CHAPTER 8

SYSTEMS ENGINEERING PROCESS OUTPUTS

8.1 DOCUMENTING REQUIREMENTS AND DESIGNS

Outputs of the systems engineering process consist of the documents that define the system requirements and design solution. The physical architecture developed through the synthesis process is expanded to include enabling products and services to complete the system architecture. *This system level architecture then becomes the reference model for further development of system requirements and documents.* System engineering process outputs include the system and configuration item architectures, specifications, and baselines, and the decision database.

Outputs are dependent on the level of development. They become increasingly technically detailed as system definition proceeds from concept to detailed design. As each stage of system definition is achieved, the information developed forms the input for succeeding applications of the system engineering process.

Architectures: System/Configuration Item

The System Architecture describes the entire system. It includes the physical architecture produced through design synthesis and adds the enabling products and services required for life cycle employment, support, and management. Military Handbook (MIL-HDBK)-881, *Work Breakdown Structures*, provides reference models for weapon systems architectures. As shown by Figure 8-1, MIL-HDBK-881 illustrates the first three levels of typical system architectures. Program Offices can use MIL-HDBK-881 templates during system definition to help develop a top-level architecture tailored to the needs of the specific system considered. The design contractor will normally develop the levels below these first three. Chapter 9 of this text describes the WBS in more detail.

Specifications

A specification is a document that clearly and accurately describes the essential technical requirements for items, materials, or services including the procedures by which it can be determined that the requirements have been met. Specifications help avoid duplication and inconsistencies, allow for accurate estimates of necessary work and resources, act as a negotiation and reference document for engineering changes, provide documentation of configuration, and allow for consistent communication among those responsible for the eight primary functions of Systems Engineering. They provide IPTs a precise idea of the problem to be solved so that they can efficiently design the system and estimate the cost of design alternatives. They provide guidance to testers for verification (qualification) of each technical requirement.

Program-Unique Specifications

During system development a series of specifications are generated to describe the system at different levels of detail. These program unique specifications form the core of the configuration baselines. As shown by Figure 8-2, in addition to referring to different levels within the system hierarchy, these baselines are defined at different phases of the design process.

Initially the system is described in terms of the top-level (system) functions, performance, and interfaces. These technical requirements are derived from the operational requirements established by

