LIFE

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MANAGEMENT

Good Practice Guide
GPG-FM-010

Project Execution and Engineering Management Planning

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Office of Field Management
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1. INTRODUCTION

Project Execution And Engineering Management Planning (PEAEMP) is one of many Guides developed for the implementation of Department of Energy (DOE) Order (O) 430.1, LIFE-CYCLE ASSET MANAGEMENT (LCAM). This Order states that DOE, in partnership with its contractors, will plan, acquire, operate, maintain, and dispose of physical assets. Requirements within the Order focus on "what must be done" not on "how it must be done."

The *PEAEMP* Guide, in conjunction with the other Guides, addresses how the requirements of LCAM can be achieved. The *Project Management Guide to the Guides*, GPG-FM-000, provides a quick reference overview of each of the Guides that support LCAM implementation. The primary Guide in this set is the *Project Management Overview*, GPG-FM-001.

The *Project Management Overview* Guide details the project life cycle and provides a matrix of areas that should be used to supply information necessary to support critical decisions through the project life cycle. It provides a framework for a systematic approach to project management. A systematic approach requires the assimilation, correlation, and/or distillation of available information, in a timely manner, so that the responsible staff, including program and project management, can integrate information to make effective decisions. The need for a systematic approach comes from:

- projects becoming more complex;
- pressure to find solutions that tend toward optimum, and not only do the job, but comply with large numbers of constraints;
- the need to address the full life cycle of a project from initiation to closeout; and
- the multidisciplinary and multidimensional nature of complex projects, which makes it difficult to track critical aspects without detailed and integrated project planning and execution documentation.

In conjunction with the *Project Management Overview*, the *PEAEMP* Guide was developed to provide guidance to a project manager for successful completion of a project. This guidance is in the form of recommended documents, management systems, and other products of project planning and execution activities. Its scope includes recommended technical and project management products (i.e., project plans, specifications, reports, change control boards, and reviews) for project planning and execution. In a manner similar to LCAM, which focuses on what must be done, the *PEAEMP* guidance is based on technical and management products rather than processes. Multiple sets of technical and management processes are available and adequate for projects, but providing guidance for each set would burden the *PEAEMP* Guide unnecessarily. Each process generates a similar set of products representing "what" must be done. These products all have a common thread necessitating that work be planned, scheduled, performed, and verified. Each product completed represents a measure of accomplishment leading to successful completion of the project.

This Guide groups the products into five categories: Planning, Management, Engineering, Specialty Engineering Integration, and Reviews.

This Guide should assist program/project managers in the selection of technical and related management products to support successful completion of the project for all project phases. Less complicated projects may not require extensive formal development and review of products described in this Guide. However, complex projects may need the support of additional products. The program/project manager can use this Guide, applying a graded approach, at any stage of a project to determine the planning and execution products needed to support the project. At a minimum, this Guide could be used as a checklist to select products for consideration in the project.

2. PRINCIPLES, PROCESSES, PRODUCTS

This Guide integrates the principles, processes, and products of project execution and engineering management as follows.

- Principles establish the parameters within which processes and products will accomplish a project.

- Processes prescribe how the principles will be implemented to execute a project and are usually in the form of methodologies and procedures. Implementation usually follows a plan-perform-verify sequence.

- Products describe what the project team should generate during implementation of processes and, as such, differ from end product. The end product is the result of a project, which satisfies a mission need. The products presented in this Guide are interim results of project execution and engineering management activities. They may be used to satisfy the needs of and demonstrate progress toward completion of a successful project. The products take three forms: (1) plans to perform a process, (2) oversight, control, and reporting on the progress to perform the plan, and (3) documented verification that performance was in accordance with the plan.

2.1 Principles, Products, and End Products

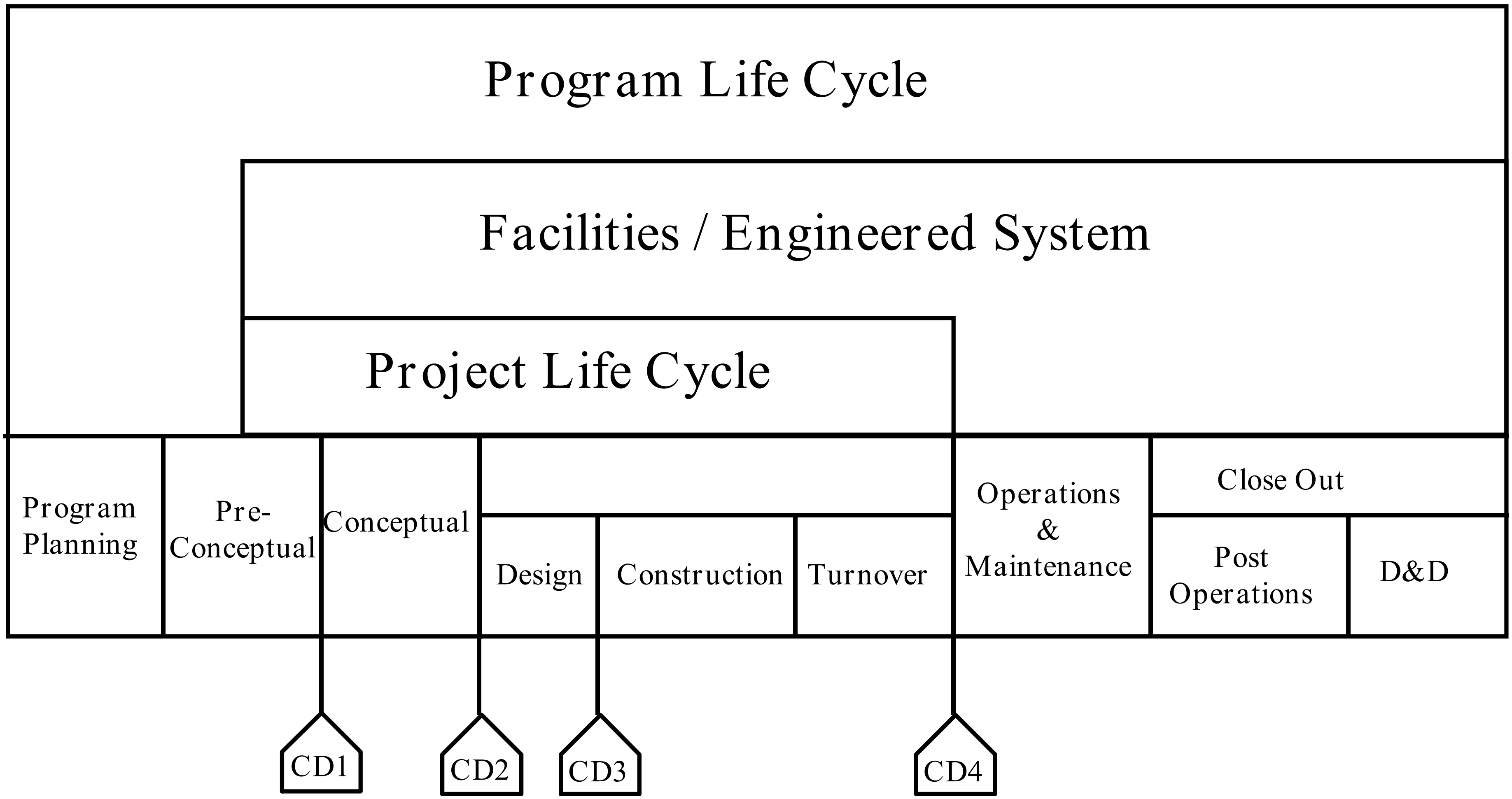
Figure 2.1-1 expands the life cycle model established in DOE O 430.1 and discussed in *Project Management Overview* illustrates how DOE organizes its project management activities into preconceptual activities, which occur prior to the formal start of a project and at least two project phases: conceptual and execution. The execution phase has three subphases: design, construction, and turnover.

2.1.1 Basic Principles

The success of project execution and engineering management rests on five basic principles.

- **Competent People**. People are the key element in any field of endeavor. Project execution and engineering management require people with superior competency in project management, accounting, systems engineering, traditional engineering and engineering specialties such as safety, security, reliability, and maintainability. Superior competency requires that the project have an organization that effectively integrates staff having adequate size and specific qualifications. It requires training that provides and maintains knowledge and skills specific for the project.

Figure 1: Life Cycle Model



CD: - Critical Decision
D&D - Decontamination and Decomissioning

- **Documented and Disciplined Processes**. The management and technical processes should be defined, graded, documented, and applied in a disciplined manner. The processes should be graded from proven general processes and should have a rationale that asserts grading is adequate for the specific project. The responsibilities and accountabilities associated with each management and technical role should be clearly identified including decision authority and change control authority.

  The graded processes should clearly define and manage all interfaces among the component parts of the end product as well as interfaces with customer and external environments including operations, maintenance, and disposal.

- **Project Environment, Methodologies, and Tools**. The project environment, methodologies, and tools should be defined, documented, and included in training curricula. The project environment should provide adequate facilities and promote communication among the entire project team. The methodologies of management and engineering should be clearly identified for each project and should provide for planning, performing and verifying the various project tasks. Tools should include computer aided engineering and management systems and other aids in support of project execution and engineering management.

- **End Product Development**. The project should define and document the end product for delivery to a customer. It should also define and document the processes to be used, if any, the project will provide for manufacturing the end product. The end product and the process should demonstrably meet requirements and perform functions that satisfy mission needs.

- **Customer Interactions**. The project should include opportunities for customers' interactions during development, delivery, and acceptance to ensure that project personnel understand mission needs and requirements.

Because each user of this Guide may have their own definition for some of the key terms used in this Guide, selected key terms and definitions used through out this Guide are presented in Table 2.1.1-1.

2.1.2 Products and End Products

As defined in *Project Management Overview*, "A project in this context is a unique effort that supports a program mission having distinct start and end points with planned interdependent activities undertaken to create a unique product facility, system or environmental condition." As used in this Guide, the term 'end product' is synonymous with "unique product, facility, system or environmental condition."

The term 'end product' may have multiple definitions. One project may have an end product that a commercial supplier manufactures and delivers to the project team for turnover testing. Another project may construct a processing facility as its end product, while the program supported by the project would have as its end product the outputs of the facility. Another project may have as its end product the completion of a site/facility decontamination/ decommissioning (D&D). As used in this Guide, the term 'end product' is the same as the term project end product. As stated previously, the term "products" refer to project technical and related management products.

Table 2.1.2-1 shows the products by life cycle phase and five primary groupings: Planning, Management, Engineering, Specialty Engineering Integration, and Reviews.

- A *planning* product defines how the project or tasks of the project will be organized and managed.

- A *management* product supports planning, execution, and verification activities such as: baselining, budget development, and tracking, project status reporting, and configuration management.

- An *engineering* product supports technical activities such as: requirements development, specifications, technical analysis, design, build, and test.

- A *specialty engineering integration* product supports a specialized area of engineering that must be integrated into the project design (e.g., Human Factors Engineering, and Safeguards and Security).

- A *review* product is an activity to assess the progress of the project or to determine that mission needs and requirements are being met.

In general, the project technical and related management products are derived from the engineering process, and management directs the activities and makes decisions based on information provided in the products.

Many of the products discussed in this Guide span more than one phase of the project life cycle, and the emphasis changes as the project progresses. Based on the work begun during preconceptual activities, the emphasis during the conceptual phase is on defining the top-level architecture and deriving the project functions and requirements. During the execution design and construction subphases, the emphasis is on deriving the lower-level definition of functions and the allocating of requirements to provide a technical basis for end product design and construction. Emphasis during the execution turnover subphase is on demonstrating that the end product meets all requirements and constraints and delivers the required capability to the user.

