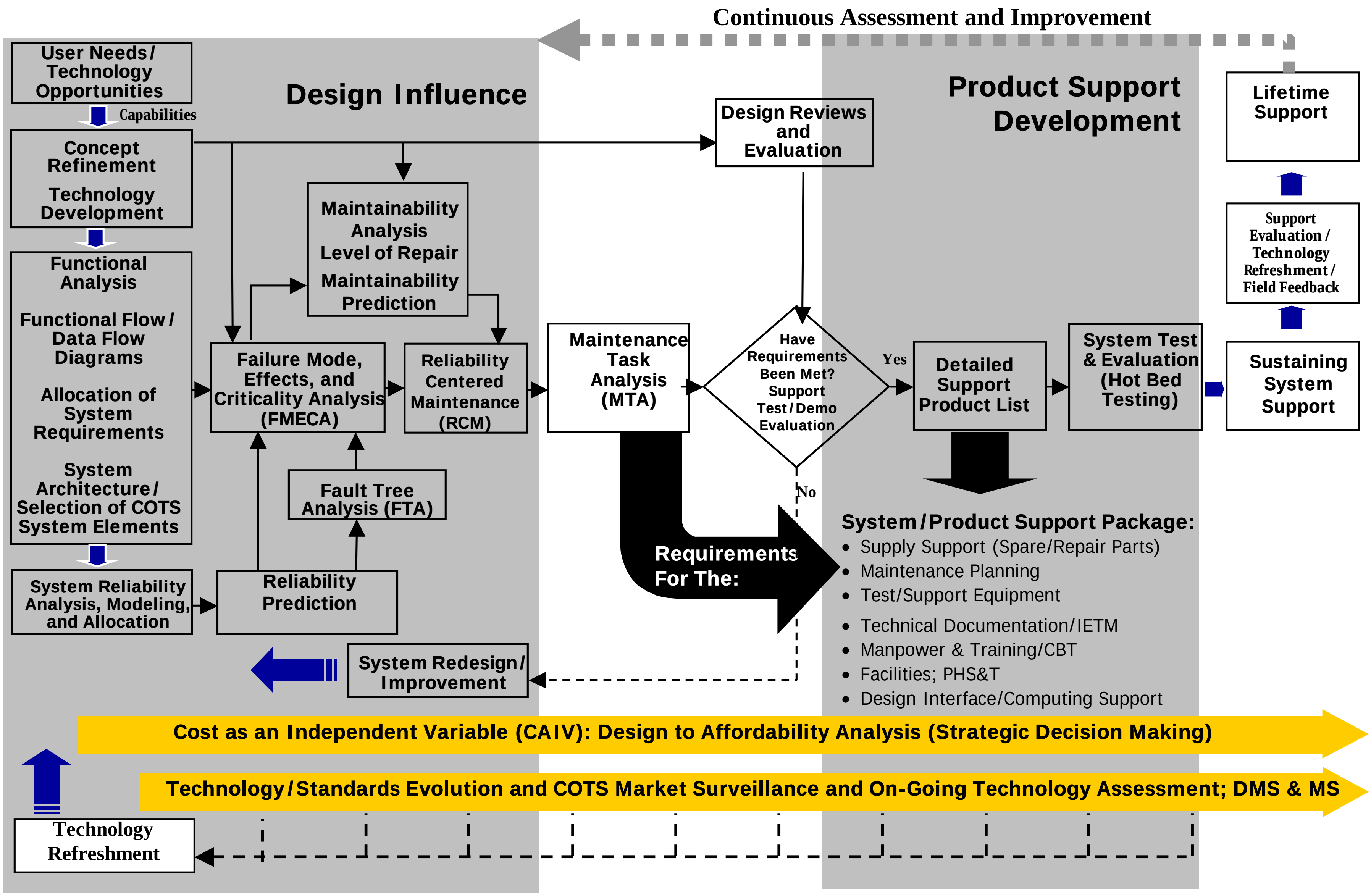
In order to facilitate the supportability assessment of a design, from conception through deployment, the RMS methods, practices, and processes must be integrated with the systems engineering process, as illustrated in Figure 3.1. As such, the concept of operations must be defined to provide the basis for defining both the top-level system requirements and capabilities, as well as the initial definition of the system maintenance and support concept. Formulating the system architecture and performing all associated trade studies with attention to system maintenance ensures a balanced and symbiotic relationship between the system and the associated support system.

A key aspect of the RMS methods and processes is their timely execution. These methods and processes must often be adapted and tailored to effectively achieve ‘design influence’ – enhancing the impact of integrating the system and the support system – especially during the very early stages of design and architecture synthesis.

3.2. Pre-Acquisition Phase

The pre-acquisition phase is defined as activities prior to initiation of a proposed acquisition program. The purpose of this phase is to examine the various alternative options to provide needed capabilities and to reduce technology risk. In this phase, user capabilities are examined against technologies, both mature and immature, to determine feasibility and alternatives to fulfill user need.

Prior to Milestone A, the first iteration of capabilities required are documented in the Initial Capabilities Document (ICD). The Concept Refinement phase accomplishes the refinement of the selected concept through development of an approved Analysis of Alternatives (AoA), leading to development of a Technology Development Strategy (TDS).



The methods and practices reflected here are applied iteratively, particularly for evolutionary acquisition and spiral development. Figure has been adapted from: Verma, D., T. Parry, and J. Beck, Maximizing Operational Effectiveness through Acquisition Logistics, Proceedings, NDIA Conference on Systems Engineering, San Diego, October 2003.

FIGURE 3.1. SOE Life Cycle Framework, linked to the Systems Engineering Process.

Concept Refinement ends when the Milestone Decision Authority (MDA) approves selection of preferred strategy resulting from AoA and approves the associated TDS. The ICD, AoA, and TDS are all key documents for entry into Technology Development Phase at Milestone A. AoA should consider, among other factors, affordability, technology maturity, and responsiveness.