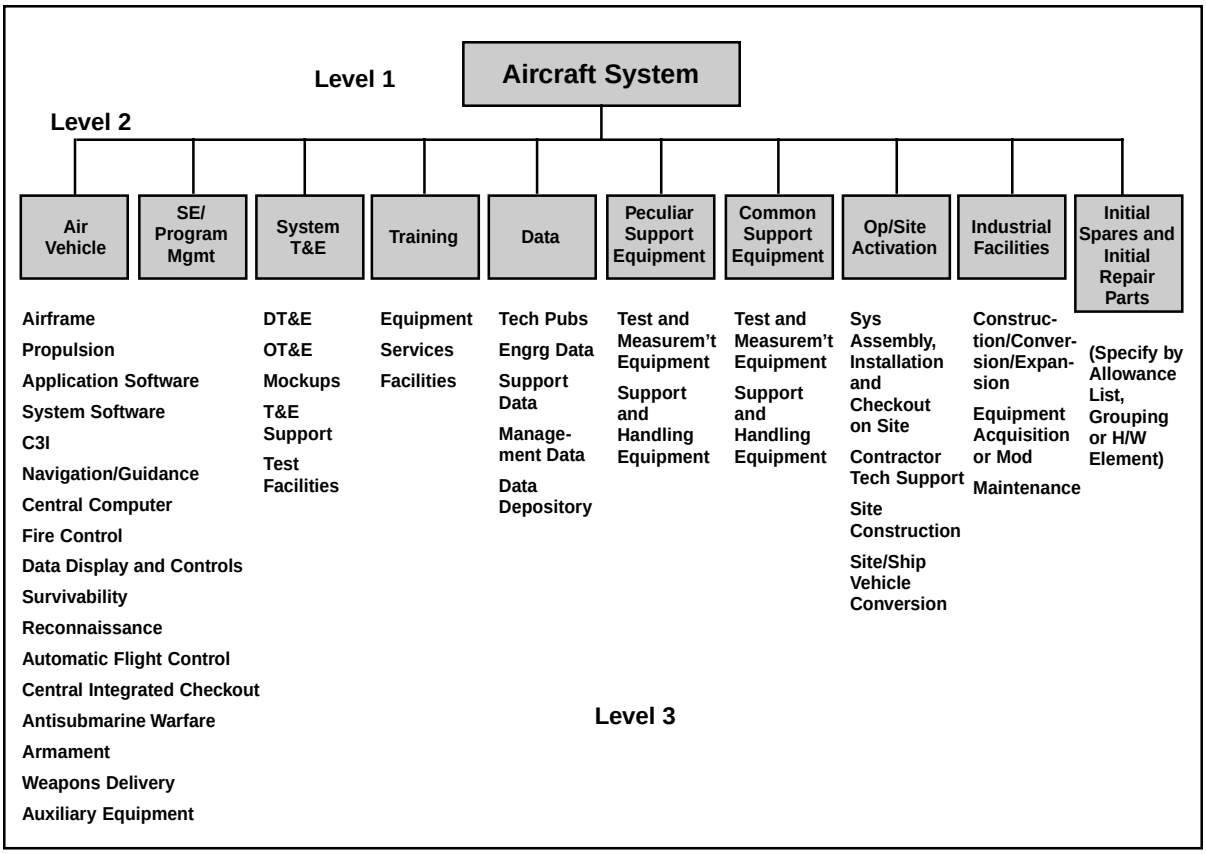

Figure 8-1. Example from MIL-HDBK-881

the user. This system-level technical description is documented in the System Specification, which is the primary documentation of the system-level Functional Baseline. The system requirements are then flowed down (allocated) to the items below the system level, such that a set of design criteria are established for each of those items. These item descriptions are captured in a set of Item Performance Specifications, which together with other interface definitions, process descriptions, and drawings, document the Allocated Baseline (sometimes referred to as the "Design To" baseline). Having baselined the design requirements for the individual items, detailed design follows. Detailed design involves defining the system from top to bottom in terms of the physical entities that will be employed to satisfy the design requirements. When detailed design is complete, a final baseline is defined. This is generally referred to as the Product Baseline, and, depending on the stage of development, may reflect a "Build to" or "As built" description. The Product Baseline is documented by the Technical Data Package, which will include not only Item Detail Specifications, but also, Process and Material Specifications, as well as drawings, parts lists, and other information that describes the final system in full physical detail. Figure 8-3 shows how these specifications relate to their associated baselines.

Role of Specifications

Requirements documents express why the development is needed. Specification documents are an intermediate expression of what the needed system has to do in terms of technical requirements (function, performance, and interface). Design documents (drawings, associated lists, etc.) describe the means by which the design requirements are to be satisfied. Figure 8-4 illustrates how requirements flow down from top-level specifications to design documentation. Preparation of specifications are part of the system engineering process, but also involve techniques that relate to