2.2 Engineering Principles and Process

In theory, the basic engineering process is simple: define needs, estimate scope, design, build, and test. Engineering must perform evaluations to identify the best design architectures that meet requirements using hardware, software, and people. In reality, the multidisciplinary and multidimensional nature of many projects makes the engineering process quite complex. Successful program and project managers integrate the products used to communicate the project engineering processes with the management, budget, and planning processes. This section will look at principles and processes and some of the things that make them complex.

A review of past projects finds a similar set of products were used in each of the projects. The same review will show a diverse range of processes being used. This Guide does not specify any process other than those presented in the *Project Management Overview* and shown in Figure 2.1.-1. However, the products discussed in this Guide are products of systems engineering, project management, and in other areas such as construction management. It is useful to examine some aspects of engineering processes and principles that are supported by the products. In the following subsections, a generalized, but complex engineering process, is described (section 3.2.1), systems engineering principles are presented (section 3.2.2) and a typical system engineering process is discussed (section 3.2.3).

2.2.1 An Engineering Process

An engineering process should accomplish the following objectives:

- Transform mission, operational or disposal requirements into a system architecture, performance parameters, and design details;

- Integrate technical parameters to ensure compatibility among all of the physical, functional, and programmatic elements of a project;

- Ensure that availability, reliability, maintainability and supportability requirements are met;

- Ensure that safety, security, environmental protection and human factor requirements are met;
- Fabricate hardware, develop software, or construct facilities;
- Accept components and functional units that will be used in the end products;
- Integrate components and functional units into an end products;
- Verify that all requirements are met; and
- Accept an end product demonstrating mission needs have been met.

These engineering process objectives can be attained easily when only one activity or one element of an overall program is involved; however, such one-dimensional cases are quite rare.

Typically, the output of more than one project must be integrated into the end product. The more multidimensional situations can involve complex interactions that must be addressed by the engineering process.

Figure 2.2.1-1 illustrates how complicated interactions can develop in a project. In this example, function and requirements analyses have identified a set of requirements (A, B, and C), which, in turn, have been assigned to functions called Elements 1, 2, and 3. In this discussion, the terms "element" and "subproject" are interchangeable. Requirements A and B are to be met by one-of-a-kind facilities. Requirement B can be met by such a facility if requirement C is met by a production run in a prototype facility developed in Element 3. Consequently, the work in Element 3 must be integrated with the work in Element 2. Work in Elements 1 and 2 must be integrated to produce the end product of this example.

Important factors of this scenario include the following:

- Each element represents an individual engineering process.
- Each process is more complex than the one before.
- Feedback or iteration loops for design change are included in each process.

- Complex external feedback or iteration loops in which changes in one element can affect the other elements exist within each process.
- The products that communicate the design, build, and test phases of each process could be called by the same names and serve similar purposes.
- Four project organizations are required: one for each element, and one to integrate all three elements.

Table 2.1.1-1. Key Definitions.

Term	Definition
Product	Any one of several deliverables needed to complete a project in addition to the end product.
End Product	What is turnover at the end of the project and meets the mission need.
Mission Statement	This should be a clear and concise identification of the need for the end product, providing a description of the problem that the new end product should solve, as well as the operating environment and how the product will be used. The mission statement represents the ultimate, top-level function for the end product. The mission statement may be qualitative in nature, but should be quantified to the extent practical.
Configuration	Is the "as-built" architecture for a given project. There is a transition from architecture to configuration during the design process.
Alternative	The conceptualization of the end product at any level of allocation. The architecture at each level must perform all functions and meet all requirements for that level. Usually, several different architectures can perform functions and meet requirements for a level of allocation, and these different architectures are called alternatives. The systems approach will select the preferred architecture from the alternatives at each level of allocation before proceeding to the next level.
Tradeoff Studies	The selection of an alternatives is accomplished by a tradeoff. The study is the process of evaluating alternatives and selecting the preferred architecture that provides input to the next level of allocation.
Decision Criteria	This is a definitive statement of the values that will be applied in developing the final decision in a tradeoff study.

Table 2.1.2-1. Products by Life-Cycle Phase

Life-Cycle Phase Products	Preconceptual	Conceptual	Execution, Design and Construction	Execution, Turnover	Closeout
Planning	• Preconceptual Development Plan	• Conceptual Development Plan	•	• Project Execution Plan • Transition Plan	•
Management	• Mission Need	• Project Organization • Management/ Engineering Processes • Training • Planning Documentation • Federal Budget Cycle • Monitoring/ Control/Oversight • Contract Management • Baseline Management • Intergroup Coordination • Decision Criteria	• Project Organization • Management/ Engineering Processes • Training • Planning Documentation • Federal Budget Cycle • Monitoring/Control/ Oversight • Contract Management • Configuration Management • Baseline Management • Construction Management • Intergroup Coordination • Decision Criteria	• Project Organization • Planning Documentation • Federal Budget Cycle • Monitoring/Control/ Oversight • Contract Management • Configuration Management • Baseline Management • Construction Management • Intergroup Coordination	• Planning Documentation • Federal Budget Cycle • Monitoring/Control/ Oversight • Contract Management • Configuration Management • Intergroup Coordination
Engineering	• • Functions and Requirements • Alternative Evaluations • Alternative Selections • Safety Assessments	• Functions and Requirements • Alternative Evaluations • Alternative Selections • Design Documentation • Safety Assessments • Interface Control Documents • Test & Evaluation • Specifications	• Functions and Requirements • Tradeoff Studies • Alternative Selections • Design Documentation • Safety Assessments • Interface Control Document • Test & Evaluation • Operations /Maintenance Requirements Documentation • Specifications	• Functions and Requirements • Alternative Evaluations • Alternative Selections • Acceptance Documentation • Safety Assessments	• Functions & Requirements • Alternative Evaluations • Alternative Selections • Safety Assessments

Table 2.1.2-1. Products by Life-Cycle Phase (continued)

Life-Cycle Phase Products	Preconceptual	Conceptual	Execution, Design and Construction	Execution, Turnover	Closeout
Specialty Engineering Integration	• Integrated Logistics Support • System Life Cycle Cost • Environment, Safety & Health • Risk Management • NEPA Documentation • Environmental, Socioeconomic and Institutional	• Integrated Logistics Support • System Life Cycle Cost • Environment, Safety & Health • Human Factors Engineering • Safeguards & Security • Risk Management • NEPA Documentation • Value Engineering • Quality Assurance • Regulatory Compliance • Environmental, Socioeconomic and Institutional	• Integrated Logistics Support • System Life Cycle Cost • Environment, Safety & Health • Human Factors Engineering • Safeguards & Security • Risk Management • NEPA Documentation • Value Engineering • Quality Assurance • Regulatory Compliance • Environmental, Socioeconomic and Institutional	• Environment, Safety & Health • Human Factors Engineering • Safeguards & Security • Risk Management • NEPA Documentation • Value Engineering • Quality Assurance • Regulatory Compliance	• Environment, Safety, Health • Human Factors Engineering • Safeguards & Security • Risk Management • NEPA Documentation • Value Engineering • Quality Assurance • Regulatory Compliance

Table 2.1.2-1. Products by Life-Cycle Phase (continued)

Life-Cycle Phase Products	Preconceptual	Conceptual	Execution, Design and Construction	Execution, Turnover	Closeout
Reviews (Rvw)	• Design Review	• Alternative System Review • Requirement Allocation Review • System Requirements Review • Conceptual Design Review	• Requirement Allocation Review • System Requirements Review • System Functional Review • Design Approach Reviews • Design Analysis Reviews • Preliminary Design Review • Instruction Reviews • Drawing Preparation Checks • Software Specification Review • Detailed Design Review • System Verification Reviews • Critical Design Review • Test Readiness Reviews • Physical Config. Audits • Functional Config. Audit • Project Completion Review	• Physical Config. Audits	• Physical Config. Audits

- Verify that all requirements are met; and

- Accept an end product demonstrating mission needs have been met.

These engineering process objectives can be attained easily when only one activity or one element of an overall program is involved; however, such one-dimensional cases are quite rare. Typically, the output of more than one project must be integrated into the end product. The more multidimensional situations can involve complex interactions that must be addressed by the engineering process.

Figure 2.2.1-1 illustrates how complicated interactions can develop in a project. In this example, function and requirements analyses have identified a set of requirements (A, B, and C), which, in turn, have been assigned to functions called Elements 1, 2, and 3. In this discussion, the terms "element" and "subproject" are interchangeable. Requirements A and B are to be met by one-of-a-kind facilities. Requirement B can be met by such a facility if requirement C is met by a production run in a prototype facility developed in Element 3. Consequently, the work in Element 3 must be integrated with the work in Element 2. Work in Elements 1 and 2 must be integrated to produce the end product of this example.

Important factors of this scenario include the following:

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- Each process is more complex than the one before.

- Feedback or iteration loops for design change are included in each process.

- Complex external feedback or iteration loops in which changes in one element can affect the other elements exist within each process.

- The products that communicate the design, build, and test phases of each process could be called by the same names and serve similar purposes.

- Four project organizations are required: one for each element, and one to integrate all three elements.

- The optimum is to have one mission need or top-level requirement for one end product.

- Funding by multiple organizations may dictate multiple projects each with their own organizations which can present unique interface problems.

Another view of iteration is addressed by the following discussion. Iteration is endemic to a well-designed engineering process. The basic functions of the engineering process are shown in Figure 2.2.1-2. Each function is separate from, but closely intertwined with, the other functions. Three iterative loops can be defined:

- Requirements Definition
- Design
- Verification and Test Planning

Each loop ties two functions and the integration and control function together. Requirements analysis relies heavily on functional analysis. Requirements analysis and allocation of the requirements to design cannot be completed until the functional analysis is done. Neither can be performed effectively without iteration. Similarly, design synthesis depends on the requirements, but the design may force changes in the requirements.

Figure 2.2.1-2 also illustrates the importance of integration and control. The iterative loops depicted all include the integration and control function. The loops operate simultaneously in a project, but not in concert, if the integration and control function is not included.

The iterative nature of the engineering process is needed to enhance effectiveness. The products discussed in this Guide are the features of the engineering process that make iteration possible, but controllable.

2.2.2 Systems Engineering Principles

This discussion addresses the basic systems engineering process for dealing with complex projects. The primary goal of the systems engineering process is the transformation of mission, operational or disposal requirements into a system architecture, performance parameters, and design details. The process can be viewed as a hierarchy beginning with the definition of a need, progressing through to a baseline and ending with a verification that the need has been met. The principles of the hierarchy are:

- **NEED**: What is the need for this project?

- **FUNCTIONS**: What are the functions to be performed by this project?

Figure 2.2.1-1. Example Engineering Process.