This pre-acquisition phase presents the first substantial opportunity to influence the supportability and affordability of weapon systems by balancing threat scenarios, technology opportunities, and operational capabilities. Emphasizing the critical performance-sustainment link, desired user capabilities should be defined in terms not only of objective metrics (e.g. speed, lethality) of performance to meet mission requirements affordably, but also the full range of operational requirements (logistics footprint, supportability criteria) to sustain the mission over the long term. Assessment and demonstration of technology risk should include those related to supportability and to product support.

3.2.1. Definition of System Operational Effectiveness Components in the Pre-Acquisition Phase

The SOE components discussed in Section 2 should be initially documented. The criteria for system performance (capabilities, functions, priorities) and system availability (RMS and producibility) should be defined in terms of objective and threshold criteria. Upper and lower boundaries should be established to meet needed operational capabilities and provide a reference for trade analyses as system concept is developed. Trade-offs made during early design provide maximum opportunity to impact requirements for system support and the support system.

User needs must be identified and carried forward in a traceable manner throughout the acquisition process such that these can be verified and tested in the operational environment envisioned for the weapon system. The term “user” includes the system operation as well as the system maintenance and support perspectives. The concept is shown in Figure 3.2.

During explorations of system technology opportunities, assessments need to be performed for associated support and maintenance requirements. Explorations should also be performed for specific logistics-related technologies that have the potential to improve maintenance and reduce the logistics footprint, e.g., technologies that would facilitate system diagnostics, prognostics, monitoring, corrosion control, training and documentation, supply support, and asset visibility.

In parallel, considerations of technology opportunities must include alternative maintenance concepts and approaches (e.g., Maintenance-Free Operating Periods (MFOP) and opportunistic maintenance) that can positively affect the readiness and affordability of deployed systems.

There has been a fortunate convergence of rapid evolution of computer technologies and a concurrent reduced acquisition cost of these technologies, coupled with the intent of the 5000 acquisition model to maximize the utilization of commercial-off-the shelf technologies. Together, these factors have unlocked exploitation of such innovative concepts in the design of new weapon systems and the upgrade of fielded systems. The benefits of commercial technologies notwithstanding, care must be taken to ensure that their assessment includes emphasis on long-term sustainability and obsolescence. Assessment of material shortages and diminishing manufacturing sources should be done system wide.

ICD, CDD, CPD, System Concept Selected, Technologies Selected ⟷ **System Support and Maintenance Concept Selected, Technologies Selected**

Drives

- **System Operational Profiles and Use Case Scenarios (Mission Capability Packages)**
- **Utilization Rates**
- **Utilization Environment and Geographical Distribution**
- **System Effectiveness**
- **Operational Horizon and System Life Cycle**

Drives

- **System Maintenance/Support Profiles and Use Case Scenarios (Support Capability Packages)**
- **Reliability and Maintenance Rates**
- **Support Environment and Locations for Support**
- **Support and Maintenance Effectiveness**
- **Duration of Support**

FIGURE 3.2. Development of Support-Related System Requirements

3.3. Concept Refinement Phase and Milestone A - Technology Development Phase

At Milestone A, the PM should address the criteria in the ICD. The purpose of concept refinement is to further refine the initial concept and develop a Technology Development Strategy (TDS). Entrance into this phase depends on a validated ICD and an approved plan for conducting an AoA for the selected concept approved in the ICD. In the ICD, the user should document those lessons learned and cost drivers of current systems, and/or constraints that impact the supportability-related design requirements of the planned system, along with those of the support system. These details guide the acquisition community in refining the concept selected in the ICD and identifying potential constraints on operating and support resource requirements.

Upon approval of the TDS and selection of an initial concept, the project enters the Technology Development phase at Milestone A. The purpose of this phase is to reduce technology risk and to determine the appropriate set of technologies to be integrated into a full system.

Key logistics criteria for consideration during Concept Refinement and Technology Development include:

- Forecast the physical and operational maintenance environment of the proposed system.
- Given the forecasted environment, assess the functional characteristics of the proposed system, its complexity, and the obstacles and enablers to effective sustainment in that environment.
- Assess the impact of the proposed system on the maintenance capabilities planned for the period in which the system will be introduced.
- Assess preliminary manpower and personnel requirements and constraints in both quantity and skill levels, and use of contractor support.

- Begin compilation of information and requirements for logistics footprint reductions, deployment requirements, and other factors affecting the in-theater operational concept.
- Initiate the development of operating and support reliability objectives and their corresponding benefits and resource requirements. Consider the performance histories of prior systems or systems of similar capability where feasible.
- Assess the concept and technology with regard to their ability to facilitate the use of embedded diagnostics, prognostics, and similar maintenance enablers.
- Initiate the compilation and assessment of data on the projected sustainment demand, standardization of platforms, and required support equipment.
- Develop Rough Order of Magnitude (ROM) Life Cycle Cost Estimates (LCCE).

Key logistics information compiled during Concept Refinement and Technology Development includes:

- AoA to include alternative operating and system support concepts, with specific consideration of performance-based options.
- Identification of key performance and related support parameters for inclusion in the CDD and their basis as design requirements for subsequent phases to affect availability, reliability, maintainability, interoperability, manpower, and deployment footprint – the overall capability of the system to perform and endure in the required mission operational environment.
- Market analysis for system and product support capabilities (public and private) to define extent and scope of opportunities for achieving support objectives through design and viable product support strategies. Analysis should include:
    - Elements of support currently provided (for a legacy system to be replaced)
    - Current measures used to evaluate support effectiveness
    - Current efficacy of required support
    - All existing support data across the logistics support elements
    - Assessment of existing technologies and associated support that impact the new system under development
- Initial identification of support-related risk and risk mitigation planning.
    - Design and technology, e.g. LOs, non-COTS, etc.
    - Future projections of domestic and foreign facilitation and logistics infrastructure
    - Cost drivers
- Where applicable, the requirements for providing sustainment during Advanced Concept Technology Demonstrations (ACTDs), Advanced Technology Demonstrations (ATDs), and other technology-oriented demonstrations.