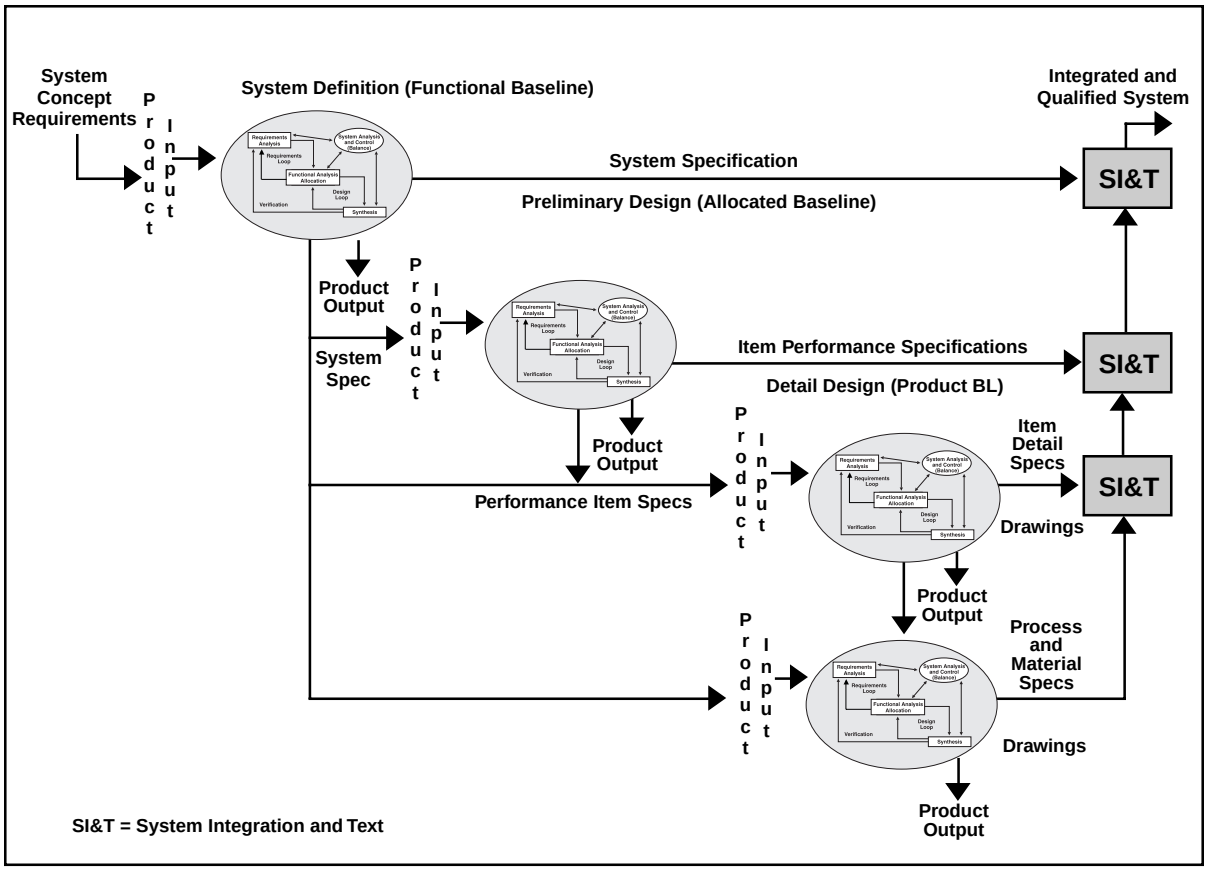

Figure 8-2. Specifications and Levels of Development

Specification	Content	Baseline
System Spec	Defines mission/technical performance requirements. Allocates requirements to functional areas and defines interfaces.	Functional
Item Performance Spec	Defines performance characteristics of CIs and CSCIs. Details design requirements and with drawings and other documents form the Allocated Baseline.	Allocated "Design To"
Item Detail Spec	Defines form, fit, function, performance, and test requirements for acceptance. (Item, process, and material specs start the Product Baseline effort, but the final audited baseline includes all the items in the TDP.)	Product "Build To" or "As Built"
Process Spec	Defines process performed during fabrication.	
Material Spec	Defines production of raw materials or semi-fabricated material used in fabrication.	

Figure 8-3. Specification Types

communication skills, both legal and editorial. Figure 8-5 provides some rules of thumb that illustrate this.

In summary, specifications document what the system has to do, how well it has to do it, and how to verify it can do it.

Baselines

Baselines formally document a product at some given level of design definition. They are references for the subsequent development to follow. Most DoD systems are developed using the three classic baselines described above: functional, allocated, and product. Though the program unique specifications are the dominant baseline documentation, they alone do not constitute a baseline.