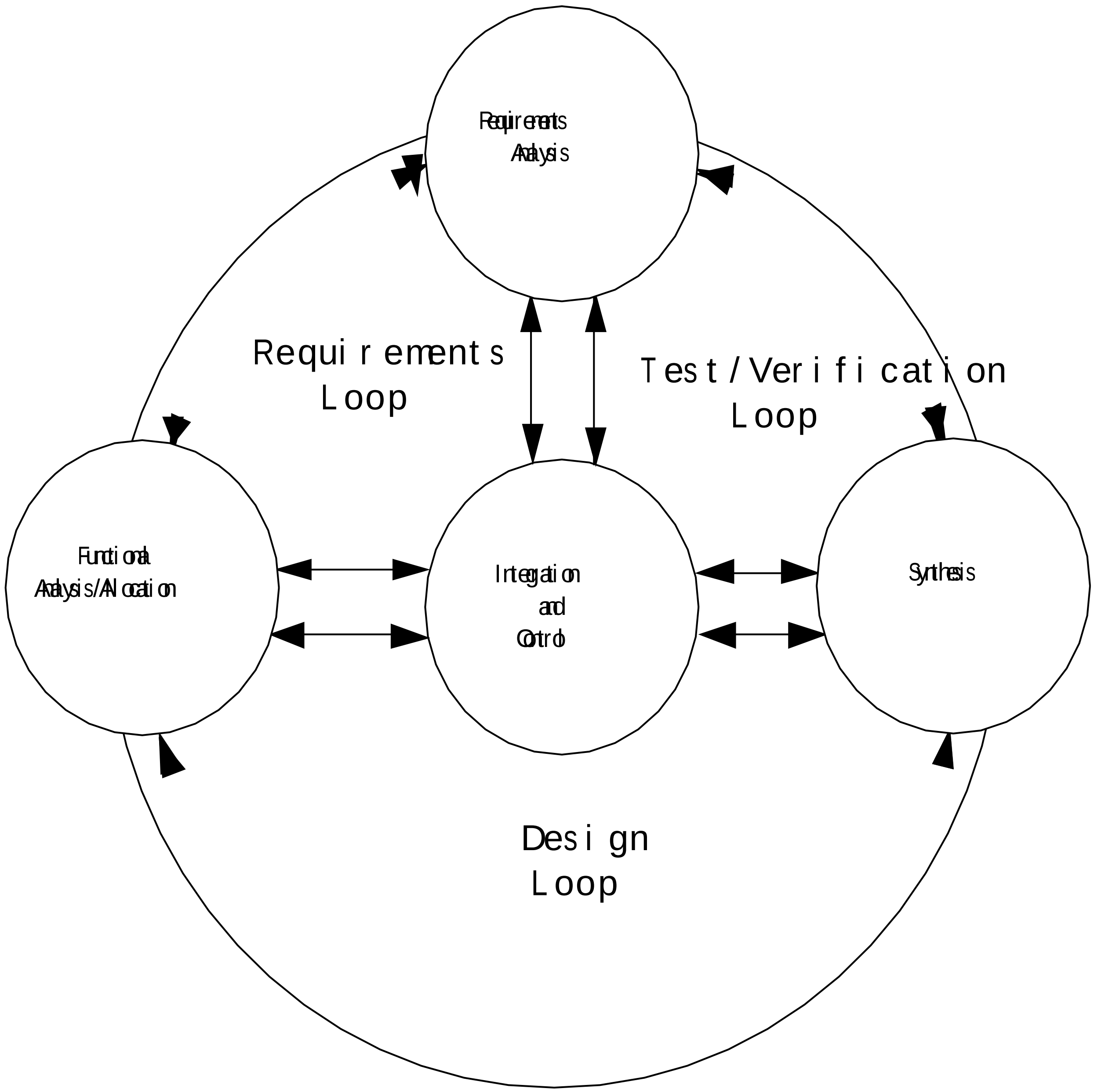


Figure 2.2.1-2. Basic Engineering Functions.

- **<u>REQUIREMENTS</u>**: What are the performance requirements and constraints on the project?

- **<u>CRITERIA</u>**: What criteria shall be used to select among alternatives for performing the functions and meeting the requirements?

- **<u>ALTERNATIVES</u>**: What alternative solutions are available to perform the functions and meeting the requirements?

- **<u>TECHNICAL BASELINE</u>**: What is the best or the preferred alternative for performing the functions and meeting the requirements?

- **<u>VERIFICATION</u>**: What is the proof that the preferred alternative performs the functions and meets the requirements?

The process to establish functions and requirements is generally straight forward for the low risk and simple projects. On the other hand, complex systems require extensive processes to identify all of the requirements. The identification of complete sets of functions and requirements necessarily involves iteration as discussed in section 3.2.1. This iterative process will yield information that should be included in specification for the project. These specifications should baseline the requirements. The relationship between these principles and the subsections of this Guide are shown in Table 2.2.2-1.

The process involves iterative applications of a series of steps: mission analysis, function definitions, requirements identification, architecture development, alternative identification, engineering tradeoff studies based on prepared decision criteria and test and evaluation. The start point generally is the high level mission statement followed by each of the listed steps. This establishes the level-1 baseline which is followed by another iteration performing the same steps at the next level of detail. The next level of detail may be based on logical allocation of the mission statement, functions or architecture. This establishes the start point for developing the level-2 baseline as the iteration continues.

At each subsequent level, the functions from the previous level are evaluated and subdivided (allocated) to identify all the subfunctions which are necessary and sufficient for accomplishment of the parent function(previous level). For example, a parent function of "remediate waste" might be decomposed to three subfunctions of "retrieve waste", "process waste", and "store waste". After completing the functional analysis to a new level, requirements from the previous level are evaluated and allocated to the subfunctions and additional requirements are identified. The remaining steps of the systems engineering process have to be performed before going to the next level.

Table 2.2.2-1. Systems Engineering Principles and Guide Subsections.

Principles	Subsection		Supporting Guide
Need	6.1	Mission Analysis	
Function	6.2.1	Function	
Requirements	6.2.2	Requirements	
Criteria	5.12	Decision Criteria	Engineering Tradeoff Studies
Alternatives	6.2.3	Architecture Identification	
Technical Baseline	6.3	Engineering Tradeoff Studies	Engineering Tradeoff Studies
Verification	6.7	Test and Evaluation	Test and Evaluation

Once the requirements and functions have been established, an essential step in the systems engineering process is the broad search for viable alternatives that will perform the functions and meet the requirements. The systems engineering process encourages creativity and innovation in the search for end product to perform functions and requirements by explicitly calling for the search for alternatives. On the other hand, the systems engineering process places great emphasis on testing and quantitative data to show that alternatives, which may be very creative and innovative, are, in fact, viable means for performing the functions and do, in fact, meet the requirements. As discussed in section 3.2.1 this search for alternatives should involve iteration with the functions and requirements steps of the process.

Selection among the viable alternatives should be based on predetermined criteria. The mission analysis should identify goals, objectives and values that will help determine the selection criteria. In most cases the criteria are obvious considerations like cost, time, and risk. Increasingly, less obvious criteria such as organization or stakeholder values need to be included in the selection process.

Preferred alternatives resulting from the selection process become the technical baseline for the project. Once the technical baseline has been selected, it becomes the basis for control of the iterative processes discussed in section 3.2.1. Iterative refinement of this technical baseline will add details and eventually yield the end product which has been verified to perform the functions and meet the requirements.

Where to stop the iteration is a key question. High level mission statements, such as clean up of a site, usually stop their iteration with the identification of systems such as a preprocessing plant and a high level waste vitrification plant. Each system then may be handed off to another organization which takes the iteration process down to the design requirements for each system. The same basic steps are used over again.

Some indications of when to stop the iteration process include:

- when a well-bounded end product has been identified;
- when no more practical functional allocations exist;
- when the end product can be provided with existing technology;
- when the end product is affordable;
- when, for the level of allocation, sufficient information is available to make the required decisions for the next set of activities (i.e., continue to the next phase or stop project work);
- when the complexity and quantity of data have reached a point that one organization cannot manage the information effectively (i.e., discrete systems are broken out to be worked by different organizations); or
- when an organization has allocated to a level at which it performs a make-buy analysis. A buy decision is made and the requirements are now included in a contract.

The program and project managers are responsible for implementing a systems engineering process when planning the project. The planners should consider the following factors:

- experience and mix or staff selected for the project;
- documentation of the engineering methodology and tools selected;
- staff access to a senior technical expert in the subject of the end product; and

- how the selected approach will yield an end product that meets the customer's needs.

2.2.3 Typical Systems Engineering Process

This section continues the discussion of engineering processes by looking at the typical systems engineering process from *Project Management Overview* and is shown in Figure 2.2.3-1. The figure illustrates that, for each phase of the life cycle, it is necessary to:

- define what must be done,
- define how well it must be done,
- evaluate alternative solutions to getting it done,
- select a solution, and
- verify that the solution meets the requirements.

The systems engineering process shown in the figure represents processes used by DoD and commercial organizations to define the system architecture for the end product. The process diagram may be entered at any one of the four main elements in the upper part of Figure 2.2.3-1; several iterations may be required before the final functions, requirements, and architecture are identified. This process diagram represents one part of the engineering process discussed in section 3.2. It should be used to develop requirements to the point that specifications can be prepared for the end product.

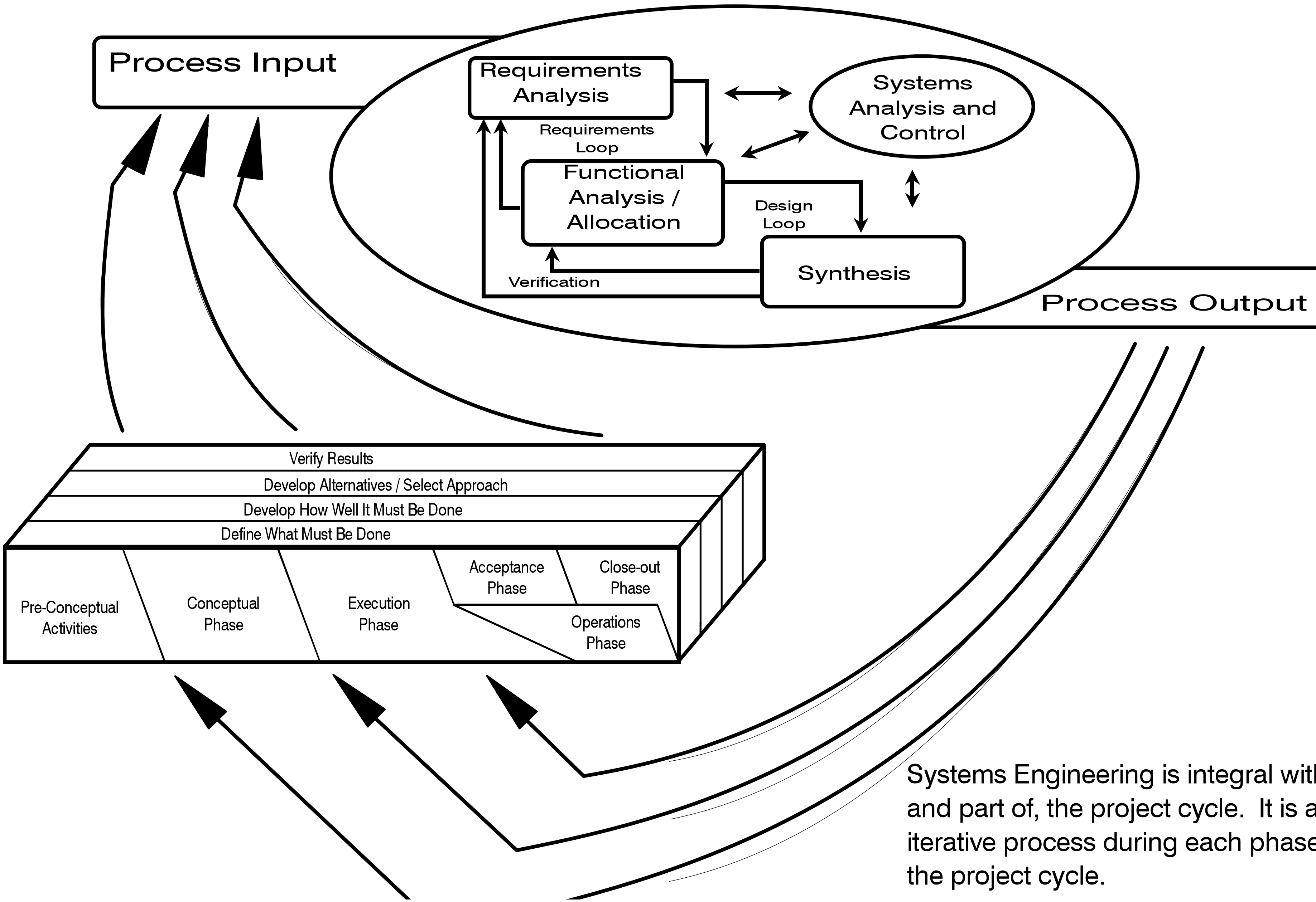
2.2.3.1 Requirements Analysis

Requirements analysis establishes what the end product must do or be capable of accomplishing (functional requirements); how well the end product must perform in quantitative, measurable terms (performance requirements); the environment(s) in which the end product must operate; and constraints that will affect design solutions. Requirements analysis is conducted iteratively with functional analysis to develop functional requirements and performance requirements to increasingly greater levels of detail. Functional requirements established in requirements analysis are used as the top-level functions for functional analysis.