Key logistics activities that must be completed before Milestone B:

- Preparation and/or assessment of sustainment planning and parameters in the CDD

- Description of the product support strategy as documented in the Acquisition Strategy (ASR)
- Description of the appropriate logistics metrics, criteria, and funding requirements in the Acquisition Program Baseline (APB)
- Description of the appropriate logistics considerations and test points in the Test and Evaluation Master Plan (TEMP)

During the Concept Refinement and Technology Development phase of the DoD System Acquisition/Life Cycle Model, system support and maintenance concepts and technologies must be included in the AoA process for each system to define:

- Operating and support concepts that identify the best balance between mission performance, life cycle cost, logistics footprint, and risk
- Logistics-related performance parameters that best represent warfighter needs
- Potential SOE of the proposed system based on available and planned technology available and planned.

Figure 3.3 illustrates the need for explicit and iterative identification of operating and support implications and opportunities. As shown, these concepts complement and support the overall system concepts being explored.

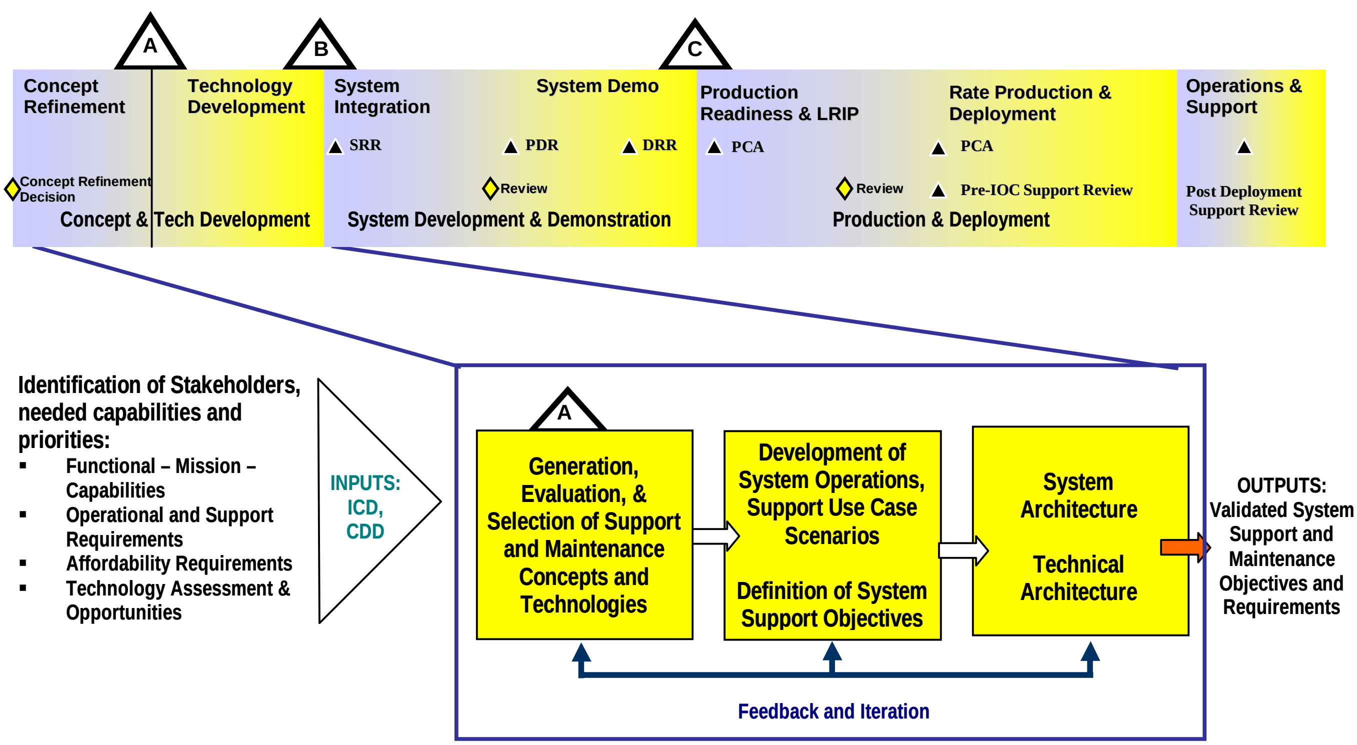


FIGURE 3.3. DoD 5000 Milestone A - Acquisition Model and Framework

Technology trade-offs and their impacts are identified and evaluated in order to ensure selection of a system concept that not only delivers weapon system performance, but also performs with regard to supportability, interoperability and system affordability. Performing a market analysis identifies opportunities to achieve support objectives through design and alternative product support strategies. Risk assessments are performed to identify and develop design tradeoffs that mitigate risk. Once the preferred system and system support concepts and technologies are selected, case scenarios reflecting system support, maintenance, and logistics scenarios must be developed. These scenarios identify significant system support, maintenance, and logistics requirements and objectives. The system and technical architectures flow from development of these requirements and objectives.

Architecture Considerations During Pre-Acquisition

The Concept Refinement and Technology Development Phases of the acquisition model offer significant opportunities to influence the system design and architecture from a support and logistics viewpoint. Figure 3.4 lists attributes of the system architecture with potential for positive impact on system reliability, maintainability, and supportability. Prior to the next acquisition phase, Milestone B, and during the assessment and evaluation of a system's architecture, a thorough exploration of these attributes yields a basis for development of the system and its support-related requirements. The attributes can provide a foundation from which to direct the system architecture toward greater openness, modularity, scalability, and upgradeability - all critical to implement an evolutionary acquisition strategy. Such attributes expand system flexibility and affordability through use of COTS system elements. Astute investigation of these attributes at this point pays big dividends later, when obsolescence and end-of-life issues and concerns must be resolved through a concerted technology refreshment strategy and plan. Accordingly, care must be taken to assess the long-term sustainability of various COTS options and to avoid or minimize single source options. This plan, in turn, becomes key to optimize logistics and support resources for COTS-intensive deployed systems.