Additional documents include both end and enabling product descriptions. End product baseline documents normally include those describing system requirements, functional architecture, physical architecture, technical drawing package, and requirements traceability. Enabling product baseline documents include a wide range of documents that could include manufacturing plans and processes, supportability planning, supply documentation, manuals, training plans and programs, test planning, deployment planning, and others. All enabling products should be reviewed for their susceptibility to impact from system configuration changes. If a document is one that describes a part of a system and could require change if the configuration changes, then most likely it should be included as a baseline document.

Acquisition Program Baselines

Acquisition Program Baselines and Configuration Baselines are related. To be accurate the Program baseline must reflect the realities of the Configuration Baseline, but the two should not be confused. Acquisition Program Baselines are high level assessments of program maturity and viability. Configuration Baselines are system descriptions. Figure 8-6 provides additional clarification.

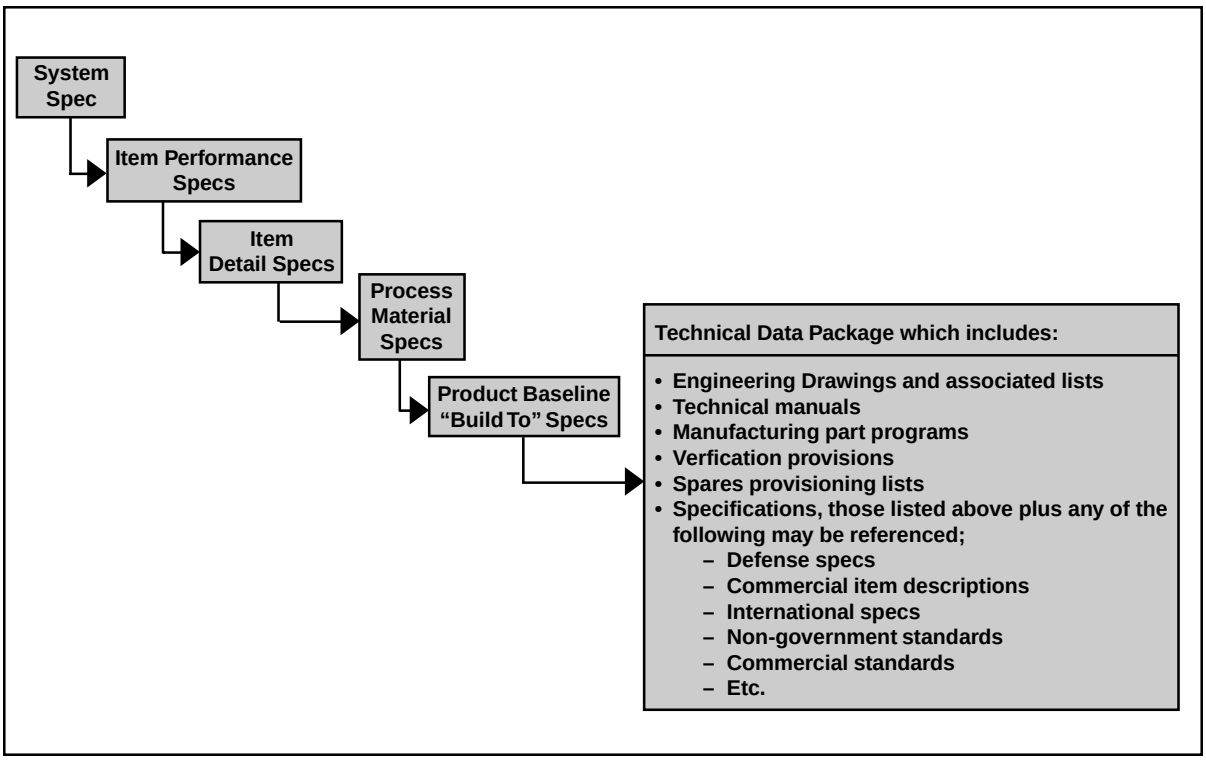

Figure 8-4. How Specifications Lead to Design Documents

- **Use a table of contents and define all abbreviations and acronyms.**
- **Use active voice.**
- **Use "shall" to denote mandatory requirement and "may" or "should" to denote guidance provisions.**
- **Avoid ambiguous provisions, such as "as necessary," "contractor's best practice," "smooth finish," and similar terms.**
- **Use the System Engineering Process to identify requirements. Do not over-specify.**
- **Avoid "tiering." Any mandatory requirement in a document below the first tier, should be stated in the specification.**
- **Only requirement sections of the MIL-STD-491D formats are binding. Do not put requirements in non-binding sections, such as *Scope*, *Documents*, or *Notes*.**
- **Data documentation requirements are specified in a Contract Data Requirements List.**

Figure 8–5. Rules of Thumb for Specification Preparation

Decision Database

The decision database is the documentation that supports and explains the configuration solution decisions. It includes trade studies, cost effectiveness analyses, Quality Function Deployment (QFD) analysis, models, simulations, and other data generated to understand a requirement, develop alternative solutions, or make a choice between them. These items are retained and controlled as part of the Data Management process described in Chapter 10.

8.2 DOD POLICY AND PRACTICE— SPECIFICATIONS AND STANDARDS

DoD uses specifications to communicate product requirements and standards to provide guidance concerning proven methods and practices.

Specifications

DoD uses three basic classifications of specifications: materiel specifications (developed by DoD components), Program-Unique Specifications, and non-DoD specifications.

- **Program Baselines**
  - **Embody only the most important cost, schedule, and performance objectives and thresholds**
  - **Threshold breach results in re-evaluation of program at MDA level**
  - **Selected key performance parameters**
  - **Specifically evolves over the development cycle and is updated at each major milestone review or program restructure**
