CHAPTER 2

SYSTEMS ENGINEERING MANAGEMENT IN DOD ACQUISITION

2.1 INTRODUCTION

The DoD acquisition process has its foundation in federal policy and public law. The development, acquisition, and operation of military systems is governed by a multitude of public laws, formal DoD directives, instructions and manuals, numerous Service and Component regulations, and many inter-service and international agreements.

Managing the development and fielding of military systems requires three basic activities: technical management, business management, and contract management. As described in this book, systems engineering management is the technical management component of DoD acquisition management.

The acquisition process runs parallel to the requirements generation process and the budgeting process (Planning, Programming, and Budgeting System.) User requirements tend to be event driven by threat. The budgeting process is date driven by constraints of the Congressional calendar. Systems Engineering Management bridges these processes and must resolve the dichotomy of event driven needs, event driven technology development, and a calendar driven budget.

Direction and Guidance

The Office of Management and Budget (OMB) provides top-level guidance for planning, budgeting, and acquisition in OMB Circular A-11, Part 3, and the Supplemental Capital Programming Guide: Planning, Budgeting, and Acquisition of Capital Assets, July 1997. These documents establish the broad responsibilities and ground rules to be followed in funding and acquiring major assets. The departments of the executive branch of government are then expected to draft their own guidance consistent with the guidelines established. The principal guidance for defense system acquisitions is the DoD 5000 series of directives and regulations. These documents reflect the actions required of DoD acquisition managers to:

- Translate operational needs into stable, affordable programs,
- Acquire quality products, and
- Organize for efficiency and effectiveness.

2.2 RECENT CHANGES

The DoD 5000 series documents were revised in 2000 to make the process more flexible, enabling the delivery of advanced technology to warfighters more rapidly and at reduced total ownership cost. The new process encourages multiple entry points, depending on the maturity of the fundamental technologies involved, and the use of evolutionary methods to define and develop systems. This encourages a tailored approach to acquisition and engineering management, but it does not alter the basic logic of the underlying systems engineering process.

2.3 ACQUISITION LIFE CYCLE

The revised acquisition process for major defense systems is shown in Figure 2-1. The process is

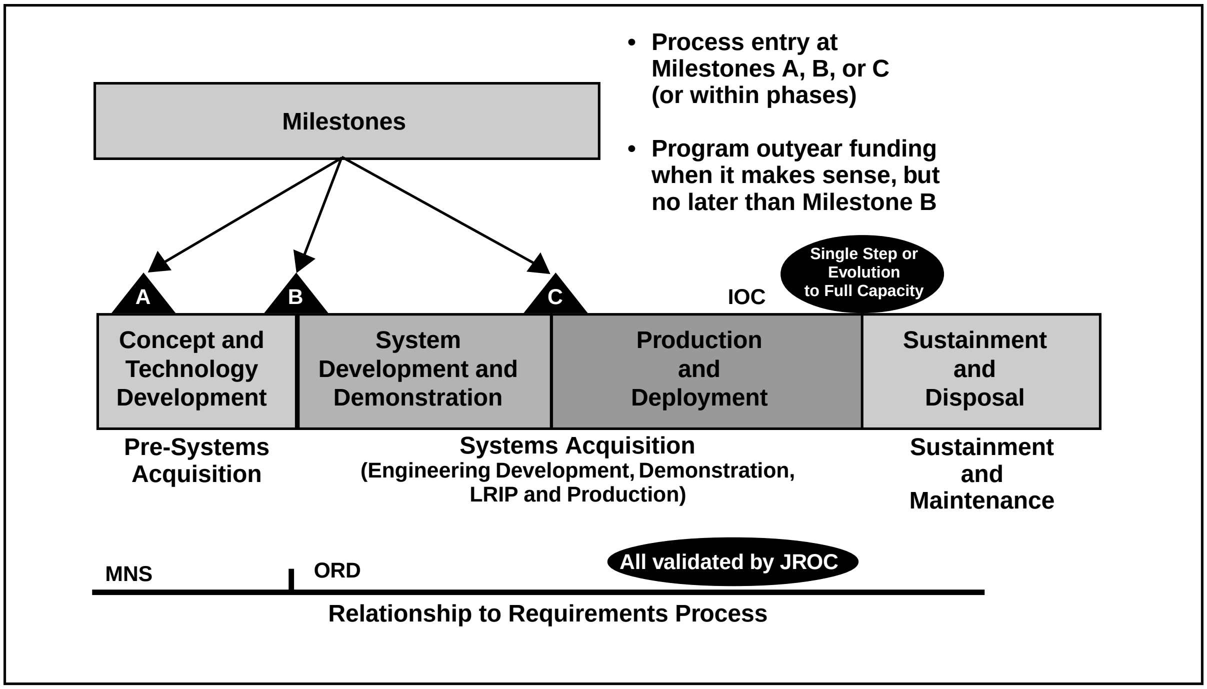

Figure 2-1. Revised DoD 5000 Acquisition Process

defined by a series of phases during which technology is defined and matured into viable concepts, which are subsequently developed and readied for production, after which the systems produced are supported in the field.

The process allows for a given system to enter the process at any of the development phases. For example, a system using unproven technology would enter at the beginning stages of the process and would proceed through a lengthy period of technology maturation, while a system based on mature and proven technologies might enter directly into engineering development or, conceivably, even production. The process itself (Figure 2-1) includes four phases of development. The first, **Concept and Technology Development**, is intended to explore alternative concepts based on assessments of operational needs, technology readiness, risk, and affordability. Entry into this phase *does not* imply that DoD has committed to a new acquisition program; rather, it is the initiation of a process to determine whether or not a need (typically described in a Mission Need Statement (MNS)) can be met at reasonable levels of technical risk and at affordable costs. The decision to enter into the Concept and Technology Development phase is made formally at the Milestone A forum.

The **Concept and Technology Development** phase begins with concept exploration. During this stage, concept studies are undertaken to define alternative concepts and to provide information about capability and risk that would permit an objective comparison of competing concepts. A decision review is held after completion of the concept exploration activities. The purpose of this review is to determine whether further technology development is required, or whether the system is ready to enter into system acquisition. If the key technologies involved are reasonably mature and have already been demonstrated, the Milestone Decision Authority (MDA) may agree to allow the system to proceed into system acquisition; if not, the system may be directed into a component advanced development stage. (See Supplement A to this chapter for a definition of Technology Readiness levels.) During this stage, system architecture definition will continue and key technologies will be demonstrated in order to ensure that technical and cost risks are understood and are at acceptable levels prior to entering acquisition. In any event, the

Concept and Technology Development phase ends with a defined system architecture supported by technologies that are at acceptable levels of maturity to justify entry into system acquisition.