PHYSICAL COMMONALITY (WITHIN THE SYSTEM)	**REQUIREMENTS ALLOCATION AND SYSTEM PACKAGING**
HW Commonality • Software Commonality	**INTERFACES – MINIMIZATION OF TYPES AND QUANTITY**
PHYSICAL FAMILIARITY (FROM OTHER SYSTEMS)	**MAINTAINABILITY/MODULARITY**
OPERATIONAL COMMONALITY	**TESTABILITY/MODELLING AND SIMULATION**
USE OF COTS	**CONFIGURATION CONSISTENCY AND COMPATIBILITY**
RELIABILITY	**OPEN SYSTEMS ORIENTATION**

FIGURE 3.4. Illustrative attributes for Supportability Assessment of System Architectures.

Risk Considerations During Pre-Acquisition

Technology risk considerations must receive intensive consideration as the system concept is developed. Maximum use of low-to-medium risk technology, as indicated in Figure 3.5, provides the greatest opportunity to hold fast to program cost, schedule and performance requirements. Medium-to-high risk technologies should be thoroughly justified and accompanied by thorough risk assessments. Use of high-risk technologies is a critical factor in choosing an evolutionary acquisition strategy.

Technology Maturity	Technology Description
Low Risk	Existing Mature Technologies
Medium Risk	Maturing Technologies; New Applications of Mature Technologies
High Risk	Immature Technologies; New Combinations of Maturing Technologies

FIGURE 3.5. Technology Risk Considerations

3.4. Milestone B - System Development and Demonstration Phase

The system formally enters the acquisition process at Milestone B. Milestone Decision Authority (MDA) approval at Milestone B permits the system to enter the System Development and Demonstration (SDD) phase. The purposes of SDD are to: develop a system; reduce integration and manufacturing risk; ensure operational supportability with particular attention to reducing the logistics footprint; implement human systems integration (HSI); design for producibility; ensure affordability and protection of critical program information (CPI); and demonstrate system integration, interoperability, safety, and utility. During this phase, the program and the system architecture are defined based upon the selection and integration of the mature technology suite accomplished during Concept Refinement and Technology Development. System design requirements are developed down to the major subsystem level. During this phase the support concept and strategy are refined and potential PBL Product Support Integrator (PSI) and providers are identified.

Key logistics criteria for consideration during SDD include:

- Mission capabilities: More discrete identification of the taxonomy and metrics driving performance-based outcomes.
- Availability requirements: A detailed assessment of the requirements for the system to operate successfully in the mission operational environment, and the necessary support requirements to achieve that objective.
- Reliability: Given the operational environment and combatant commander availability requirements, define the logistics reliability targets and the corresponding sustainment infrastructure necessary to ensure achievement of the reliability objectives.
- Maintainability: Comprehensive identification of both projected maintenance strategy, including diagnostics, prognostics, maintenance duration targets, and similar measures.
- Manpower and personnel requirements, both organic and contractor sourced.
- Continued refinement of LCCEs.
- Support-related performance and acceptance criteria to be demonstrated during planned testing and through modeling and simulation.
- The collection, analysis, and evaluation of system performance and maintenance performance data to determine the need for and prescribe changes to the system

configuration, maintenance support structure, and maintenance resource requirements. Utilization of on-board (embedded) monitoring sensors, diagnostics, and prognostics are integral to this process.

- Continued inclusion of logistics support considerations in detailed design reviews to include life cycle costs, and characteristics such as openness of design, upgradeability, modularity, testability, and commercial technology insertion.
- Iterative refinement of logistics support considerations correspondent with the evolutionary acquisition strategy (when employed).
- Begin verification of support-related design characteristics and product support strategy and infrastructure.
- Identification of PSI, potential support providers (public and private), and potential partnering opportunities.
- Depot-level maintenance core capability assessment and the identification of workloads required to sustain those capabilities.
- Identification of potential organic depot-level sources of maintenance.
- Development of PBL Business Case Analysis (BCA) to determine:
  - The relative cost vs. benefits of different support strategies.
  - The impact and value of performance/cost/schedule/sustainment trade-offs
  - Data required to support and justify the PBL strategy
- PSI performance outcomes/requirements, e.g. mission readiness, logistics footprint, response times, etc.
- Development of performance based logistics product support concept to include development of warfighter and support provider agreements.

Key logistics information compiled during SDD includes:

- Updated support strategy, sustainment funding requirements, key logistics parameters, and logistics testing criteria (see information that must be completed before Milestone C, below).
- PBL BCA.
- Auditable depot-level maintenance core capability and workload assessment (to be completed bi-annually).
- As required by statute, an annual determination of the distribution of maintenance workloads.

Key logistics information/activities that must be completed or updated before Milestone C include:

- Updated support strategy within the ASR
- Updated logistics criteria and parameters with the APB
- Logistics and overall sustainment requirements as referenced in the CPD
- Logistics parameters and test points in the TEMP

- Acceptable performance in development, test and evaluation, and operational assessment, to include:
  - Mature software capability
  - Acceptable interoperability
  - Acceptable operational supportability
- Demonstration that the system is affordable throughout the life cycle, optimally funded, and properly phased for rapid acquisition.

The System Development and Demonstration phase following Milestone B approval is the most critical timeframe to optimize system sustainment through designed-in criteria. The CDD has been initiated and is refined toward a CPD prior to Milestone C.

During this phase, the two major focus areas for sustainment are:

- Designing-in the critical aspects of supportability through application of the SOE model, and
- Initial framework and options development for the long-term performance-based support strategy.

Critical support parameters are selected, metrics defined, and incentives developed for eventual performance-based support contracts and/or performance-based agreements. Stakeholders (including potential support providers) are identified and included in Integrated Product/Process Team (IPT) processes to build early understanding of and buy-in for support requirements and objectives. Incentives to design for support and to design a cost-effective support concept can, and should, be linked to the product support strategy. Identification and involvement of the potential support providers and integrator early during these efforts is essential for the program to be a success.