- **Required on ALL programs for measuring and reporting status**

- **Configuration Baselines**

  Identify and define an item's functional and physical characteristics
  - ***Functional Baseline* – Describes system level requirements**
  - ***Allocated Baseline* – Describes design requirements for items below system level**
  - ***Product Baseline* – Describes product physical detail**
- **Documents outputs of Systems Engineering Process**

Figure 8–6. Acquisition Program Baselines and Configuration Baselines

DoD developed specifications describe essential technical requirements for purchase of materiel. Program-Unique Specifications are an integral part of the system development process. Standard practice for preparation of DoD and Program-Unique Specifications is guided by MIL-STD-961D. This standard provides guidance for the development of performance and detail specifications. MIL-STD-961D, Appendix A provides further guidance for the development of Program-Unique Specifications.

Non-DoD specifications and standards approved for DoD use are listed in the *DoD Index of Specifications and Standards* (DoDISS).

DoD Policy (Specifications)

DoD policy is to develop *performance* specifications for procurement and acquisition. In general, detail specifications are left for contractor development and use. Use of a detail specification in DoD procurement or acquisition should be considered only where absolutely necessary, and then only with supporting trade studies and acquisition authority approval.

DoD policy gives preference to the use of commercial solutions to government requirements, rather than development of unique designs. Therefore, the use of commercial item specifications and descriptions should be a priority in system architecture development. Only when no commercial solution is available should government detail specifications be employed.

In the case of re-procurement, where detail specifications and drawings are government owned, standardization or interface requirements may present a need for use of detailed specifications. Trade studies that reflect total ownership costs and the concerns related to all eight primary functions should govern decisions concerning the type of specification used for re-procurement of systems, subsystems, and configuration items. Such trade studies and cost analysis should be preformed prior to the use of detail specifications or the decision to develop and use performance specifications in a reprocurement.

Performance Specifications

Performance Specifications state requirements in terms of the required results with criteria for verifying compliance, but without stating the methods for achieving the required results. In general, performance specifications define products in terms of functions, performance, and interface requirements. They define the functional requirements for the item, the environment in which it must operate, and interface and interchangeability characteristics. The contractor is provided the flexibility to decide how the requirements are best achieved, subject to the constraints imposed by the government, typically through interface requirements. System Specifications and Item Performance Specifications are examples of performance specifications.