Formal system acquisition begins with a Milestone B decision. The decision is based on an integrated assessment of technology maturity, user requirements, and funding. A successful Milestone B is followed by the **System Development and Demonstration** phase. This phase could be entered directly as a result of a technological opportunity and urgent user need, as well as having come through concept and technology development. The System Development and Demonstration phase consists of two stages of development, system integration and system demonstration. Depending upon the maturity level of the system, it could enter at either stage, or the stages could be combined. This is the phase during which the technologies, components and subsystems defined earlier are first integrated at the system level, and then demonstrated and tested. If the system has never been integrated into a complete system, it will enter this phase at the system integration stage. When subsystems have been integrated, prototypes demonstrated, and risks are considered acceptable, the program will normally enter the system demonstration stage following an interim review by the MDA to ensure readiness. The system demonstration stage is intended to demonstrate that the system has operational utility consistent with the operational requirements. Engineering demonstration models are developed and system level development testing and operational assessments are performed to ensure that the system performs as required. These demonstrations are to be conducted in environments that represent the eventual operational environments intended. Once a system has been demonstrated in an operationally relevant environment, it may enter the Production and Deployment phase.

The **Production and Deployment** phase consists of two stages: production readiness and low rate initial production (LRIP), and rate production and deployment. The decision forum for entry into this phase is the Milestone C event. Again, the fundamental issue as to where a program enters the process is a function of technology maturity, so the possibility exists that a system could enter directly into this phase if it were sufficiently mature, for example, a commercial product to be produced for defense applications. However the entry is made—directly or through the maturation process described, the production readiness and LRIP stage is where initial operational test, live fire test, and low rate initial production are conducted. Upon completion of the LRIP stage and following a favorable Beyond LRIP test report, the system enters the rate production and deployment stage during which the item is produced and deployed to the user. As the system is produced and deployed, the final phase, Sustainment and Disposal, begins.

The last, and longest, phase is the **Sustainment and Disposal** phase of the program. During this phase all necessary activities are accomplished to maintain and sustain the system in the field in the most cost-effective manner possible. The scope of activities is broad and includes everything from maintenance and supply to safety, health, and environmental management. This period may also include transition from contractor to organic support, if appropriate. During this phase, modifications and product improvements are usually implemented to update and maintain the required levels of operational capability as technologies and threat systems evolve. At the end of the system service life it is disposed of in accordance with applicable classified and environmental laws, regulations, and directives. Disposal activities also include recycling, material recovery, salvage of reutilization, and disposal of by-products from development and production.

The key to this model of the acquisition process is that programs have the flexibility to enter at any of the first three phases described. The decision as to where the program should enter the process is primarily a function of user needs and technology maturity. The MDA makes the decision for the program in question. Program managers are encouraged to work with their users to develop evolutionary acquisition strategies that will permit deliveries of usable capabilities in as short a timeframe as possible, with improvements and enhancements added as needed through continuing definition of requirements and development activities to support the evolving needs.

2.4 SYSTEMS ENGINEERING IN ACQUISITION

As required by DoD 5000.2-R, the systems engineering process shall:

1. Transform operational needs and requirements into an integrated system design solution through concurrent consideration of all life-cycle needs (i.e., development, manufacturing, test and evaluation, verification, deployment, operations, support, training and disposal).

2. Ensure the compatibility, interoperability and integration of all functional and physical interfaces and ensure that system definition and design reflect the requirements for all system elements: hardware, software, facilities, people, and data; and

3. Characterize and manage technical risks.

4. Apply scientific and engineering principles to identify security vulnerabilities and to minimize or contain associated information assurance and force protection risks.

These objectives are accomplished with use of the management concepts and techniques described in the chapters which follow in this book. The application of systems engineering management coincides with acquisition phasing. In order to support milestone decisions, major technical reviews are conducted to evaluate system design maturity.

Concept and Technology Development

The Concept and Technology Development phase consists of two pre-acquisition stages of development. The first, **Concept Exploration**, is represented in Figure 2-2. The exploration of concepts is usually accomplished through multiple short-term studies. Development of these studies is

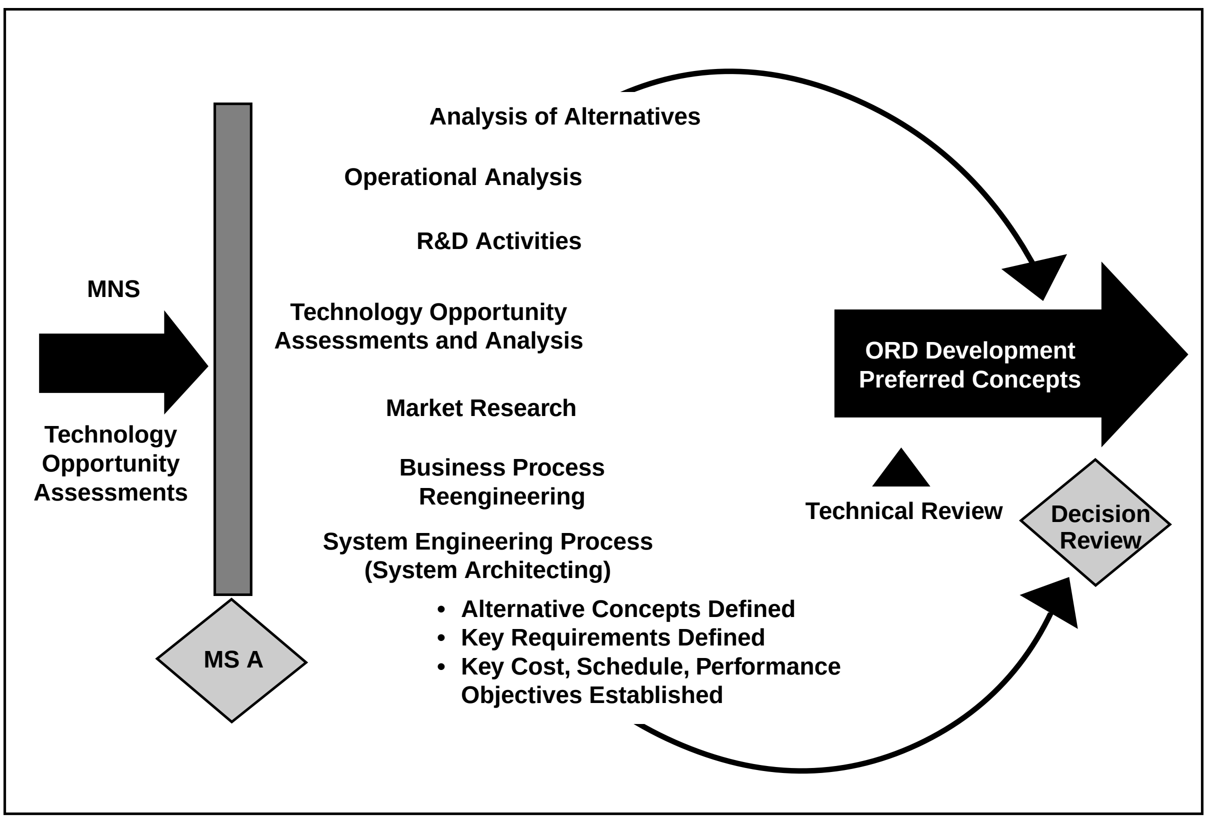

Figure 2-2. Concept and Technology Development (Concept Exploration Stage)

expected to employ various techniques including the systems engineering process that translates inputs into viable concept architectures whose functionality can be traced to the requirements. In addition, market surveys, Business Process Reengineering activities, operational analysis, and trade studies support the process.