2.2.3.2 Functional Analysis/Allocation

Functional analysis describes the problem in greater detail defined by requirements analysis. This is accomplished by breaking down (decomposition or allocation) the functions established in requirements analysis, to their subfunctions. Functional

Figure 2: TYPICAL SYSTEMS ENGINEERING PROCESS



Systems Engineering is integral with, and part of, the project cycle. It is an iterative process during each phase of the project cycle.

analysis/allocation is conducted iteratively with requirements analysis to accomplish the following:

- Define successively lower-level functions required to satisfy higher-level functional requirements.
- Define their functional interfaces and alternative architectures to meet the functional solutions.
- Identify architectural solutions for tradeoff studies.
- Define operational and environmental driven performance requirements in conjunction with requirements analysis and determine that higher level requirements are satisfied.
- Define flowdown performance requirements and design constraints and
- Define and refine in conjunction with the synthesis process solution alternatives which meet requirements and allocate derived requirements to the physical architecture.

The extent of allocation depends on establishing a clear understanding of what the end product must accomplish. Alternatives analyses and tradeoff studies are performed to select subfunctions that satisfy the previously established performance requirements.

2.2.3.3 Synthesis

A synthesis process translates the functional allocation into a physical architecture by grouping functions and subfunctions into logical physical elements that will make up the end product. These physical elements will be composed of hardware, software, material, data, facilities, people, services, and/or processes. Alternatives are analyzed to determine which best satisfies allocated functional and performance requirements, derived requirements, interface requirements, and constraints. The synthesis process defines and integrates the physical architecture to a level of detail that enables verification that functional and performance requirements have been met. The process translates the architecture into a work breakdown structure, specifications, and configuration baselines.

2.2.3.4 Systems Analysis and Control

Systems analysis and control are used to measure progress, evaluate alternatives, select preferred alternatives and document data and decisions. These two elements, (1) systems analysis and (2) control, are discussed separately in the following paragraphs but are closely integrated in actual application.

Systems analysis provides a rigorous quantitative basis for establishing requirements and physical architecture of the end product and assessing the effectiveness of the current solution. As part of the system analysis, alternative analysis are performed to accomplish the following:

- Resolve conflicts between functional and performance requirement and constraints that arise during requirements analyses.
- Decompose functional requirements and allocate performance requirements during functional analyses.
- Evaluate the effectiveness of alternative physical architectures and select the best solution during synthesis.
- Identify and analyze risk factors.
- Select appropriate risk handling approaches.
- Manage risk factors.

Control includes activities that manage and document the activities of the engineering process such as (1) planning for the engineering process, (2) statusing activities and results which are used in other management and engineering process activities, (3) providing information for production, test, and operations, and (4) providing information for decision makers. Control mechanisms include risk management, configuration management, data management and performance based progress measurement, including reviews.

Material for the above discussion is taken from two commercial standards, EIA Standard IS-632 and IEEE P1220, which provide greater detail and are excellent references for the systems engineering process.

3. Planning Products

Planning provides the basis for defining and executing the management and technical activities that ultimately result in an end product that satisfies a mission need. Planning begins with an understanding of the mission need, goals, objectives, requirements, constraints, and risks that help define and bound a project. It identifies the steps required to negotiate commitments and to estimate the size of the various tasks (including end product/deliverables), the resources needed, the cost and schedule estimates and the risks.

Table 3-1. Planning Allocation

Level-1	Level-2	Level-3
Management Planning	Strategic Plans	DOE Strategic Plan
		Program Strategic Plan
	Program Plans	Program Management, Policies and Requirements Documents
		Management Plans
		Preconceptual Development Plans
	Project Plans	Conceptual Development Plans
		Project Execution Plans

Table 3-1 shows an allocation of planning functions to three levels. Each successive level represents greater levels of planning detail. The allocation levels for planning products follows a similar approach, but does not equate to, the decomposition levels for functions, architecture, and work breakdown structure. Level-1 is a management planning product allocated to three Level-2 planning products: Strategic Plans, Program Plans and Project Plans. The Level-2 plans allocate to several Level-3 plans. For example, the Level-2 Program Plans decompose into three Level-3 plans, and the Level-2 Project Plans decompose into two key plans at Level-3. This *PEAEMP* Guide focuses only on three of the Level-3 plans:

A. Preconceptual Development Plan for accomplishing preconceptual activities

B. Conceptual Development Plan for accomplishing conceptual phase activities

C. Project Execution Plan for accomplishing execution phase activities

The following subsections describe key elements of these three Level-3 plans. For all plans, a graded approach should be used to determine the key elements and the amount of detail required for a specific project. If the performing contractor has acceptable plans, processes, or standards for these elements, they should be used. For complex projects, some of these elements may warrant development of stand-alone Level-4 plans. Examples of such plans are Quality Assurance, Test and Evaluation and Configuration Management.

3.1 Planning to Conduct Preconceptual Activities

DOE initiates a project with approval at Critical Decision 1. However the preconceptual activities completes much work that carries into the conceptual phase. At the transition to the conceptual phase, the organization may change significantly. Where the preconceptual activities may have been performed by a Program, Headquarters, or Field Element, a new project organization is usually established at the start of the conceptual phase.

Planning to conduct preconceptual activities should address two objectives: (1) planning to define a mission need and its relationship to the DOE mission and (2) planning to develop a preliminary and high-level definition of a project to meet the mission need. Preconceptual activities should provide information sufficiently detailed and reliable to support the Approval of Mission Need Critical Decision (CD-1). Detail will usually be minimal because of the preliminary nature of the preconceptual activities.

Preconceptual planning should include activities to determine the organization(s) which will perform the preconceptual activities and activities necessary to develop the highest-level definitions of products discussed in section 6.1 of this Guide. A way to ensure continuity is to involve the conceptual phase project manager in developing the preconceptual planning before it is finalized. Changing the functions, requirements, or architecture after start of the conceptual phase is difficult because of the approvals required. Planning to conduct preconceptual activities should also provide for status reports and reviews, preparation of documentation, and the process for obtaining the Approval of Mission Need Critical Decision (CD-1).

Preconceptual products are usually prepared by the Program, Headquarters, or Field Element and sets the stage for continuing project definition and planning in the conceptual phase. Preconceptual products should include:

- Results of a mission analysis that: describes the proposed mission need and relates the project need to the Program mission and DOE Strategic Plan; identifies the preliminary technical functions and performance objectives for transforming to a final state from the initial state; and describes the preliminary risk assessment for the project and basis for the assessment (section 6.1);

- Top-most definition of requirements, functions and architecture (section 6.2);

- An estimate of project schedule including major project milestones and a start date for fiscal year funding (section 5.9);

- Rough order of magnitude cost estimates including annual funding needs and life cycle costs (section 5.9);

- Specific cost and schedule estimates for completing the conceptual phase (section 5.9);

- A preliminary evaluation of key environmental impacts including pollution prevention, waste management issues, and a recommendation on National Environmental Policy Act (NEPA) documentation (sections 7.3 and 7.7);

- A preliminary safety assessment (section 7.3); and

- The anticipated results and benefits to be gained from the project, quantified to the extent practical.

- The anticipated results and benefits to be gained from the project, quantified to the extent practical.

Planning should be documented. A formal Preconceptual Development Plan (PDP) should be prepared when it is clear that substantial effort is needed to develop a set of new project requirements to meet a new or revised mission. Upon Approval of Mission Need, all preconceptual documentation should be placed under configuration control.

3.2 Planning to Conduct Conceptual Phase Activities

Conceptual phase planning should address two objectives: (1) planning to conduct conceptual phase activities, including preparation of the Project Execution Plan (section 4.3) and (2) planning to further define the scope, schedule, and total project cost to provide a baseline for the project. The conceptual phase should provide information sufficiently detailed and reliable to support Approval of Baseline Critical Decision (CD-2). Conceptual activities will usually develop less than 20 percent of completed design but will establish Congressional and public expectations for 100 percent of the total project cost.

Planning should be documented. A formal Conceptual Development Plan (CDP) should be prepared when a PDP has been prepared or when it is clear that substantial effort is needed to develop new project requirements to meet a new or revised mission. All conceptual documentation should be placed under configuration control.

Conceptual phase planning should provide for the following activities:

- Determine and describe the organization(s) that will perform the conceptual activities. Organizational descriptions should include staffing levels and qualifications (section 5.1).

- Further develop the technical objectives and stakeholder values that will form part of the basis for decision criteria to select from alternative solutions (section 5.12).

- Further develop a listing of imposed external constraints such as Federal and State laws and regulations, Departmental directives, and Program policies.

- Further develop operational and closeout scenarios including cost estimates to be used in the life-cycle cost analysis (section 7.2).

- Identify and analyze requirements and functions for the project end product (section 6.2). For complex projects, this activity should include the following:

    - Prepare decision criteria, which incorporates stakeholder and DOE values. Establish a decision process for combining various values to identify the preferred architecture from among alternatives (section 5.12).

    - Evaluate alternative architectures for the project end product including life cycle cost analysis, socioeconomic evaluations and value engineering assessments, as appropriate (sections 6.3, 7.2 and 7.8).

- Select a site, including institutional concerns (e.g., technical expertise, land use, etc.) and the preferred architecture for the project end product (section 6.3).

- Verify that the preferred architecture meets requirements and validate that the preferred architecture is consistent with the operational and closeout scenarios (sections 6.3 and 6.7).

- Assess physical, technical, schedule, and cost progress of the project (Performance Measures, section 5.6).

• Assess specific risk to evaluate the impacts on functions, requirements, schedule, cost and resources. The risk assessment should evaluate impacts from any enabling assumptions (i.e., assumptions made, in lieu of factual information, that enable project planning to go forward). These assumptions should be tracked from identification through resolution. Resolution will usually require completion of an alternative evaluation, which should also be tracked from identification through resolution (section 7.6).

• Prepare a project schedule. Include major project milestones and a start date for fiscal year funding (section 5.9).

• Prepare cost estimates. Include total estimated cost and related other project costs that together represent total project cost (section 5.9).

• Prepare annual funding requirements and life cycle costs (section 5.9).

• Evaluate environmental impacts. Include pollution prevention, waste management issues, and a determination on NEPA documentation (i.e., Categorical Exclusion, Environmental Assessments, Environmental Impact Statement) (sections 7.3 and 7.7).

• Prepare a preliminary safety assessment (section 7.3).

• Prepare an initial Work Breakdown Structure (WBS) and WBS dictionary. The WBS should align closely with the main subsystem and major elements of the end product (section 5.0).

• Provide scheduled and event-driven reporting necessary to satisfy a project's monitoring, control and oversight needs during the conceptual phase. The planning should also provide for in-house reviews and independent reviews to confirm self assessments of work progress (section 5.6).

- Provide for evaluations of various project performance reports, identification and assessment of new issues, and development of corrective actions for unacceptable deviations from performance norms (sections 5.6, 7.11 and 8.0).

- Implement the process for obtaining Approval of Baseline Critical Decision (CD-2).