Detail Specifications

Detail Specifications, such as Item Detail, Material and Process Specifications, provide design requirements. This can include materials to be used, how a requirement is to be achieved, or how an item is to be fabricated or constructed. If a specification contains both performance and detail requirements, it is considered a Detail Specification, with the following exception: Interface and interchangeability requirements in Performance Specifications may be expressed in detailed terms. For example, a Performance Specification for shoes would specify size requirements in detailed terms, but material or method of construction would be stated in performance terms.

Software Documentation – IEEE/EIA 12207

IEEE/EIA 12207, *Software Life Cycle Processes*, describes the U.S. implementation of the ISO standard on software processes. This standard describes the development of software specifications as one aspect of the software development process.

The process described in IEEE/EIA 12207 for allocating requirements in a top-down fashion and documenting the requirements at all levels parallels the systems engineering process described in this text. The standard requires first that system-level requirements be allocated to software items (or configuration items) and that the software requirements then be documented in terms of functionality, performance, and interfaces, and that qualification requirements be specified. Software item requirements must be traceable to system-level, and be consistent and verifiable.

The developer is then required to decompose each software item into software components and then into software units that can be coded. Requirements are allocated from item level, to component, and finally to unit level. This is the detailed design activity and IEEE/EIA 12207 requires that these allocations of requirements be documented in documents that are referred to as "descriptions," or, if the item is a "stand alone" item, as "specifications." The content of these documents is defined in the IEEE/EIA standard; however, the level of detail required will vary by project. Each project must therefore ensure that a common level of expectation is established among all stakeholders in the software development activity.

Standard Practice for Defense Specifications – MIL-STD-961D

The purpose of MIL-STD-961D is to establish uniform practices for specification preparation, to ensure inclusion of essential requirements, to ensure Verification (qualification) methods are established for each requirement, and to aid in the use and analysis of specification content. MIL-STD-961D establishes the format and content of system, configuration item, software, process and material specifications. These Program-Unique Specifications are developed through application of the systems engineering process and represent a hierarchy as shown in Figure 8-7.

Standards

Standards establish engineering and technical limitations and applications for items, materials, processes, methods, designs, and engineering practices. They are "corporate knowledge" documents describing how to do some process or a