Available tools and opportunities - such as modeling and simulation, performance testing, supportability testing/demonstration, technical data validation, and maintenance assessments - should be vigorously applied. For example, system requirements can be used to develop a system reliability/availability block diagram as a basis for modeling and analysis. This approach can identify opportunities for targeted system redundancy, ease of reconfiguration, and derating, etc., and can thereby enhance system-level reliability and availability. In addition, Reliability, Maintainability (BIT/Prognostics), and Supportability/Logistics Demonstrations provide the data to assess achievement of RMS requirements.

The Design Readiness Review (DRR) during SDD provides an opportunity for mid-phase assessment of design maturity. Successful completion of the DRR ends Systems Integration and continues the SDD phase into the System Demonstration effort. The System Requirements Review (SRR) and Preliminary Design Review (PDR) often precede the DRR.

Figure 3.6 shows how key selected system reliability, maintainability, and supportability engineering processes, which are part of the overall systems engineering process, fit within the Defense Acquisition Management Framework. A Failure Modes and Effects Criticality Analysis (FMECA) helps identify the ways in which systems can fail, performance consequences, and the support remedies for system failures. When conducted in a timely fashion, the FMECA can be used to support trade-offs between performance and life cycle costs to drive design improvements. A Fault Tree Analysis (FTA) assesses the safety-critical functions within the system's architecture and design. A Maintainability Analysis and Prediction (MAP) assesses the maintenance aspects of the system's architecture, including maintenance times and resources. This analysis identifies strategic opportunities for focused diagnostics, prognostics, and Performance Monitoring/Fault Localization (PM/FL), leading to reduced system maintenance times and cost drivers. A level of repair analysis (LORA) optimally allocates maintenance functions for maximum affordability.

Once FMECA, FTA, and MAP are completed and system design has been established, Reliability-Centered Maintenance (RCM) develops a focused, cost-effective system preventive maintenance program[2]. RCM uses a system-based methodical approach to determine causes of failure, failure consequences, and a logic tree analysis to identify the most applicable and effective maintenance task(s) to prevent failure, if possible. A maintenance task analysis identifies detailed logistics and support resource requirements to sustain system readiness. Appropriate use of proactive maintenance technologies embodied in diagnostics and prognostics pay system dividends. Integrating on-board and off-board monitoring, testing, data collection, and analysis capabilities can significantly enhance system maintainability and overall supportability. Typically, practices here include enhanced prognosis/diagnosis techniques, failure trend analysis, electronic portable or point-of-maintenance aids, corrosion mitigation, serial item management, automatic identification technology, and data-driven interactive maintenance training. Ultimately, these practices can increase operational availability and readiness at a reduced cost throughout the weapon system life cycle.

RCM provides rules for determining evidence of need for Condition-Based Maintenance (CBM). The goal of CBM is to perform maintenance only upon evidence of need. It is the Department of Defense policy that the tenets of CBM Plus (CBM+) shall be implemented in weapon systems maintenance and logistics support programs where cost effective. CBM+ expands on these basic concepts, encompassing other technologies, processes, and procedures that enable improved maintenance and logistics practices. CBM+ can be defined as a set of maintenance processes and capabilities derived, in large part, from real-time assessment of weapon system condition, obtained from embedded sensors and/or external tests and measurements.

The desirable objective is a force of maintainers with knowledge, skill-sets, and tools for timely maintenance of complex systems through use of technologies that improve maintenance decisions and integrate the logistics processes.

3.5. Milestone C - Production and Deployment Phase

The purpose of the Production and Deployment phase is to achieve an operational capability that satisfies mission needs. Milestone C authorizes entry into Low-Rate Initial Production (LRIP). At Milestone C, the system design should be sufficient to initiate production. The system level technical requirements have been demonstrated to be adequate for acceptable operational capability. The product support strategy is fully defined, a PSI (Product Support Integrator) has been selected, and PBL agreements that reflect performance, support, and funding expectations should be documented and signed. Funding should be identified and available for testing and implementation of the selected performance based logistics strategy with a selected PSI.

[2] SAE JA1011 (Evaluation Criteria for RCM Programs) and SAE JA1012 (A Guide to the RCM Standard) are illustrative commercial standards for this method.