The primary inputs to these activities include requirements, in form of the MNS, assessments of technology opportunities and status, and the outputs from any efforts undertaken to explore potential solutions. When the contractor studies are complete, a specific concept to be pursued is selected based on a integrated assessment of technical performance; technical, schedule and cost risk; as well as other relevant factors. A decision review is then held to evaluate the concept recommended and the state of technology upon which the concept depends. The MDA then makes a decision as to whether the concept development work needs to be extended or redirected, or whether the technology maturity is such that the program can proceed directly to either Mile-stone B (System Development and Demonstration) or Milestone C (Production and Deployment).

If the details of the concept require definition, i.e., the system has yet to be designed and demonstrated previously, or the system appears to be based on technologies that hold significant risk, then it is likely that the system will proceed to the second stage of the Concept and Technology Development phase. This stage, **Component Advanced Development**, is represented in Figure 2-3. This is also a pre-acquisition stage of development and is usually characterized by extensive involvement of the DoD Science and Technology (S&T) community. The fundamental objectives of this stage of development are to define a system-level architecture and to accomplish risk-reduction activities as required to establish confidence that the building blocks of the system are sufficiently well-defined, tested and demonstrated to provide confidence that, when integrated into higher level assemblies and subsystems, they will perform reliably.

Development of a system-level architecture entails continuing refinement of system level requirements based on comparative analyses of the system concepts under consideration. It also requires that consideration be given to the role that the system

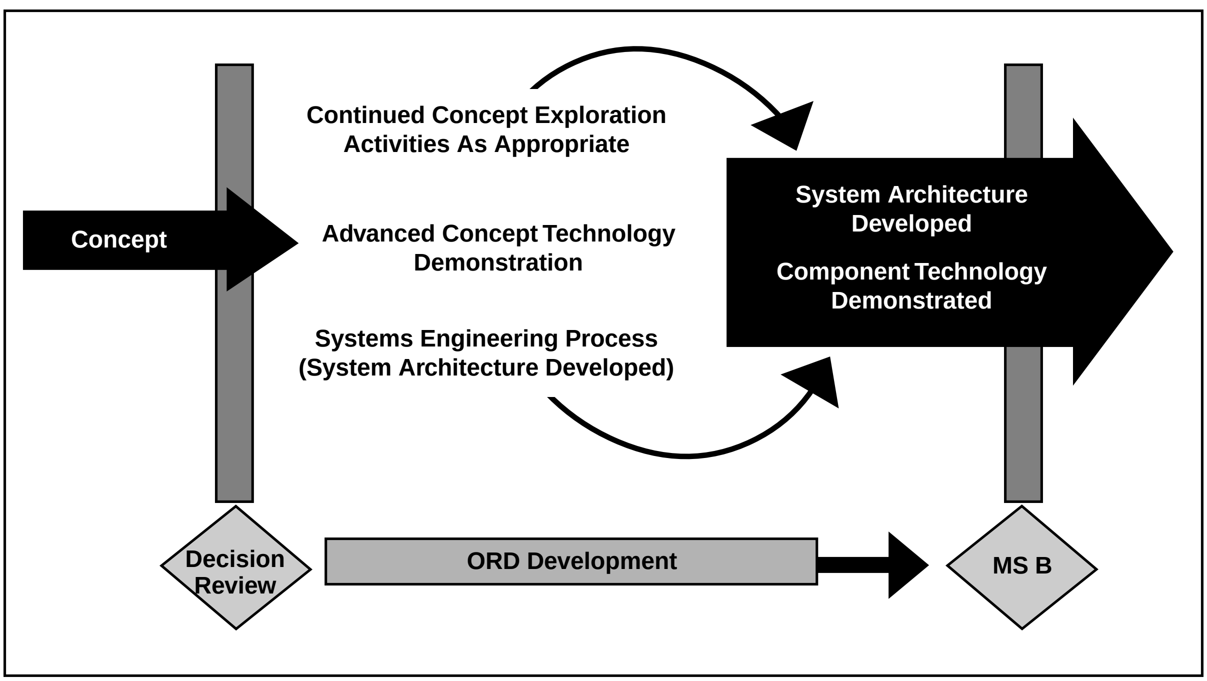

Figure 2-3. Concept and Technology Development (Component Advanced Development Stage)

will play in the system of systems of which it will be a part. System level interfaces must be established. Communications and interoperability requirements must be established, data flows defined, and operational concepts refined. Top level planning should also address the strategies that will be employed to maintain the supportability and affordability of the system over its life cycle including the use of common interface standards and open systems architectures. Important design requirements such as interoperability, open systems, and the use of commercial components should also be addressed during this stage of the program.

Risk reduction activities such as modeling and simulation, component testing, bench testing, and man-in-the-loop testing are emphasized as decisions are made regarding the various technologies that must be integrated to form the system. The primary focus at this stage is to ensure that the key technologies that represent the system components (assemblies and sub-systems) are well understood and are mature enough to justify their use in a system design and development effort. The next stage of the life cycle involves engineering development, so research and development (R&D) activities conducted within the science and technology appropriations should be completed during this stage.

System Development and Demonstration

The decision forum for entry into the System Development and Demonstration (SD&D) phase is the Milestone B event. Entry into this phase represents *program initiation*, the formal beginning of a system acquisition effort. This is the government commitment to pursue the program. Entry requires mature technology, validated requirements, and funding. At this point, the program requirement must be defined by an Operational Requirements Document (ORD). This phase consists of two primary stages, system integration (Figure 2-4) and system demonstration (Figure 2-5).