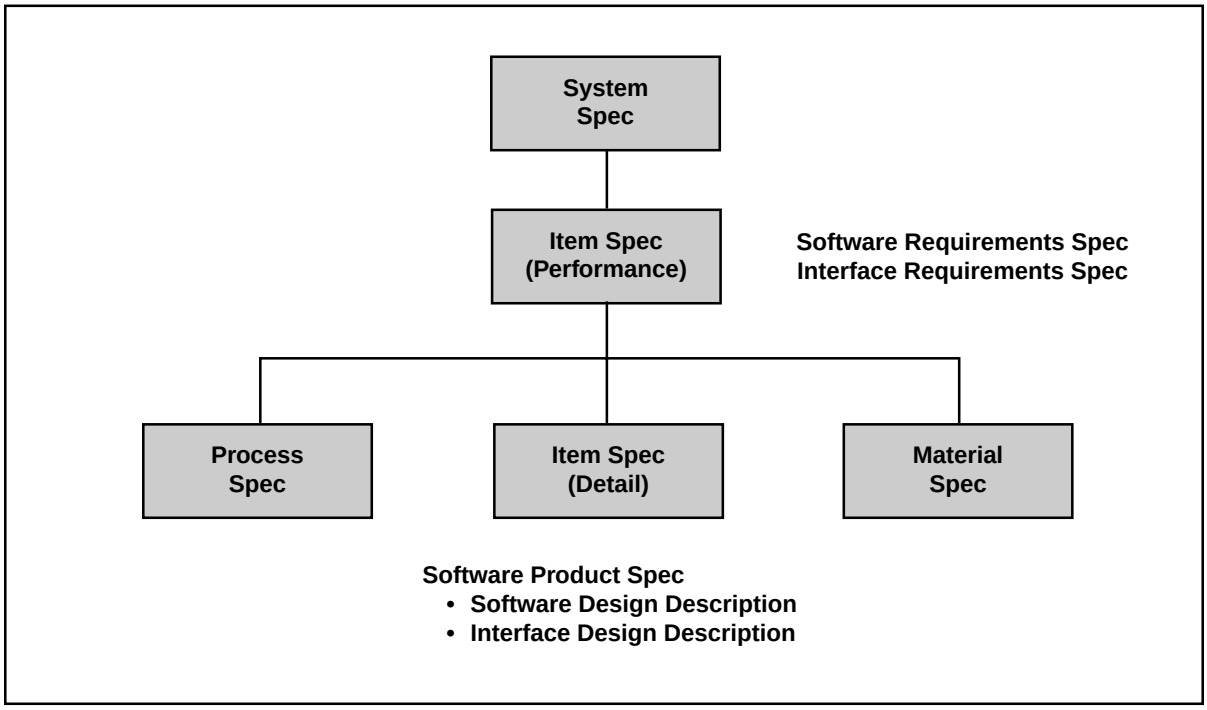

Figure 8–7. Specification Hierarchy

description of a body of knowledge. Standards come from many sources, reflecting the practices or knowledge base of the source. Format and content of Defense Standards, including Handbooks, are governed by MIL-STD-962. Other types of standards in use in DoD include Commercial Standards, Corporate Standards, International Standards, Federal Standards, and Federal Information Processing Standards.

DoD Policy (Standards)

DoD policy does not require standard management approaches or manufacturing processes on contracts. This policy applies to the imposition of both Military Specifications and Standards and, in addition, to the imposition of Commercial and Industry Standards. In general, the preferred approach is to allow contractors to use industry, government, corporate, or company standards they have determined to be appropriate to meet government's needs. The government reviews and accepts the contractor's approach through a contract selection process or a contractual review process.

The government should impose a process or standard only as a last resort, and only with the support of an appropriate trade study analysis. If a specific standard is imposed in a solicitation or contract, a waiver will be required from an appropriate Service authority.

However, there is need on occasion to direct the use of some standards for reasons of standardization, interfaces, and development of open systems. A case in point is the mandated use of the Joint Technical Architecture (JTA) for defining interoperability standards. The JTA sets forth the set of interface standards that are expected to be employed in DoD systems. The JTA is justifiably mandatory because it promotes needed interoperability standardization, establishes supportable interface standards, and promotes the development of open systems.

DoD technical managers should be alert to situations when directed standards are appropriate to their program. Decisions concerning use of directed standards should be confirmed by trade studies and requirements traceability.

DoD Index of Specifications and Standards

The DoDISS lists all international, adopted industry standardization documents authorized for use by the military departments, federal and military specifications and standards. Published in three volumes, it contains over 30,000 documents in 103 Federal Supply Groups broken down into 850 Federal Supply Classes. It covers the total DoD use of specifications and standards, ranging from fuel specifications to international quality standards.

8.3 SUMMARY POINTS

- System Engineering Process Outputs include the system/configuration item architecture, specifications and baselines, and the decision database.

- System/Configuration Item Architectures include the physical architecture and the associated products and services.

- Program-Unique specifications are a primary output of the System Engineering Process. Program-Unique specifications describe what the system or configuration item must accomplish and how it will be verified. Program-Unique specifications include the System, Item Performance, and Item Detail Specifications. The System Specification describes the system requirements, while Item Performance and Item Detail Specifications describe configuration item requirements.

- Configuration baselines are used to manage and control the technical development. Program baselines are used for measuring and supporting program status.

- The Decision Database includes those documents or software that support understanding and decision making during formulation of the configuration baselines.