3.3 Project Execution Planning

During the conceptual phase, a formal Project Execution Plan (PEP) should be prepared for all projects and submitted for approval at CD-2. The PEP defines how the execution phase will be conducted. It addresses the objective of executing a project that will deliver an end product to satisfy a mission need. The PEP should be jointly prepared by the project manager and the performing contractor. The PEP and its supporting documentation should be placed under configuration control.

The project manager should establish the content for the initial PEP. Over the course of a project, the PEP should provide planning and documentation for the activities, structures, and reports described in the following sections.

3.3.1 Management Activities

- A description of the DOE and contractor organizational structure

  - Define roles, responsibilities and authority, including decision authority.

  - Identify key personnel by name, staffing levels, disciplines, and qualifications.

  - Describe planning for inter-group coordination of organizational interfaces and work stations, and the management process tailored for the project.

  - Identify the major project activities with their inputs, outputs, performance metrics, and completion criteria.

  - Include training curriculum and facilities necessary to establish and maintain staff qualifications (section 5.1).

- Planning to develop funding request document (i.e., Project Data Sheets, Activity Data Sheets, etc.) submitted into the Congressional budget each fiscal year (section 5.5)

- Scope, cost and schedule baselines and planning for baseline management, including establishment of change control thresholds (section 5.9)

- Contracts management plan to determine the scope of work best suited for performance by contractors, to request and evaluate bids, and to select a contractor. The plan should provide for:

  - specific statements of the contracted work including how requirements and functions flow down from the project,

  - interfacing project engineering management plans with the contractor's management plans,

  - approval authorities for any changes in the contract, and

  - periodic reporting and review of contractor performance and accepting the contracted end product (section 5.7).

- Construction management plan to establish a beneficial management system replacing a conventional procurement-delivery system for construction of facilities within the project. This plan should provide for preparing the information for Approval to Start Remedial Action/Construction Critical Decision (CD-3) and for conducting the critical decision process (section 5.10).

- Planning for monitoring, control, and oversight

  - Provide for monitoring the identified key project activities and identifying and controlling these activities to a target performance level.

  - Provide for project oversight to identify and resolve new project issues, to assess outcomes of project activities, and to initiate corrective actions as necessary for acceptable outcomes (section 5.6).

- Scheduled and event-driven status reporting necessary to satisfy a project's monitoring, control, and oversight needs (section 5.6)

3.3.2 Engineering Activities

- Planning for development of the engineering organization and staff levels with disciplines and qualifications

  - Provide for defining the interfaces between the engineering organization and the project management organization. Candidate engineering organizations could include integrated product development teams, functional organizations and matrixed organizations.

  - Include tailoring of a generalized systems engineering process and a design engineering process to a specific project.

  - Specify goals, objectives, requirements, and functions for the engineering organization and for the tailored engineering processes (section 5.1).

- A justification of mission need and a brief description of the project's conceptual design with anticipated results and benefits (section 6.1)

- Planning for transition to operations

  - Include test, evaluation, and turnover of the completed end product, as-built design drawings, vendor manuals, and procedures (section 6.7).

  - Provide for preparing the information for the Approval of Turnover/Completion Critical Decision (CD-4) and for conducting the critical decision process (sections 6.8 and 6.9).

- Planning for Closeout Phase

  - Include proposed method and activities for closing out the project after the operations phase is complete.

  - Include appropriate design drawings, vendor manuals, and procedures necessary to decommission a project.

- Decision criteria and process that update or restate the decision criteria and process from the conceptual phase

  - Include changes in stakeholder or DOE values for the project.

  - Include changes in the decision process that affect selection of preferred project architecture from among alternatives (section 5.1.2).

- Planning to further develop operational scenarios and closeout scenarios for the project's end product. Provide for extending the technical baseline to a level appropriate for preliminary and final design including:

  - requirements and functions,

  - studies of alternative concepts,

  - selection of preferred architectures, and

  - verification/validation for each preferred architecture.

Planning should provide for public and stakeholder inputs to baseline development. The plan should also provide for defining the technical interfaces for integration activities (sections 6.2, 6.3, and 6.6).

- Plans to integrate Specialty Engineering into the engineering design effort. Specialty areas to be considered include:

  - Human Factors Engineering

  - Reliability, Availability, and Maintainability

  - Inspectability, Manufacturability, Operability, and Survivability

  - Safeguards and Security

  - Risk Management

  - Integrated Logistics Support

  - Value Engineering

  - Environmental, Safety and Health

  - Configuration Management

  - Quality Assurance

- Planning for the scheduled or event-driven project-specific specifications of types A, B, and C that provide, respectively, for:
  - definition of end product;
  - definition of requirements, functions and interfaces for end product segments, elements, and/or components to permit design, engineering, evaluation, and procurement make-versus-buy decisions; and
  - specification for services performed on a segment, element, or component of the end product such as welding, plating, heat treating, etc. (section 6.10).

- Test and evaluation planning to ensure that design considers and includes the needs for effective and economical test and evaluation of the end product
  - Address the testing, evaluation, inspection, and integration of the end product for each project phase.
  - Outline the responsibilities of participating organizations, including independent testing.
  - Include rationale for the kind, amount, and schedule of the project tests and inspections.
  - Relate the efforts to technical risks, operational concepts and issues, performance requirements, reliability, availability, maintainability, and critical decision points (section 6.7).

- Plans for technical performance measurement and reporting
  - Identify the technical performance parameters selected for tracking and testing, the specification in which each parameter resides, a time-phased profile of expected performance (with a tolerance band) for each parameter, and any events significantly related to achievement of the expected performance and test conditions under which the performance measurement should occur.

- Provide for re-planning if the technical achievement falls outside the tolerance band, with development of a new time-phased profile and tolerance band as warranted.

- Provide for analysis of the variations from expected performance to determine causes, impacts on other parameters and interfaces, and develop recovery plans as necessary (sections 5.6 and 8.0).

3.3.3 Specialty Engineering Integration Activities

- Planning for environmental, safety and health (ES&H) documentation to provide information on critical statutory, regulatory, and directive requirements necessary to develop the project's ES&H milestones and schedules. ES&H documentation should include policies, organization, training, safety analyses, environmental permits, reviews and audits, reporting of unusual occurrence and remedial actions, management procedures to protect health and safety of employees and public, and risks from hazards to life and property (section 7.3).

- Planning for a review of the NEPA documentation determination from the conceptual phase to determine if the impact analysis is sufficiently broad or still valid for the execution phase. The plan should also provide for preparation of the required NEPA documentation [i.e., Categorical Exclusion, Environmental Assessment, Environmental Impact Statement (section 7.7)].

- Planning for safeguards and security requirements and documentation necessary to develop and document a design of security systems. and the integration of the design into the end product (section 7.5)

- Planning for Quality Assurance requirements and documentation for both contracted work and in-house work (section 7.11)

- Planning for configuration management requirements and documentation including organizational structure and responsibilities, technical baseline identification, configuration change control and configuration recording and reporting (section 5.8)

3.3.4 Review Activities

- Planning for periodic, milestone and event-driven internal reviews of the project's progress in developing scope, cost, and schedule baselines. The plan should also provide for independent reviews of milestones or events to confirm self-assessments of work progress (section 8.0).

3.4 Software

So far, the engineering process has been described from the perspective of construction, manufacturing or fabricating hardware/facilities with almost no mention of software. Many of today's systems require software to meet their design objective. Software discussions are as extensive as hardware, hence space limits this to be the only direct discussion of software in this Guide.

Managers must recognize the importance, and expense, of software and the need for an engineered process to generate it. Software generation must be approached with the same care and planning used in constructing hardware and facilities to ensure that a fully functional integrated end product is available on time. Software must be planned, have requirements established, interfaces managed, documentation developed, designs completed, code accomplished, and testing performed. Software can be an end product, the same as a facility, or may be a necessary integrated part of a larger system, which may not function without it.

Many parallels exist between the process for the development of hardware and those for software. The process names are usually different and a separate set of planning, management and engineering products are required. The current industry standard for software development is EIA-IS-640. The military standard for software is MIL-STD-498 Software Development and Documentation and the MIL-STD-498 Guidebook for Overview and Tailoring; this standard supersedes DoD-STD-2167A, DoD-STD-7935A, and DoD-STD-1703 (NS).

The purpose of these standards is to establish uniform requirements for software development and documentation. These standards define a set of activities and documentation suitable for the development of both weapon systems and Automated Information Systems. The standards have improved compatibility with incremental and evolutionary development models; improved compatibility with non-hierarchical design methods; improved compatibility with computer-aided software engineering (CASE) tools; provided alternatives to, and more flexibility in, preparing documents; clarified requirements for incorporating reusable software; introduced software

management indicators; added emphasis on software supportability, and improved links to systems engineering.

The following outline for a Software Development Plan (SDP) taken from the Superconducting Super Collider Engineering Management Plan is presented as a minimum consideration for managing software. All software development should have an SDP graded as necessary. The SDP should address the following issues as they relate to the software being developed.

- Organization and Resources
  - Software Engineering Environment (operating system, development system and target hardware).
  - Personnel
- Software Standards and Procedures
  - Techniques
  - Software Development Files
- Software Development Library
- Performance Requirements
- Risk Analysis
- Schedules and Milestones
- Critical Path Network
- Security
- Subcontractor Management
- Formal Reviews
  - Programmers Work Area
  - Integration Area
  - Librarian's Work Area
  - Software Test Area
  - CM Controlled Area
- Corrective Action Process
- Non Development Software
- Final Qualification Testing
  - Test Approach
  - Test Plans
  - Test Conduction
  - Test Reporting
- Software Configuration Management
  - Identification
  - Configuration Control
    - Flow of Control
    - Reporting Documentation
    - Storage, Handling, Delivery
  - Configuration Status Accounting
    - Baseline
    - Internal
  - Configuration Audits
- Software Quality Assurance

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4. MANAGEMENT PRODUCTS

This Guide gives the fundamental “products” of project management and engineering management functions. The distinction between the products of project management and engineering management can differ among projects and is, therefore, left to the project manager.

The systems approach should break down management functions and products starting at the top-most (Level-0) management activities and terminating at the lowest level of products appropriate for a particular project. This section terminates at Level 3, recognizing that some projects may require Level 4 or lower levels of decomposition to achieve the needed detail. (See Table 4.0-1)

At Level 1, nearly all management systems will share a set of seven fundamental areas: Organizations, Staffs, Finances, Plans, Directives, Coordinations, and Reports. These seven Level 1 areas are not independent of one another. 'Plans', for example, are a prominent area which interfaces with the other six areas, resulting in lower-level products such as the Organizational Plan, Staffing Plan, Budget Plan, Reporting Plan, etc. Likewise, management products at the next level down are not fully independent of one another either.

Table 4.0-1 identifies the Level 2 and Level 3 fundamental products. It indicates by "(Others)" that grading for some complex projects could identify products in addition to those at Level 2. The grading effort should supply those additional products.

This section briefly describes Level 3 key products, but relegates detail to other project management guides. Each product should be developed using the following three-step process.

1. <u>PLAN</u> the performance of the effort that produce the product,

2. <u>PERFORM</u> the plan,

3. <u>VERIFY</u> the correct performance of the plan.

While a management product may persist over much of the project life cycle, its form will vary in accordance with the plan, perform, and verify process.

- Early Form. The product is a plan for executing a function or activity that will generate the final product form,

Table 4.0-1. Management Products.