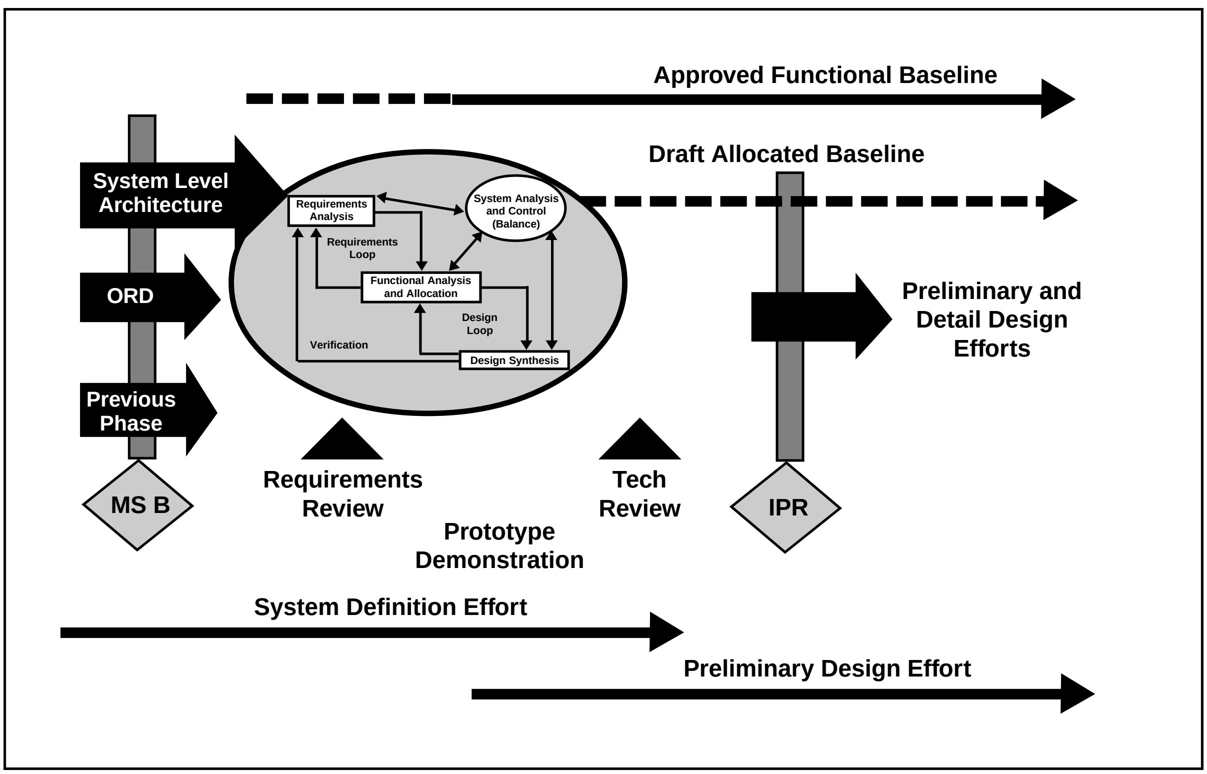

Figure 2-4. System Development and Demonstration (System Integration Stage)

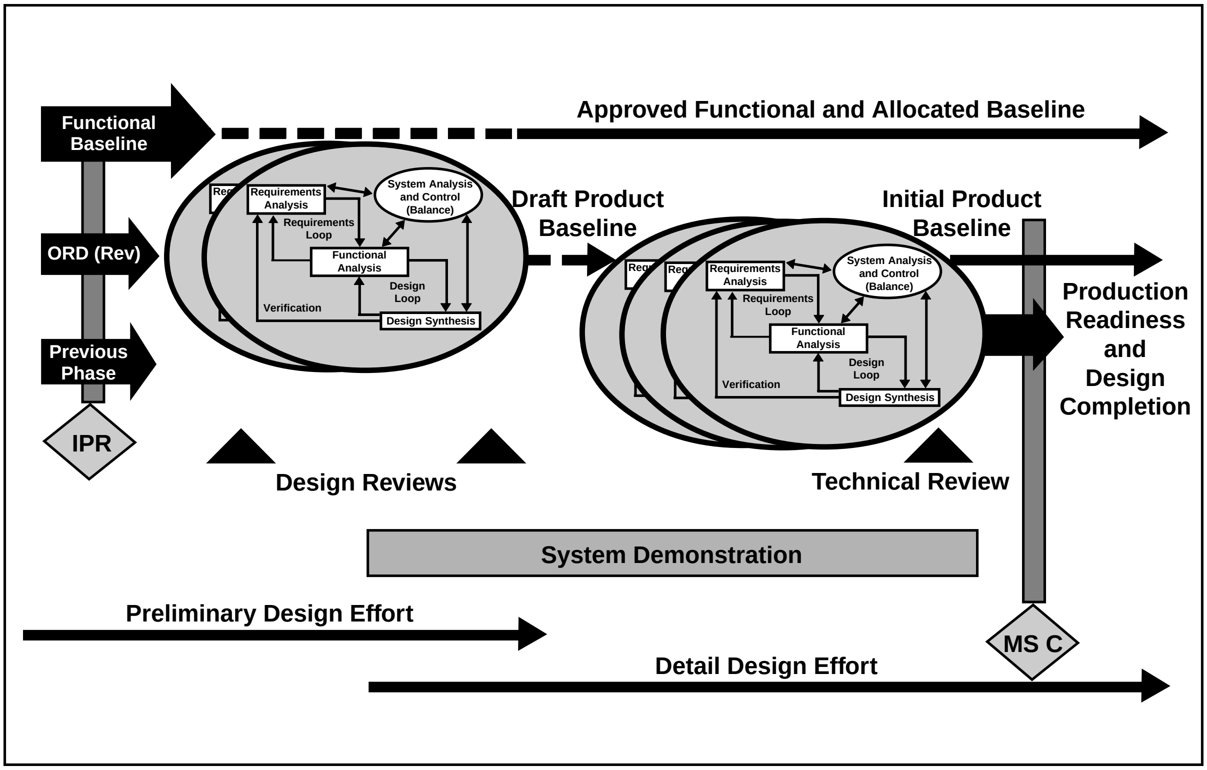

Figure 2-5. System Development and Demonstration (System Demonstration Stage)

There is no hard and fast guidance that stipulates precisely how the systems engineering process is to intersect with the DoD acquisition process. There are no specified technical events, e.g., DoD designated technical reviews, that are to be accomplished during identified stages of the SD&D phase. However, the results of a SD&D phase should support a production go-ahead decision at Milestone C. That being the case, the process described below reflects a configuration control approach that includes a system level design (functional baseline), final preliminary designs (allocated baselines), and detail designs (initial product baselines). Along with their associated documentation, they represent the systems engineering products developed during SD&D that are most likely needed to appropriately support Milestone C.

System Integration is that stage of SD&D that applies to systems that have yet to achieve system level design maturity as demonstrated by the integration of components at the system level in relevant environments. For an unprecedented system (one not previously defined and developed), this stage will continue the work begun in the component advanced development stage, but the flavor of the effort now becomes oriented to engineering development, rather than the research-oriented efforts that preceded this stage. A formal ORD, technology assessments, and a high-level system architecture have been established. (These will form major inputs to the systems engineering process.) The engineering focus becomes establishment and agreement on system level technical requirements stated such that designs based on those technical requirements will meet the intent of the operational requirements. The system level technical requirements are stabilized and documented in an approved system level requirements specification. In addition, the system-level requirements baseline (functional baseline) is established. This baseline is verified by development and demonstration of prototypes that show that key technologies can be integrated and that associated risks are sufficiently low to justify developing the system.

Program initiation signals the transition from an S&T focus to management by the program office. The R&D community, the users, and the program office may have all been involved in defining the concepts and technologies that will be key to the system development. It is appropriate at this point, therefore, to conduct a thorough requirements analysis and review to ensure that the user, the contractor, and the program office all hold a common view of the requirements and to preserve the lessons learned through the R&D efforts conducted in the earlier phase. The risk at this point can be high, because misunderstandings and errors regarding system-level requirements will flow down to subsequent designs and can eventually result in overruns and even program failure. The contractor will normally use the occasion of the system requirements review early in this stage to set the functional baseline that will govern the flow-down of requirements to lower level items as preliminary designs are elaborated.