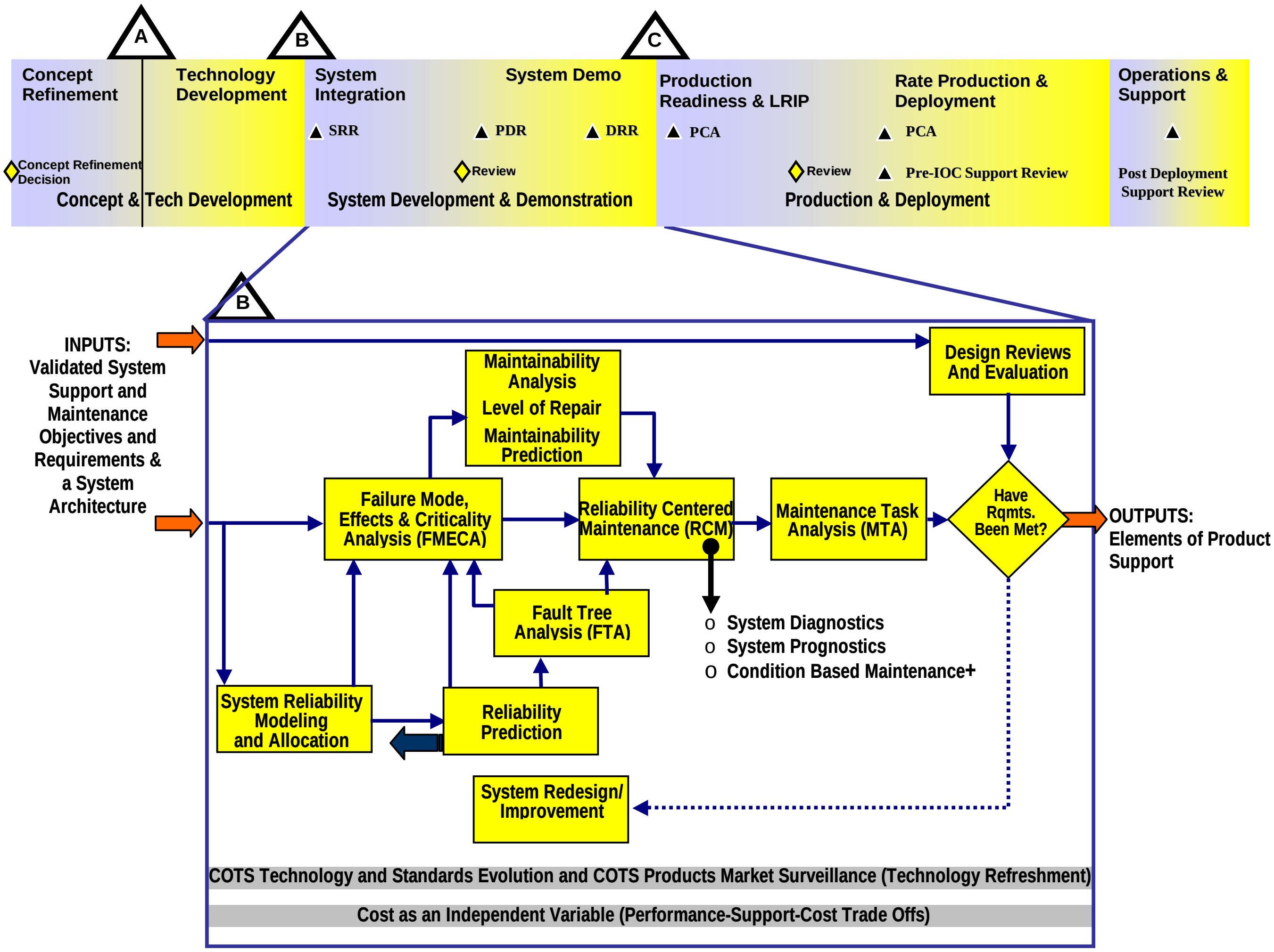


Figure 3.6. The DOD 5000 Milestone B Acquisition Model and Framework

Key logistics criteria for consideration during Production and Deployment include:

System Requirements:

- Mission capabilities: Reviewed and modified as final testing and configuration decisions are made. Emphasis on the capability of the sustainment strategy to meet overall mission capability requirements.
- Reliability: Mission and logistics reliability should clearly meet desired metric targets while supporting the achievement of overall system performance objectives.
- Maintainability: The effective operation of diagnostics, prognostics, and performance-based maintenance arrangements should be in place or in transition, meeting previously specified objectives.
- Manpower and Personnel: Goals for both organic and contractor manpower requirements should be validated.
- LCCE: Final refinement of life cycle costs should be validated.

Product Support:

- Completed BCA on performance based logistics approach (consistent with evolutionary acquisition/spiral development planning, where applicable).
- Completed, approved and funded product support/sustainment approach to include:
    - Documented performance agreements between the PM, PSI, and the force provider that define the system's operational performance requirements, e.g. readiness, availability, response times, etc.
    - The PM, PSI, and the support provider(s) define required support metrics necessary to meet the system performance requirements. Support providers may be public, private, or a mix to include public – private partnerships. Examples of public support providers include Service maintenance depots, Service and Defense Logistics Agency (DLA) inventory control points, and DLA distribution depots.
- Funding commitments commensurate with support provided
- Planned product support integrator/product support provider and warfighter implementation structure to include:
    - Integrator accountability for managing and integrating all support providers to meet established requirements.
    - Roles, relationships and functions between PM, PSI, provider(s) (public/private), and warfighter to include funding.
- Comprehensive review of support-related performance and acceptance criteria in a pre-IOC supportability assessment (see below).
    - Verify implementation and execution of performance based logistics agreements.
    - Verify funding of operations and support to required levels.

Key logistics information compiled during Production and Deployment includes:

- Updated support strategy within the overall ASR to include technology development strategy updated for follow on increments if evolutionary acquisition is employed.
- Updated logistics parameters in the APB.
- Updated logistics and sustainment criteria and test points in the TEMP.
- PBL agreements, i.e., among PM, PSI, and warfighter, and PM, PSI, and providers.

Key logistics activities that must be completed or updated before Operations and Support include:

- Satisfaction of sustainment criteria addressed in Initial Operational Test and Evaluation (IOT&E)
- PBL agreements among PM, PSI, and warfighter, and PM, PSI, and providers
- Fully funded sustainment program
- Pre-IOC Review
    - This review performed at Service – level is carried out to:
        - Confirm design maturity of the system

- Determine status of correction of any deficiencies identified
- Confirm configuration control
- Certify Product Support Integrator/Providers plans to meet war fighter requirements
- Verify Product Support Integrator/Provider agreements/contracts and funding in place

During the SDD phase, there is a shift from the design aspects of RMS to ensuring that the logistics elements are developed, procured, and deployed to required locations in quantities adequate to ensure readiness and preparedness objectives. As identified in the discussion of SDD activities, performance agreements must document critical support metrics necessary to achieve operational performance capabilities. Full accountability, incentives, and resource requirements are specified in the agreements.

Support and logistics elements are deployed to facilitate IOT&E. Then, upon approval for production by the MDA, procurement and deployment for these elements expand to support LRIP levels and deployment that demonstrate primary mission capabilities. At Milestone C, program funding is finalized. Review of final BCA for support strategy is completed and appropriate stakeholders sign performance agreements.

This phase focuses attention on supply chain management and spares optimization, training and manpower, test and support equipment and facilities, and maintenance planning, e.g., optimizing the initial preventive and condition based maintenance program as a result of actual system deployment and usage. For a COTS-intensive system, on-going assessment of technology maturity and standards evolution lowers obsolescence and end-of-life risks.

Periodic re-assessments of initial performance levels and logistics elements must be performed and appropriate corrective action taken to ensure cost-effective compatibility between the system and its support infrastructure. The ultimate benefit is achievement of required readiness rates, mission capability and reduced system life cycle costs.