Decomposition of Management System Fundamental Products			
Level-0	**Level-1**	**Level-2**	**Level-3**
Management	Organization	• Project Organization	• Graded Organizations for Management Administrative, Financial & Technical Functions • Management Environment & Tools • (Others)
		• Management and Engineering Processes	• Graded Processes for Management, Administrative, Financial, & Technical Functions • Interface Management • Performance Management • Requirements & Standards Management • Engineering Changes during Construction • (Others)
		• (Others)	
	Staffs	• Training	• Classroom, On-the-Job, Simulator, Reading, Conferences, Workshops, and Other Training • (Others)
		• Others	
	Plans	• Planning Documentation	• See section 4.0 of *PEAEMP* Guide
		• Others	
	Finances	• Federal Budget Cycle	• Short Form Data Sheet • Long Form Data Sheet • (Others)
		• (Others)	
	Directions	• Monitoring, Control and Oversight of Management, Administrative, Technical and Financial Processes	• Evaluation of Scope, Cost & Schedule Performance Data • New Issues Reports • Corrective Action Reports • (Others)
		• Contract Management	• Bidding & Selection • Scope, Cost & Schedule • Turnover for Delivered End Products • (Others)

Table 4.0-1. Management Products (continued).

Decomposition of Management System Fundamental Products			
Level-0	**Level-1**	**Level-2**	**Level-3**
Management (continued)	Directions (continued)	• Configuration Management	• Policies, Facilities, Tools, Procedures and Staff • Change Control Board • Records for Each Configuration Item • Configuration Verification • (Others)
		• Scope, Cost and Schedule Baselines	• Work Breakdown Structure • Baseline Development • Baseline Management • (Others)
		• Construction Management	• Construction Process Document • Infrastructure Capability Document • Evaluations of Reviews • Evaluations of Progress and Status Reports • Corrective Action Reports • (Others)
	Coordinations	• Inter-Group Coordination	• Identification of Customers, Suppliers and Interfaces with Project Disciplines • Communication Channels and Other Essential Coordinations • (Others)
		• Decision Criteria	• Value System • Criteria and Decision Processes • (Others)
		• (Others)	
	Reports	• Project Status Reports	• Scope, Cost & Schedule Performance Reports • (Others)
		• Project Reviews	• See section 8.0 of *PEAEMP* Guide
		• (Others)	

- Intermediate Form. The product is usually a status report, which reflects how management has executed the perform step in accordance with the plan.

- Final Form. The product may be either a document (i.e., safety analysis report) or a functioning entity (i.e., a change control board). The product is also a verification and validation report prepared when management completes the verify step.

At whatever level the grading effort stops, the management definition of the management system should occur third in a sequential development of an engineered end product. The sequence should be as follows:

1. Deliverable end product definition,

2. Constructed process end product definition (not always required), and

3. Management system definition.

This sequence ensures that a constructed process end product (i.e., a vitrification plant) can manufacture the deliverable end product (i.e., a vitrified high-level waste form) and that the management system can manage both of the projects for the end product.

4.1 Project Organization

This product should document the structured organization of DOE and contractor personnel and their management environment and tools for implementing a project during preconceptual activities and the conceptual and execution phases. The product's basic form should be:

- organization charts;

- descriptions of responsibilities, accountabilities, disciplines, staffing levels, and qualification requirements for management, technical, administrative, and financial systems for the project; and

- descriptions of the management environment, including facilities, shops, work spaces, policies, procedures and communication channels, and media.

Both DOE and contractors are expected to have general policies, standards, guides, and procedures; however, this product should document the grade selection for the specific project. The general items may be included by reference for application to the project. The product emphasis may differ in each project phase. It may be somewhat informal for preconceptual activities, but should be formal beginning in the conceptual and succeeding phases.

Management is the primary user of this product for preconceptual activities. The Head of the Field Element should use the product to ensure that the appropriate organization is in place to develop mission need documentation, define end product functions, requirements, and architecture to the level appropriate. The early product should specify the organization that is to prepare the information necessary for Approval of Mission Need; i.e., Critical Decision (CD-1).

For conceptual and execution phases, the project manager should use the organizational plans to ensure that the organization is in place to achieve the following:

- Determine and obtain the preferred (graded) management environment and tools;
- Maintain the environment and tools at a level consistent with needs, while monitoring opportunities and replacing components of the environment or tools as they become obsolete;
- Define end product, to the level appropriate for a project phase; and
- Manage the design and construction of process facilities or the contractual relationships with other manufacturing infrastructure to produce and deliver an end product that satisfies mission needs.

Management prepares the organization plan for preconceptual activities. The Head of the Field Element may direct preparation of the DOE organizational structure, environment and tools and identification of the contractor organization's supporting preconceptual activities. For all other project phases, the project manager should direct preparation of the organizational plan to define the DOE organizations, environment and tools and facilitate preparation of contractor organizations. DOE does not normally become involved with the contractor management environment but may prescribe a compatibility interface for the DOE and contractor tools. Desirable features of each organization include single point accountability, clear customer interface, short communication channels, high control capability, and assured technology transfer. A systems approach using a decision process that considers various alternatives should be used to determine the preferred organization, environment, and tools. Organizational alternatives may include, for example, alignment by functions, projects, integrated product teams, or matrix concepts.

The product may take different forms depending on the project phase. During preconceptual activities or conceptual phase, the product is usually a plan to establish organizations, environment, and tools using a systems approach. During the execution phases, the product is the actual organizational structure with an implementation document that describes them.

An external interface exists if the project uses contractors to accomplish some or all of the end product development, manufacturing, or acceptance testing. Interface management should strive to provide maximum flexibility to the contractors while ensuring that contractors have adequate capacities and qualifications to handle the allocated work load within cost, schedule, and quality requirements.

4.2 Management and Engineering Processes

This product is a definition of a project's engineering process and management process that result from grading of a generalized process. It identifies the management and engineering tools the project will use to implement the process.

The processes should include the grading information, inputs, outputs, performance metrics, and completion criteria for the major activities of each process. Inputs could include policies, goals, objectives, procedures, and standard guidelines for quality, ethics, and performance measures; and criteria for documenting, grading, tracking, assessing, and improving management and engineering processes. The tools should include the following:

- Information management systems,
- Models and simulations for synthesis and analysis of architectures,
- Cost and schedule estimating models, and
- Decision criteria and processes for selecting preferred architectures (section 5.12).

The *Productivity Tools: Automated Models and Simulations*, GPG-FM-028, gives guidance for determining whether models or simulations are appropriate and the type of models or simulations the project has available for use. Similarly, the *Systems Analysis and Assessment* Guide, GPG-FM-029, gives guidance for determining if automated tools are appropriate and the types of tools available for project use.

This product appears very early in the project during preconceptual activities; it takes the form of a preliminary plan which, when performed, results in the definition and brief description of high-level management and engineering processes. The conceptual phase finalizes the plan and uses it to extend the definition of processes to a lower level. The plan should provide for tracking, assessing, and improving the performance of both processes over time. Following implementation of the plan, the product takes the form of verification reports. Management uses the product to accomplish the following:

- Evaluate performance of the implemented processes to understand their strengths and weaknesses, and take actions to resolve issues and correct errors.

- Improve processes continuously and communicate improvements to affected groups.

- Obtain and implement the tools that management will use to implement the processes.

The project's planning group should prepare the initial product by accomplishing the following:

- Prepare a plan using a systems approach to select the preferred process from among graded alternative processes.

  - Identify and select tools for implementing the processes.

  - Revise the plan whenever performance metrics or other assessments indicate an adjustment is necessary.

- Compile and maintain a library of acceptable management and engineering processes and tools. The library should include guidelines and criteria for selecting and tailoring processes and tools specifically for a project. The library should also include reference documentation.

Management prepares the product in the intermediate and final stages by implementing the plan and documenting its implementation. Management verifies and documents that implementation was correct and, thereafter, provides for assessing performance of the product and taking corrective action for significant deficiencies.

An external interface could exist between the project and the program manager and the DOE field office or a parent organization of a contractor. Inputs across this interface could include general policies for all projects (i.e., criteria for documenting, tailoring, tracking, assessing, and improving these processes and tools). Inputs could also include standards and guidelines for quality goals, ethical standards, technical standards, and performance measures for management and engineering processes and tools. An external interface could also exist between project and contractor. This interface should ensure suitable compatibility of management and engineering processes and tools among the various organizations. Outputs across this interface should include the plan, reports of its implementation, a verification report, and assessment reports of effectiveness of the product.

4.3 Training

This product is a project-specific program that helps ensure project participants have the necessary knowledge and skills to perform effectively.

Training should include classroom training, on-job training, simulator exercises, reading, conferences, and workshops. Subject matter includes project mission, selected engineering and management processes, communication and approval channels, identification and management of project interfaces, and definition of the end product. The training team uses the product in preparing training materials and conducting training. Also, the team maintains records of training and experience in accordance with the plan.

The project manager should use the product to assess effectiveness of the training and to initiate actions to correct deficiencies and provide for improvement.

Generation of the product should begin with the project's planning group, which gathers information from the project staff and prepares a training plan, identifying training needs through the organization. This effort should evaluate project needs, organizational plan, and required employee qualifications. The planning group prepares the plan as a joint effort with the project training team.

The training team generates the program in accordance with the plan. The materials should be commensurate with the need to train in new skills and to maintain existing skills, and should cover technologies, tools, methods, and procedures. The training team should also update materials as needed and maintain them in an accessible repository.

An external interface should exist with the training program for the operations and maintenance phase. Interfaces may also exist in the form of conferences, work shops, and symposia, which may significantly enrich training programs with discussions on state-of-the-art training and technical systems. The training group should seek these interfaces and promote their use within the project organizations. The training group may need to interface with the larger training group for an organization or site. In this case, the larger group can lend facilities, personnel, and visual aids and provide basic and special training.

4.4 Planning Documentation

Section 5 provides more detail for project planning documentation.

4.5 Federal Budget Cycle

The *Baseline Development* Guide, GPG-FM-016, gives guidance for effective fiscal year budget planning and management within overall project baselines.

The product provides for inputs of scope, cost, and schedule baseline information into the federal budget cycle, and facilitates the management of fiscal year disbursements to the project. Beginning during the preconceptual activities, the product is a short form project data sheet, which DOE submits as the project's first input to the budget cycle. In the conceptual phase, the product includes a long form project data sheet and associated documentation containing validated baseline information, which DOE submits for Congressional authorization and appropriation. Thereafter, the product is comprised of various documents related to appropriations, disbursements, and management actions necessary to fund the project on a fiscal year basis.

Management uses the product to secure funding for the project. Failure to secure the required funds will cause a project replan. The potential for a funds shortfall should be considered in the initial project planning.

An external interface exists between DOE Field Element and Headquarters personnel working the federal budget cycle. Across this interface should flow:

- inputs of project baseline information necessary for the budget cycle, and

- outputs of funding disbursements from the budgetary actions to fund scheduled project activities in each fiscal year.

4.6 Monitoring, Control, and Oversight

Monitoring and control involves tracking performance against targets and controlling activities to achieve targets, in accordance with a management plan. Oversight complements monitoring and control by identifying and analyzing new project issues that may surface, assessing the outcome of project activities, and initiating corrective actions to ensure acceptable outcomes, in accordance with a plan. The plan should identify the tracked activities, their performance measures and reporting requirements, and the communication channels for results, including:

- senior management in periodic reviews,
- project management in periodic and event-driven reviews, and
- quality assurance group as warranted.

The tracked activities should include as a minimum:

- planning and replanning;
- development of scope, cost, and schedule baselines;
- assessment of technology, cost, and schedule risks;
- management and administrative activities; and
- availability and deployment of critical resources.

Evaluations should include developing profiles of actual progress, risks, and resources against the planned profiles for the above activities. The *Performance Analysis and Reporting* Guide, GPG-FM-006, gives additional guidance for measurement and evaluation of contract and overall project performance.

Users of this product include management and quality assurance groups. Management should use information from periodic, scheduled, and event-driven reports and reviews to identify and evaluate actual accomplishments and outcomes of tracked project activities and new project issues. These activities will usually lead to additional, lower-level management products such as:

- Scope, Cost and Schedule Evaluation Reports which report actual project performance against targets;

- New Issue Reports, which identify, evaluate, and track new issues that can have substantial impacts on the project; and

- Oversight to determine and implement any necessary adjustments or corrective actions if deviations from planned outcomes become unacceptable. Oversight activities usually lead to management lower-level reports such as Corrective Action Reports, which describe steps planned to correct discrepancies or resolve issues.