The Interim Progress Review held between System Integration and System Demonstration has no established agenda. The agenda is defined by the MDA and can be flexible in its timing and content. Because of the flexibility built into the acquisition process, not all programs will conform to the model presented here. Programs may find themselves in various stages of preliminary design and detailed design as the program passes from one stage of the SD&D phase to the succeeding stage. With these caveats, **System Demonstration** (Figure 2-5) is the stage of the SD&D phase during which preliminary and detailed designs are elaborated, engineering demonstration models are fabricated, and the system is demonstrated in operationally relevant environments.

System level requirements are flowed down to the lower level items in the architecture and requirements are documented in the item performance specifications, which represent the preliminary design requirements for those items. The item performance specifications and supporting documentation, when finalized, together form the allocated baseline for the system. Design then proceeds toward the elaboration of a detailed design for the product or system. The product baseline is drafted as the design is elaborated. This physical description of the system may change as a result of testing that will follow, but it forms the basis for initial fabrication and demonstration of these items. If the system has been previously designed and fabricated, then, clearly, this process would be curtailed to take advantage of work already completed.

Following the elaboration of the detailed design, components and subsystems are fabricated, integrated, and tested in a bottom-up approach until system level engineering demonstration models are developed. These demonstration models are not, as a rule, production representative systems. Rather, they are system demonstration models, or integrated commercial items, that serve the purpose of enabling the developer to accomplish development testing on the integrated system. These models are often configured specifically to enable testing of critical elements of the system, for example, in the case of an aircraft development, there may be separate engineering demonstration models developed specifically to test the integrated avionics subsystems, while others demonstrate the flying qualities and flight controls subsystems.

For purposes of making decisions relative to progress through the acquisition process, these system-level demonstrations are not intended to be restricted to laboratory test and demonstrations. They are expected to include rigorous demonstrations that the integrated system is capable of performing operationally useful tasks under conditions that, while not necessarily equal to the rigor of formal operational testing, represent the eventual environment in which the system must perform. The result of these demonstrations provide the confidence required to convince the decision-maker (MDA) that the system is ready to enter the production phase of the life cycle. This implies that the system has demonstrated not only that technical performance is adequate, but also that the affordability, supportability, and producibility risks are sufficiently low to justify a production decision.

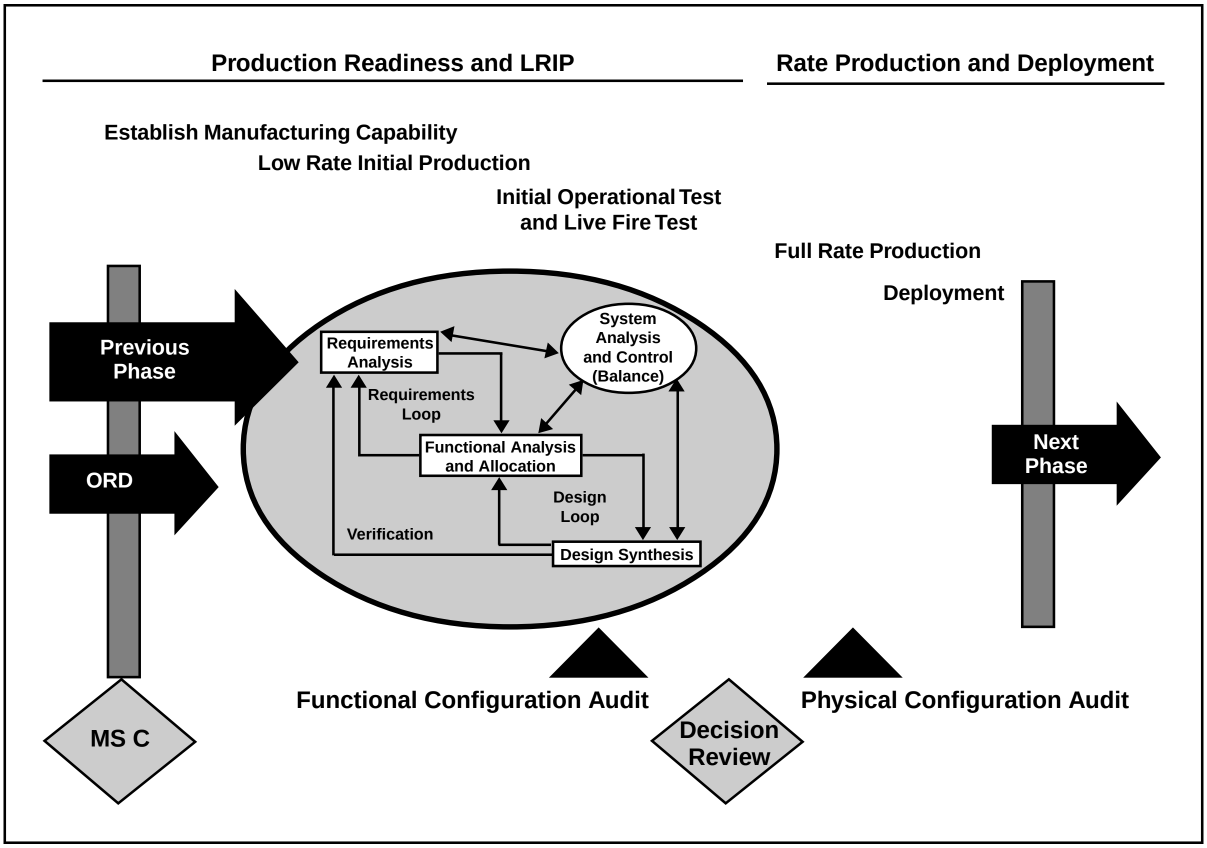

Figure 2-6. Production and Deployment

Production and Deployment

Milestone C is the decision forum for entry into the Production and Deployment phase of the program. Like other phases, this phase is also divided into stages of development. Production Readiness and LRIP is the first of these. At this point, system-level demonstrations have been accomplished and the product baseline is defined (although it will be refined as a result of the activities undertaken during this phase). The effort is now directed toward development of the manufacturing capability that will produce the product or system under development. When a manufacturing capability is established, a LRIP effort begins.

The development of a LRIP manufacturing capability has multiple purposes. The items produced are used to proof and refine the production line itself, items produced on this line are used for Initial Operational Test and Evaluation (IOT&E) and Live Fire Test and Evaluation (LFT&E), and this is also the means by which manufacturing rates are ramped upward to the rates intended when manufacturing is fully underway.

Following the completion of formal testing, the submission of required Beyond-LRIP and Live Fire Test reports, and a full-rate production decision by the MDA, the system enters the Rate Production and Deployment stage. After the decision to go to full-rate production, the systems engineering process is used to refine the design to incorporate findings of the independent operational testing, direction from the MDA, and feedback from deployment activities. Once configuration changes have been made and incorporated into production, and the configuration and production is considered stable, Follow-on Operational Test and Evaluation (FOT&E), if required, is typically performed on the stable production system. Test results are used to further refine the production configuration. Once this has been accomplished and production again becomes stable, detailed audits are held to confirm that the Product Baseline documentation correctly describes the system being produced. The Product Baseline is then put under formal configuration control.