3.6. Post-IOC Evolution of Sustainment Strategies

Sustainment strategies for iterative production increments in an evolutionary acquisition strategy should fully address the support requirements for each block increment. A thorough assessment of the existing support strategy vis-à-vis new system performance and support requirements should be conducted at each evolutionary phase, and changes made as necessary. An initial assessment at increment one should address the support implications of the logistics support strategy for both the initial block and follow-on increments. At each successive increment, a total systems support assessment should be conducted for that block. This introduces the need for assessment and revision of support strategies as a continuing, life cycle process, with the corresponding need for regular reviews, as outlined below.

3.7. Post Deployment Reviews

While acquisition phase activities are critical to designing and implementing a successful and affordable sustainment strategy, the ultimate measure of success is application of that strategy after the system has been deployed for operational use. TLCSM, through single point accountability, and PBL, by designating performance outcomes vs. segmented functional support, enables that objective. Warfighters require operational readiness and operation effectiveness – systems accomplishing their missions in accordance with their design parameters in a mission environment. Systems, regardless of the application of design for supportability, suffer varying stresses during actual operational deployment and use. Accordingly, the Services shall conduct periodic assessments of system support strategies vis-à-vis actual vs. expected levels of performance and support. These reviews occur nominally every three to five years after IOC, or when precipitated by changes in requirements/design or performance problems, and should include, at minimum:

- PSI/provider performance
- Product improvements incorporated
- Configuration control

Modification of PBL agreements are made as needed, based on changing warfighter requirements or system design changes. When assessing and revising agreements and support strategies, the process should encompass all previous configuration/block increments, and also include elements of SDD phase activities, with an emphasis on not only 'adding on' new support as required, but also on addressing the support strategy in total across the entire platform and range of deployed configurations. This task requires close coordination with appropriate systems engineering IPTs.

Post-Deployment Reviews Address Total Support Strategy

Assessment and revision of agreements and support strategies should encompass all previous configuration/block increments, as well as elements of SDD phase activities. Life cycle assessments address not only 'adding on' new support as required, but also the total support strategy across the entire platform and range of deployed configurations.

3.8. Post Deployment System Modifications

Performance agreements approved at Milestone C address the initial fielded system configuration. Inevitably, the original product support strategy must be reassessed due to:

- System modifications
- OPTEMPO revisions
- Changes in mission or capability
- Service-initiated weapon system modifications as needed to improve warfighting capability, to enhance weapon system safety, and/or to reduce system ownership costs

Additionally, spiral development and evolutionary acquisition drive modifications to weapon system configurations that impact product support.

Mitigating Risks from Post-Deployment System Modifications

In accord with TLCSM, the PM assesses proposed system modifications in light of supportability and impact on logistics support. Continued assessment of in-service system performance may identify needs for system redesign to address inadequate characteristics, e.g., reliability, obsolescence, etc. This iterative modification assessment process is illustrated in

Figure 3.7. As an example, field data and age exploration studies might suggest reassessment of system preventive maintenance addressed through the RCM analysis. Production modifications, either single or block modifications coincident with production, could require significant logistics system changes that lack funds for retrofit of previously-produced weapon systems. The PM can mitigate these associated support risks through a PBL strategy that holds PBL providers responsible for logistics support of modifications.