The quality assurance group should use the information to assess compliance with quality goals, objectives, and control parameters. These assessments usually lead to lower-level specialty reports with recommendations for management actions.

Generation of this product should be a management responsibility. A project planning group should generate a plan for monitoring, control, and oversight. Management should arrange for review, evaluation, control, and oversight of tracked activities. Management should also arrange for special monitoring, control, and oversight as driven by unexpected events.

An external interface could exist for this product, involving mostly interactions with external personnel in the reporting and review of project activities. External stakeholders and DOE program or other Departmental personnel may evaluate and react to project reports and attend the reviews of tracked activities. In this case, the reports and reviews should be tailored to deal with special interests, particularly with respect to the mission and mission analysis.

4.7 Contract Management

4.7.1 Considerations for Contracting

The *Performance Measures* Guide, GPG-FM-020, gives detailed guidance for contracting strategy and methods for selecting a contractor.

Developing a contracting strategy helps ensure effective and efficient use of contractors to accomplish specific project objectives within the framework of documented plans, procedures and requirements, which describe the products and processes being contracted. Contract Management includes:

- scope, cost, and schedule of contracted work, including a requirements and functional flowdown from the project;
- correct interfacing of DOE and contractor project and engineering management plans;
- review and approval authorities for changes in statement of work, contract terms or other commitments;
- periodic reporting, interchanges, and reviews of contractor work status and accomplishments; and
- sequences and procedures for accepting contracted products.

Users of a contracting strategy should include the project manager, quality assurance, and configuration management groups. The project manager, in partnership with the contracting officer, should use a contracting strategy to help select the contractor, monitor and evaluate contractor performance periodically, and review results with the contractor, in accordance with a plan. The project manager should use a contracting strategy to conduct acceptance testing of products upon delivery, also in accordance with a plan.

The quality assurance group uses a contracting strategy to monitor the contractor's quality assurance group and the products for delivery. The configuration management group uses a contracting strategy to monitor contractor's activities and products related to configuration management.

Management prepares a contracting strategy. The planning group prepares the contract management plan jointly with a designated and qualified contract group, which is familiar with contracted aspects of the project. The contracts group may be part of the project team, or it may provide the service as part of a larger DOE or corporate function. The contracts group is responsible for preparing the bid package, selecting the contractor, and managing the contract. Management, working with the contracts group, is responsible for implementing the plan and providing monitoring, control, and oversight of contractor performance and accepting the contracted end product.

The contract is itself an external interface. Through this interface, the project should pass to the contractor:

- allocated portions of the project mission, functions, requirements, expected results, and work breakdown structure;

- reporting and review requirements; and

- funding.

Through this interface, the contractor should pass to the project:

- contractor management plan,
- reports of scope, cost, and schedule status,
- reviews of progress and accomplishments, and
- delivered products.

The interface should allow maximum flexibility in the contractor's management systems, consistent with satisfying the needs of DOE and the contractor.

4.7.2 DOE and Contractor Relationship

This subsection does not replace any acquisition and contracting needs. It is, however, a strong reminder for DOE management that most of their work is contracted for, and the recommendations of this Guide should be considered for inclusion in the contract.

4.7.2.1 Roles

DOE projects will generally have two defined roles: DOE's role and the performing contractor's role. Both DOE and the performing contractor direct project activities through a decision-making process and evaluate through reviews, meetings and available data. However, the decisions made, reviews and meetings attended, and data evaluated may be different because of the defined roles. Both roles must work together to adequately evaluate and direct a project.

Although decisions are the responsibility of management, inputs from engineering are required to obtain information to support the decision process. Within the DOE role, inputs to the technical side are:

- a criteria that DOE management will use in making decisions, and

- identification of the type of data to be generated to support the decision process.

As required, the performing contractor should request information from DOE to direct their data generation process. The performing contractor's management should be required to provide information including:

- a criteria that management will use in making decisions,

- identification of the type and form of data to be generated to support both the DOE and performing contractor's decision process.

Having the overall responsibility for the management of a project, the cognizant DOE organization receives management input that affects the engineering process from several sources. These include:

- DOE HQ
- Stakeholders
- Groups or offices within the cognizant DOE organization
- Groups or offices within the performing contractor's organization
- Government evaluation committees and boards (i.e. GAO, DNFSB, NAS, etc.)

Some of the input, although sound, may conflict with the input from other sources, and the direction of the cognizant DOE organization. A change control process should be used to deal with these inputs. This process is used to:

- logically review and approve/disapprove changes to the project and the directions provided to the performing contractor,

- trace the changes in the project and the directions given to the performing contractor, and

- document the rationale for all changes.

Once the review of inputs has been completed, input to the performing contractor should be provided one or more of the following:

- Direction for preparing the Fiscal Year Work Plan,
- Management Directives,
- Statements of Work (SOW)s, and/or
- Letters of Direction.

Though only the SOW is discussed in this Guide, its contents should not conflict with the others.

4.7.2.2 Statement of Work (SOW)

The scope of work is the means by which the cognizant DOE organization directs the performing contractor on engineering objectives DOE expects to be met during a phase of the project that is contracted for. The objectives will be directed towards achieving the project's mission through the development of the appropriate organization, definition and development of an end product, and definition of the environment in which it is to function. With respect to this, the SOW will direct the performing contractor towards the accomplishment of work necessary to meet the success criteria of DOE sponsored reviews. DOE SOWs should contain, but not be limited to, the following information:

- An identification of the SOW and its relationship to all other SOWs (to support traceability);

- A definition of the SOW objectives;

- A description of the scope of work covered within the SOW;

- The high level Work Breakdown Structure and Dictionary, or a reference to it, if it is included in a higher level document;

- Identification of the work to be performed;
- Identification and description of the reviews to take place;
- Description of deliverables;
- Identification of Milestones; and
- Definition of responsibilities;

DOE should ensure that the SOWs for the project are integrated and present a clear description of the project's mission.

After the release of a SOW, proposed change to the work direction defined within it shall be fully evaluated for its impacts prior to formal approval. These evaluations should cover the areas of cost, schedule, and technical impact. Once the impact of the proposed change has been completed and the change approved, a formal letter shall be provided to the performing contractor directing the change.

After receiving a SOW, the performing contractor should develop an approach to meeting the objectives defined, and present it to DOE for review and approval at a SOW Approach Review.

4.8 Configuration Management

The *Configuration and Data Management* Guide, GPG-GM-012, gives detailed guidance for maintaining the physical configuration. Also, it defines and classifies the various data types and describes methods for effective management for each type. This product helps maintain data and status of the project's end product and the identified configuration units. It helps to analyze and control changes to the configuration units of the end product, including the documentation.

Configuration management differs from baseline management by focusing solely on the end product and its configuration units and the associated documentation. Baseline management deals more broadly with scope, cost, and schedule baselines, which increase in complexity and detail as the project proceeds phase-to-phase. The configuration management process and its requirements should be graded to the specific project and should address as a minimum:

- organizational structure and responsibilities;

- configuration identification, including the technical baseline;
- configuration control, including waivers and deviations;
- configuration recording and reporting;
- configuration change control board with procedures and approval levels for changes; and
- special considerations such as peculiarities or innovations.

This product may take different forms in each project phase. In the conceptual phase, the product is a configuration management plan. During the execution phases, it is a configuration management system of facilities, tools, policies, and procedures, staffed organizational structure, and a change control board. The product includes a verification document that demonstrates the configuration management system complies with the plan.

Users of the product should be the following:

- Project configuration management group, which implements the configuration management plan, thereby establishing the project's configuration management system. This group operates the established system in accordance with written policies and procedures. This group uses the product to ensure correct interfacing of configuration management for the project and the contractor systems.
- Configuration change control board which reviews, assesses, and disposes of proposed changes to the configuration.

Generators of the product include the planning group and management. The planning group prepares a configuration management plan with the help of designated, experienced configuration management advisor(s) familiar with the project. In the absence of a planning group, the project manager, or alternately the Head of Field Office, should prepare the plan. The project manager should implement the plan to establish the configuration management system and appoint and coordinate a configuration change control board.

An external interface could exist between the project configuration management and a larger (site) configuration management system. The configuration management plan should explicitly address this possible interface.

An external interface should exist between project configuration management system and contractor(s) configuration management systems. The contract management group is responsible for establishing and maintaining this interface.

4.9 Scope, Cost, and Schedule Baseline

The *Baseline Development* (GPG-FM-016) and *Baseline Change Control* (GPG-FM-009) Guides give detailed guidance for the product. Typical work products of baseline development include work scope planning, scheduling, cost estimating, and time-phased budgets. Typical work products of baseline management include baseline change control, work authorization, and cost accounting.

The product consists of scope, cost, and schedule baselines established for each critical decision point. Each of these three baselines increases in complexity and detail as the project proceeds phase-to-phase.

Baseline management differs from configuration management by dealing broadly with scope, cost, and schedule baselines. In contrast, configuration management focuses on the end product, its configuration units, and their associated documentation.

4.10 Construction Management

The product includes procedures, services, and guidance for construction of any facilities, with the objective of obtaining the facilities at the lowest practical cost and in the shortest practical time. Construction management planning should begin during the conceptual phase and continue to project completion.

The product replaces the conventional end product procurement-delivery approach, but only if it is beneficial to a project. An evaluation should determine if construction management is beneficial. Project size, facility complexity, delivery schedule, procurement strategy, and availability of qualified project personnel are the major factors in the evaluation. If the evaluation concludes this product is beneficial, it is important to tailor construction management to a particular project.

Project management is the primary user of this product, to help ensure project accomplishment in the most economic, efficient, and effective manner. Project management should also use the product to:

- gain professional expertise in particular construction services required,

- determine the benefits of phased construction,

- receive reliable assessments of industrial infrastructure capability and labor conditions for use in the decision-making process, and

- establish a more accurate and reliable time, cost, and quality schedules and controls.

Management initiates generation of the product by determining if construction management would be beneficial and designating a construction manager. If sufficient government expertise is not available, management should contract for a construction manager. The construction manager should generate the product while serving as a staff expediter and advisor to all construction members rather than as a director of any portion of design or construction. Generation of the product entails providing important construction-related inputs to project planning, budgeting, materials selection, labor conditions, construction technologies and methods (including phased construction), and quality assurance.

Generating the product results in more detailed products that depend in part on the available government expertise and project size, complexity, requirements, and procurement strategy. Typical detailed products could include the following:

- **Contract for a Construction Manager**. This product is necessary if adequate government expertise is not available to perform the construction management function.

- **Planning and Design Services**. This product includes construction inputs to the preparation and review of project planning, project scope, design criteria, regulatory constraints, environmental and safety assessments, quality control, construction schedules, and construction cost estimates. This product could also involve requests for proposal, bid evaluations, constructability determinations, phased-construction plans, contracts for field services such as collection of geotechnical data or environmental data, special studies such as transportation and socioeconomic studies, and monitoring schedules for all project activities.

- **Construction and Post-Construction Services**. This product should include performing all management and administrative aspects of the project related to construction, including coordinating/integrating the efforts of the projects of various contractors and other participants and providing for on-site personnel to facilitate or implement security, temporary field facilities, and other project needs not part of a construction contract. This product could also include identification and resolution of problems and issues, compliance monitoring, status reporting, voucher processing and other financial analyses, change request initiation and processing, as-built drawings preparation, and preparation of turnover procedures, tests, and project completion documents.

External interfaces exist with each of the architecture-engineer firms, various equipment suppliers, and construction. The product should ensure the coordination and integration of all inputs and outputs across these external interfaces so as to maintain integrity of the scope, cost, and schedule baselines.