As the system is produced, individual items are delivered to the field units that will actually employ and use them in their military missions. Careful coordination and planning is essential to make the deployment as smooth as possible. Integrated planning is absolutely critical to ensure that the training, equipment, and facilities that will be required to support the system, once deployed, are in place as the system is delivered. The systems engineering function during this activity is focused on the integration of the functional specialties to make certain that no critical omission has been made that will render the system less effective than it might otherwise be. Achieving the user's required initial operational capability (IOC) schedule demands careful attention to the details of the transition at this point. Furthermore, as the system is delivered and operational capability achieved, the system transitions to the Sustainment and Disposal phase of the system life cycle—the longest and most expensive of all phases.

Sustainment and Disposal

There is no separate milestone decision required for a program to enter this phase of the system life cycle. The requirement for the Sustainment phase is implicit in the decision to produce and deploy the system. This phase overlaps the Production phase. Systems Engineering activities in the Sustainment phase are focused on maintaining the system's performance capability relative to the threat the system faces. If the military threat changes or a technology opportunity emerges, then the system may require modification. These modifications must be approved at an appropriate level for the particular change being considered. The change then drives the initiation of new systems engineering processes, starting the cycle (or parts of it) all over again.

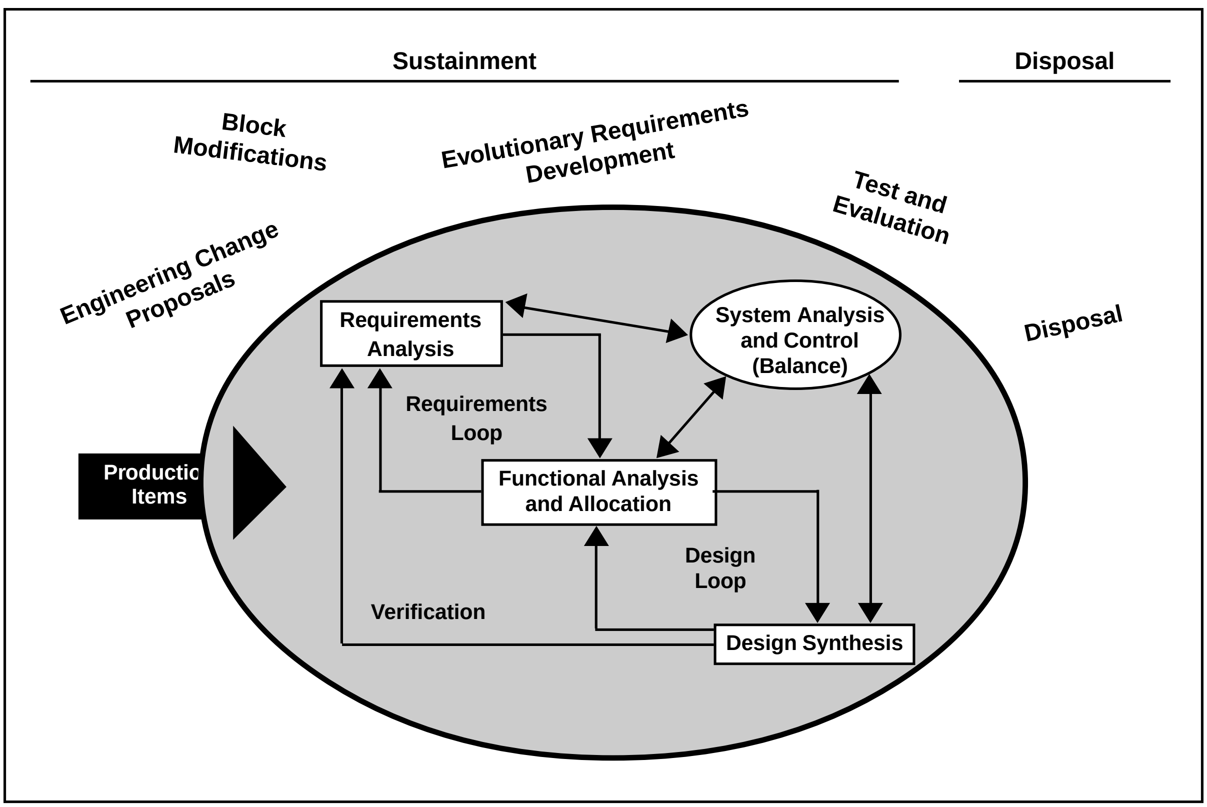

Figure 2-7. Sustainment and Disposal

Also, in an evolutionary development environment, there will be a continuing effort to develop and refine additional operational requirements based on the experience of the user with the portion of the system already delivered. As new requirements are generated, a new development cycle begins, with technology demonstrations, risk reduction, system demonstrations and testing—the same cycle just described—all tailored to the specific needs and demands of the technology to be added to the core system already delivered.

The final activity in the system life cycle is Disposal. System engineers plan for and conduct system disposal throughout the life cycle beginning with concept development. System components can require disposal because of decommissioning, their destruction, or irreparable damage. In addition, processes and material used for development, production, operation, or maintenance can raise disposal issues throughout the life cycle. Disposal must be done in accordance with applicable laws, regulations, and directives that are continually changing, usually to require more severe constraints. They mostly relate to security and environment issues that include recycling, material recovery, salvage, and disposal of by-products from development and production.

Every Development is Different

The process described above is intended to be very flexible in application. There is no “typical” system acquisition. The process is therefore defined to accommodate a wide range of possibilities, from systems that have been proven in commercial applications and are being purchased for military use, to systems that are designed and developed essentially from scratch. The path that the system development takes through the process will depend primarily on the level of maturity of the technology employed. As explained in the preceding discussion, if the system design will rely significantly on the use of proven or commercial items, then process can be adjusted to allow the system to skip phases, or move quickly from stage to stage within phases. If the type of system is well understood within the applicable technical domains, or it is an advanced version of a current well understood system, then the program definition and risk reduction efforts could be adjusted appropriately.

It is the role of the system engineer to advise the program manager of the recommended path that the development should take, outlining the reasons for that recommendation. The decision as to the appropriate path through the process is actually made by the MDA, normally based on the recommendation of the program manager. The process must be tailored to the specific development, both because it is good engineering and because it is DoD policy as part of the Acquisition Reform initiative. But tailoring must done with the intent of preserving the requirements traceability, baseline control, lifecycle focus, maturity tracking, and integration inherent in the systems engineering approach. The validity of tailoring the process should always be a risk management issue. Acquisition Reform issues will be addressed again in Part IV of this text.

2.5 SUMMARY POINTS

- The development, acquisition, and operation of military systems is governed by a multitude of public laws, formal DoD directives, instructions and manuals, numerous Service and Component regulations, and many inter-service and international agreements.

- The system acquisition life cycle process is a model used to guide the program manager through the process of maturing technology based systems and readying them for production and deployment to military users.

- The acquisition process model is intended to be flexible and to accommodate systems and technologies of varying maturities. Systems dependent on immature technologies will take longer to develop and produce, while those that employ mature technologies can proceed through the process relatively quickly.