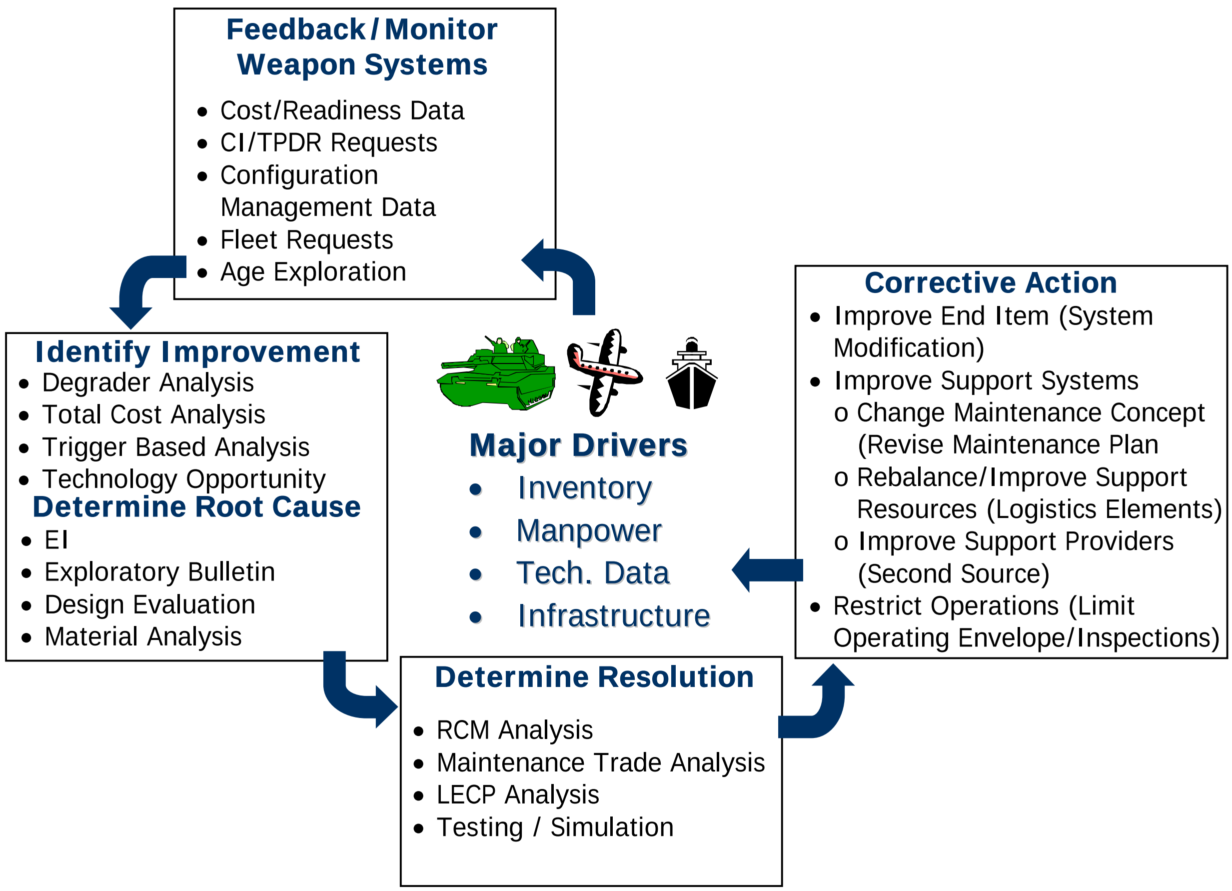


FIGURE 3.7. RCM Sustained Maintenance Planning in Modification Environment

3.9. Assessing and Revising Product Support Strategies

While some system deficiencies are best addressed through system design, many can be resolved by adjusting the product support strategy itself. Often, due to revisions in funding, mission requirements, or support organizations, logistics resources become out of balance or poorly-synchronized. Therefore, PM efforts to increase weapon system availability while reducing life cycle costs and logistics footprint must include periodic assessments and, where necessary, improvements of the product support strategy. Approaches useful to the PM in making these improvements include:

- A Maintenance Plan Analysis: This analysis can help balance logistics support through thorough review of readiness degraders, maintenance data, maintenance program and implementation, and industrial coordination.
- PBAs: Under a PBL strategy, properly documented and incentivized PBAs with support providers encourage product support assessment and improvements. Performance agreements provide for comparison of performance expectations against actual performance data.
- Changes to Integrated Logistics Support: PMs can revise, correct, and improve product support strategies to meet warfighters' performance requirements. PMs can improve system supportability by balancing logistics resources and decreasing repair cycle times. Examples of product support improvements include performing an overhaul vs. repair, changing maintenance plans, improving off-aircraft diagnostic capabilities, transitioning to a commercial supply chain management system, etc.

The ability to continually compare performance against expectations takes actual equipment and support performance data to drive operational data analyses and a RCM decision analysis. Results are implemented through maintenance plan changes.

4.0. SUMMARY

Linking the Defense Acquisition Management Framework with the systems engineering process provides a framework for the PM to design-in enhanced system reliability, maintainability, and supportability to achieve the desired reductions in the necessary logistics footprint and the associated life cycle cost. The concept and the objective remains the same for new development, for modifications and enhancements in fielded systems, and for adapting the logistics support strategy for fielded systems.

Each of these scenarios has been addressed in this guide. Inherent in every case are the necessary tradeoffs among system performance, sustainment, and cost. The stakeholder value system and priorities facilitate this process, and the concept of SOE provides a platform to make such tradeoffs explicit and visible for the PM.

The PM must apply the processes for designing and assessing supportability not only in the acquisition framework, but throughout the entire life cycle. These processes should be applied for all modifications including those configuration changes resulting from evolutionary acquisition and spiral development. Supportability assessments, coordinated with systems engineering, may identify redesign opportunities for fielded systems that would enhance weapon system operational effectiveness. These assessments can also identify sub-optimal performers in the fielded product support system which can be corrected through rebalanced logistics elements or changes to maintenance program. Designing-in, and subsequent continuing assessment of, supportability throughout the life cycle is essential to maintaining the effectiveness of fielded systems, and are responsibilities of the PM.

APPENDIX A - ACRONYM INDEX

ACAT	Acquisition Category
ACTD	Advanced Concept Technology Development
AoA	Analysis of Alternatives
ATD	Advanced Technology Demonstration
BCA	Business Case Analysis
CAIV	Cost as an Independent Variable
CBM	Condition Based Maintenance
CDD	Capabilities Development Document
DRR	Design Readiness Review
COTS	Commercial Off the Shelf
CPD	Capabilities Production Document
CRD	Capstone Requirements Document
DLA	Defense Logistics Agency
DLR	Depot Level Repairable
DMS	Diminishing Manufacturing Sources
DoD	Department of Defense
EI	Engineering Investigation
FLE	Future Logistics Enterprise
FRP	Full Rate Production
FMECA	Failure Modes and Effects Criticality Analysis
FOC	Final Operating Capability
FTA	Fault Tree Analysis
HMR	Hazardous Material Report
HW	Hardware
ICD	Initial Capabilities Document
ICP	Inventory Control Point
IOC	Initial Operating Capability
ILS	Integrated Logistics Support
IPPD	Integrated Product and Process Development

IPT	Integrated Product/Process Team
IOT&E	Initial Operational Test and Evaluation
JTA	Joint Technical Architecture
LCCE	Life Cycle Cost Estimate
LO	Low Observable
LRIP	Low Rate Initial Production
MDA	Milestone Decision Authority
MFOP	Maintenance-Free Operating Period
MTA	Maintenance Task Analysis
OEM	Original Equipment Manufacturer
O&S	Operations and Support
OT&E	Operational Test and Evaluation
PBA	Performance Based Agreement
PPBS	Planning, Programming, and Budgeting System
PBL	Performance Based Logistics
PDR	Preliminary Design Review
PHS&T	Packaging, Handling, Storage and Transportation
PM	Program Manager
PM/FL	Performance Monitoring/Fault Localization
PSI	Product Support Integrator
QDR	Quadrennial Defense Review
RCM	Reliability-Centered Maintenance
RMS	Reliability, Maintainability, and Supportability
SCM	Supply Chain Management
SDOE	System Design for Operational Effectiveness
SDD	System Design and Demonstration
SOE	System Operational Effectiveness
SRR	System Requirements Review
SW	Software
TDS	Technology Development Strategy
TEMP	Test and Evaluation Master Plan

TLCSM	Total Life Cycle System Management
TOC	Total Ownership Costs
TTF	Time to Failure
TTM	Time and Cost to Maintain
TTS	Time and Cost to Support