- The system engineering effort is integrated into the systems acquisition process such that the activities associated with systems engineering (development of documentation, technical reviews, configuration management, etc.) support and strengthen the acquisition process. The challenge for the engineering manager is to ensure that engineering activities are conducted at appropriate points in the process to ensure that the system has, in fact, achieved the levels of maturity expected prior to progressing into succeeding phases.

SUPPLEMENT 2-A

TECHNOLOGY READINESS LEVELS

Technology Readiness Level	Description
1. Basic principles observed and reported.	Lowest level of technology readiness. Scientific research begins to be translated into technology's basic properties.
2. Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. The application is speculative and there is no proof or detailed analysis to support the assumption. Examples are still limited to paper studies.
3. Analytical and experimental critical function and/or characteristic proof of concept.	Active R&D is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4. Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that the pieces will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in a laboratory.
5. Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so that the technology can be tested in simulated environment. Examples include "high fidelity" laboratory integration of components.
6. System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond the breadboard tested for level 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness. Examples include testing a prototype in a high fidelity laboratory environment or in a simulated operational environment.
7. System prototype demonstration in an operational environment.	Prototype near or at planned operational system. Represents a major step up from level 6, requiring the demonstration of an actual system prototype in an operational environment. Examples include testing the prototype in a test bed aircraft. (continued)

Technology Readiness Level	Description
8. Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this level represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9. Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

SUPPLEMENT 2-B

EVOLUTIONARY ACQUISITION CONSIDERATIONS

The evolutionary approach to defense acquisition is the simple recognition that systems evolve as a result of changing user needs, technological opportunities, and knowledge gained in operation. Evolutionary Acquisition is not new to military systems. No naval ship in a class is the same; aircraft and vehicles have block changes designed to improve the design; variants of systems perform different missions; satellites have evolutionary improvements between the first and last launched; and due to fast evolving technology, computer resources and software systems are in constant evolution.

As shown by Figure 2-8, evolutionary acquisition starts with the development and delivery of a core capability. As knowledge is gained through system use and as technology changes, the system is evolved to a more useful or effective product. At the beginning of an evolutionary acquisition the ultimate user need is understood in general terms, but a core need that has immediate utility can be well-defined. Because future events will affect the eventual form of the product, the requirements can not be fully defined at the program initiation. However, the evolutionary development must be accomplished in a management system that demands

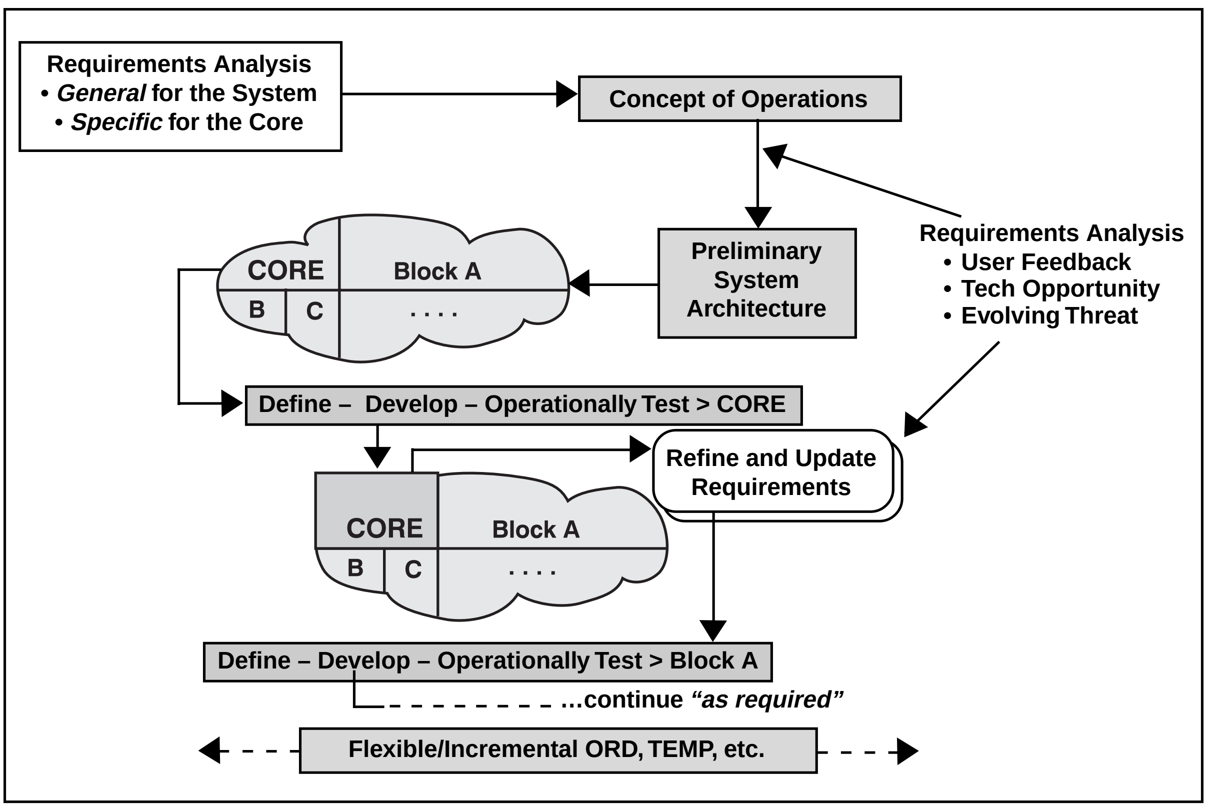

Figure 2-8. Evolutionary Acquisition

requirements validation, fully funded budgets, and rigorous review. In addition, the systems engineering function remains responsible for controlling requirements traceability and configuration control in the absence of complete definition of all requirements or final configurations. These constraints and concerns require the evolutionary approach be accomplished in a manner such the various concerns of users, developers, and managers are adequately addressed, while the risks associated with these issues are mitigated.

Acquisition Managment

Acquisition management requirements established in the DoD 5000 documents and associated component regulations or instructions establish a series of program-specific analyses, reports, and decision documents that support the milestone decision process. In addition, prior to decision points in the acquisition process, substantial coordination is required with an array of stakeholders. This process is resource consuming but necessary to establish the program's validity in the eyes of those responsible to approve the public resources committed to the program.

Evolutionary acquisition, by its nature, represents an "acquisition within an acquisition." On one level, the engineering manager is confronted with the management and control of the system as it progresses to its eventual final configuration, and, on another level, there is the management and control of the modifications, or blocks, that are successively integrated into the system as they are developed. The system has associated requirements, baselines, reviews—the normal elements of a system acquisition; however, each block also has specified requirements, configuration, and management activities. The challenge for technical management then becomes to ensure that good technical management principles are applied to the development of each block, while simultaneously ensuring that the definition and control of requirements and baselines at the system level include and accommodate the evolving architecture.

System Engineering Concerns

Evolutionary acquisition will require incremental and parallel development activities. These activities are developing evolutionary designs that represent a modification as well as an evolved system. The evolutionary upgrade is developed as a modification, but the new evolved system must be evaluated and verified as a system with new, evolved requirements. This implies that, though we can enter the acquisition process at any point, the basic baselining process required by systems engineering must somehow be satisfied for each block upgrade to assure requirements traceability and configuration control.

As shown by Figure 2-9, incremental delivery of capability can be the result of an evolutionary block upgrade or be an incremental release of capability within the approved program (or current evolutionary block) baseline. System engineering is concerned with both. There is no check list approach to structure these relationships, but the following is presented to provide some general guidance in a difficult and complex area of acquisition management planning and implementation.

Evolutionary upgrades may be based on known operational requirements where delivery of the capability is incremental due to immediate operational need, continuing refinement of the product baseline prior to full operational capability, and pre-planned parallel developments. If the modification is only at the allocated or product baseline, and the program's approved performance, cost, and schedule is not impacted, then the system would not necessarily require the management approvals and milestones normal to the acquisition process.

In all cases, the key to maintaining a proper systems engineering effort is to assure that architectures and configuration baselines used for evolutionary development can be upgraded with minimal impact to documented and demonstrated configurations. The risk associated with this issue can be significantly reduced through program planning that addresses optimization of the acquisition baseline and control of the evolving configuration.

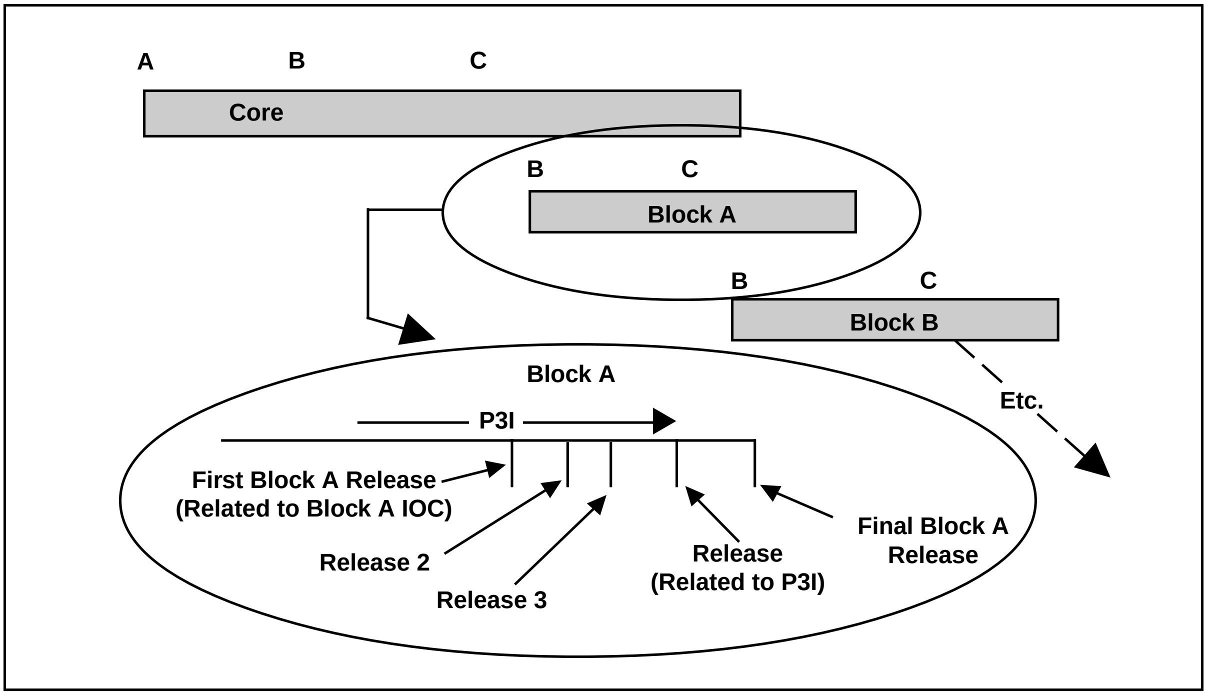

Figure 2-9. Incremental Release Within Evolutionary Blocks

Planning

Evolutionary acquisition program planning must clearly define how the core and evolutionary blocks will be structured, including:

1. A clear description of an operationally suitable core system including identification of subsystems and components most likely to evolve.

2. Establishment of a process for obtaining, evaluating and integrating operational feedback, technology advancements, and emerging commercial products.

3. Planning for evolutionary block upgrade evaluation, requirements validation, and program initiation.

4. Description of the management approach for evolutionary upgrades within a block and the constraints and controls associated with incremental delivery of capability.

5. Risk analysis of the developmental approach, both technical and managerial.

Systems engineering planning should emphasize:

1. The openness and modularity of the design of the core system architecture in order to facilitate modification and upgrades,

2. How baseline documentation is structured to improve flexibility for upgrade,

3. How evolutionary acquisition planning impacts baseline development and documentation control,

4. How technical reviews will be structured to best support the acquisition decision points, and

5. How risk management will monitor and control the management and technical complexity introduced by evolutionary development.

The basic system architecture should be designed to accommodate change. Techniques such as open architecting, functional partitioning, modular design, and open system design (all described later in this book) are key to planning for a flexible system that can be easily and affordably modified.

Notional Example of Evolutionary MAIS Acquisition Relationships					
Characterization	**System Level**	**Acquisition Program Level**	**Acquisition Documentation Required**	**Baseline**	**CM Authority**
Overall Need	Major Program or Business Area	Capstone or Sub-Portfolio	Capstone Acquisition Documentaion	Top Level Functional Baseline	PMO
Core and Evolutionary Blocks	Build or Block of Major Program	Acquisition Program	Full Program Documentation	Cumulative Functional and Allocated Baseline	PMO with Contractor Support
Incremental Delivery of Capability	Release or Version of Block	Internal to Acquisition Program	Separate Acquisition Documentation Not Required	Product Baseline	Contractor (Must Meet Allocated Basleine)
Associated Product Improvements	Application or Bridge	Parallel Product Improvement (Less than MAIS)	Component or Lower Decision Level Acquisition Processing	Functional, Allocated, and Product Baselines	PMO/Contractor

Table 2-1. Evolutionary Acquisition Relationships

Example

Table 2-1 illustrates some of the relationships discussed above as it might apply to a Major Automated Information System (MAIS) program. Due to the nature of complex software development, a MAIS acquisition inevitably will be an evolutionary acquisition. In the notional MAIS shown in the table, management control is primarily defined for capstone, program, subsystem or incremental delivery, and supporting program levels. The table provides relationships showing how key acquisition and system engineering activities correlate in the evolutionary environment. Probably the most important lesson of Table 2-1 is that these relationships are complex and if they are not planned for properly, they will present a significant risk to the program.

Summary

Acquisition oversight is directly related to the performance, cost, and schedule defined in the acquisition baseline. It establishes the approved scope of the developmental effort. Evolutionary development that exceeds the boundaries established by the acquisition baseline requires a new or revised acquisition review process with additional oversight requirements. The development and approval of the ORD and Acquisition Program Baseline are key activities that must structure an evolutionary process that provides user and oversight needs, budgetary control, requirements traceability, risk mitigation, and configuration management.