4.11 Intergroup Coordination

This product identifies the groups and intergroup relationships for a project's life cycle, and to help foster an environment promoting interactions toward a common agenda. The product should cover the following points as a minimum:

- Identify customers, suppliers, project disciplines and specialties, their working interfaces and the interactions necessary for a successful project completion. Disciplines may include marketing, engineering, design, research and development, manufacturing, reliability, maintainability, human factors, logistics, environmental, safety, security, and others.

- Identify essential characteristics of the project environment, including facility, tool and organizational environments that support the engineering process while promoting vertical and horizontal two-way communications.

During the preconceptual activities or conceptual phase, a plan to perform inter-group integration should be developed. The execution phases should implement the plan. The plan's implementation will also be verified during the execution phases, and the verification document will be added to the plan. Management uses the product to:

- justify and obtain the requisite human resources and disciplines for the project,

- integrate the efforts of and facilitate agreements among the various groups,

- facilitate identification and resolution of intergroup problems and issues,

- create the proper environment in which these resources will work.

Management generates the product by preparing, implementing, and verifying a plan for intergroup integration. Customers and suppliers provide mission-related input. Through this external interface customers and suppliers will also communicate and reach agreements with the project team on issues including the end product and programmatic requirements.

4.12 Decision Criteria

Development of decision criteria is one of the key elements in the management decision making process. Decision criteria is generally mandatory in the selection of the preferred architectures from among acceptable alternative architectures.

Prior to evaluating alternatives, decision criteria should be established as a basis for the evaluation. Decision criteria can ensure consistency in the decision making process. Decision criteria is a way to include project risk, socioeconomic considerations, and public and stakeholder values as well as project requirements and constraints.

Decision criteria needs to be quantifiable. Decision criteria can have diverse units (dollars, years, rems and others) which complicate comparisons of alternatives. To facilitate comparisons, techniques such as "weighing," "utility functions," and "sensitivity analysis" can be used. These techniques are discussed in the Engineering Trade-Off Study Guide.

It is difficult to describe a generic method to develop decision criteria that quantitatively combine goals, objectives, requirements, constraints, stakeholder values, and risk. The method is dependent upon the specific engineering process being used by the project, the complexity of the project, and decision techniques selected. However, a typical selection process should be similar to the following:

- Select those alternatives that meet the goals and objectives.
- Select those alternatives that satisfy the requirements and constraints and perform the mission functions.
- Perform risk analysis to evaluate the probability of failure and the consequences associated with each alternative.
- Apply utility function technique and evaluate each alternative's risk and performance compared to the decision criteria.

- Perform sensitivity analysis to establish the relative impact of different performance criteria and value systems.
- Rank the alternatives on the basis of decision criteria, sensitivity analysis, and risk analysis.
- Select the preferred alternative.

Management should use the results of the decision process to select the preferred architecture from among the alternative architectures that satisfy mission needs.

4.13 Project Status Reports

The *Performance Analysis and Reporting* Guide, GPG-FM-006, gives details for preparing this product. It includes the periodic reports and event-driven reports of performance towards completing project scope, cost, and schedule baselines.

Management uses the product to evaluate deviations from expected performance and the causes for the deviations. Management takes corrective actions based on the evaluations when deviations fall outside acceptance limits.

The various project groups generate reports for their area of specialty. That is, the financial group will report performance against the cost baseline, the engineering group will report against the technical baseline, and so on.

4.14 Project Reviews

See section 8.0 of the *PEAEMP* Guide.

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5. ENGINEERING PRODUCTS

Engineering is the activity that implements the planning guidance based on management direction that ultimately results in an end product that satisfies a mission need. Engineering begins with an understanding of the mission need, goals, objectives, requirements, constraints, and risks that help define and bound a project.

Table 5.0-1 shows a decomposition of the engineering activities for three levels, with each successive level representing greater detail. The breakdown for engineering products is similar to, but not the same as, the breakdown levels for functions, architecture, or work breakdown structures. Level-0 is the engineering start level, which breaks down into five Level-1 engineering areas. The Level-1 synthesis, for example, decomposes into several Level-2 engineering products. The table has subsection reference for Level-2 for products presented in this Guide. Level-3 is a list of resulting products that may be outputs of the activities that support the Level-2 products.

For all engineering products, a graded approach should be used to determine the key needs and the amount of detail a given product should include for a specific project. If the performing contractor has acceptable processes or standards for developing or applying these products, they should be used. For complex projects, some of these products may warrant development as stand-alone products as well as some of the items at Level-3.

5.1 Mission Analysis

Mission analysis should develop a Mission Statement which relates the DOE Strategic Plan to the Program mission and the project need. This is one of the steps in the systems engineering process (see subsection 3.2.2). It is usually prepared by the Program Office as part of preconceptual activities and sets the stage for detailed project definition and planning in the conceptual phase.

The scope of the mission analysis should include the operations and closeout phases of the program life cycle as well as the preconceptual activities and two project phases: conceptual, and execution. The mission analysis should identify the current situation (initial state), determine the desired outcome (final state), and establish the initial, high level set of functions and requirements that will transform the initial state to the final state. The determination of final state should identify all the end product the project must deliver to satisfy the identified mission need.

Mission Need documentation should include the following:

- A description of the project need in relation to the Program Mission and DOE Strategic Plan, of the initial state, and of anticipated results.

- The scope and boundary descriptions for the project including interfaces with other programs and projects.

- A listing of external constraints such as Federal and State laws and regulations, Departmental directives, and Program policies.

- Technical objectives and stakeholder values which will help form the decision criteria to select the final solution.

- Results of preliminary operational and closeout scenarios.

- A description of the final state, including the end product. For complex projects, this should include:

  - Identification and analysis of functions and requirements for the end product;

  - Preparation of decision criteria, which incorporates goals, objectives, stakeholder, and DOE values, and a decision process to identify the preferred concept among the alternatives;

  - Need for engineering tradeoff studies that evaluate alternative architectures for the project end product and select a preferred alternative (architectures) for the project end product,

  - Verification that the preferred alternative meets requirements and validation that the preferred alternative is consistent with the operational and closeout scenarios.

- The key requirements and measures of effectiveness to identify and measure how well the end product must perform.

- A preliminary risk assessment that evaluates the impacts of risk on functions, requirements, schedule, cost, and resources. The risk assessment should include evaluation of impacts from any enabling assumptions (i.e., assumptions made, in lieu of factual information at a given point in time, that enable project planning to go forward). These assumptions should be tracked from identification through

Table 5.0-1. Engineering Products.

Level-0	Level-1	Level-2	Level-3

Engineering	Requirements Analysis	Mission Analysis (6.1)	• Mission Analysis Report
			  • External Constraints
			  • Technical Objectives & Decision Criteria
			  • Initial & Final States
			  • Preliminary Risk Assessment

	Functional Analysis/ Allocation	Functions and Requirements for Functional Architecture (6.2)	• Functions
			• Requirements
			  • Performance
			  • Interface
			• Constraints

	Synthesis	Functions and Requirements for Physical Architecture (6.2)	• Functions
			• Requirements
			  • Performance
			  • Interface
			• Constraints

		Design Documentation (6.4)	Design and construction calculations, drawings, and specifications
		Safety Assessments (6.5)	• Hazard Assessment • Preliminary Safety Evaluation
		Interface Control Documentation (6.6)	• Memoranda of Understanding • Memoranda of Agreement • Interface Control Documents
		Operations and Maintenance Requirements Documentation (6.8)	• Operating Limits • Operating Procedures • Vendor Equipment Documentation • Maintenance Requirements
		Turnover Documentation (6.9)	Sum total of Design Documentation, Operations and Maintenance Requirements Documentation, and Test and Evaluation Documentation.
		Specifications (6.10)	• Level 1 (Type A) Project/ System • Level 2 (Type B) Subsystem/ End product • Development & Performance • Product • Process • Material • Design Requirements • Level 3 (Type C) As-Built
Engineering (continued)	Specialty Engineering Integration	Integrated Logistics Support (7.1)	Integrated Logistics Support Plans
		System Life Cycle Cost (7.2)	Life Cycle Cost Estimates

Level-0	Level-1	Level-2	Level-3
		Environment, Safety, & Health (7.3)	E'S&H Plan
		Human Factors Engineering (7.4)	Human Factors Engineering Plan
		Safeguards and Security (7.5)	Safeguards and Security Plan
		Risk Management (7.6)	• Risk Management Plan including: risk assessments, risk abatement, and risk monitoring • Risk Assessments • Risk Sensitivity Analysis • Risk Handling Plan • Risk Reduction Report
		NEPA Documentation (7.7)	• NEPA Recommendation • NEPA Assessment • EIS • ROD
		Value Engineering (VE) (7.8)	VE Assessments
		Reliability, Availability and Maintainability Reviews (7.9)	• Review Plan • Review Documentation • Review Reports
		Constructability Operability & Survivability Reviews (7.10)	• Review Plan • Review Documentation • Review Reports
		Quality Assurance (7.11)	• QA Requirements Document (QARD) • QA Program Description Document (QAPD) • Audit Plans & Reports Surveillance Plans & Reports
		Programmatic Specialty Integration (7.12)	Programmatic Specialty Integration Plan
		Tests and Evaluation (6.7)	• Test & Evaluation Plans • Design Review Reports • Inspection Plans • Test Procedures • Inspection Reports • Test Reports • Assessment Reports

resolution. Resolution will usually require completion of an alternative evaluation, and the alternative evaluation should also be tracked from identification through resolution.

5.2 Functions, Requirements, and Architecture Identification

These three steps in the systems engineering process are closely related and have many interactions as the allocation process progresses. The systems engineering process is discussed in subsection 3.2.2.

5.2.1 Functions

Determining a project's functions is one of the key steps supporting project planning and project definition. Accurate formulation of the functions leads to assurance that the end product will satisfy the mission need. Once defined, the functions are the basis for many other planning elements including design criteria, specifications, work breakdown structure, cost estimates, alternative evaluations, and value engineering studies.

A function is a task, action or activity that must be performed. A function receives an input, does something to it, and produces an output. It may require one or more inputs and may produce one or more outputs. A function is generally described using a verb-noun combination such as "remediate waste" and has an interface with at least one other function. It describes what must be done, not how.

The initial, high level project functions are established during preconceptual activities. However, they are not normally of sufficient detail to produce the end product. Additional detail is developed during the conceptual and execution phases through an allocation process.

Functional allocation in conjunction with the other steps of the systems engineering process is a top down approach for developing a functional definition of the end product and the translation of high-level functions into detailed design criteria. It is an iterative process of breaking functions down from the system level to the subsystem and as far down as necessary to identify detailed design criteria for the various components of the system.

Those performing the functional allocation need to ensure that each function has at least one requirement associated with it.

Functional allocation is not confined to any single phase of the life cycle and functional definition of the end product is not accomplished in any single life cycle phase. Successive phases of the life cycle develop the functional definition to lower, more detailed, levels.

No predefined level of detail exists to which the functional definition should be developed in any particular phase. However, the functions from any particular phase should be the basis for the next phase. The allocation of functions in conjunction with the other steps through the project phases could be similar to the following:

- **Mission Analysis** - Through a high level evaluation of project functions, provides sufficient information to develop more detailed functions and requirements during the conceptual and execution phases of the project.

- **Conceptual Phase** - Takes the high-level functions developed during preconceptual activities and uses functional allocation to determine functions to the system and subsystem level.

- **Execution Phase** - Functional analysis is used to determine functions to the component level based on those developed for the system and subsystem levels during the conceptual phase.

For complex projects, a data base should be established to provide traceability of functions. The data base should contain, at a minimum for all of the steps, the following information:

- the functions, requirements, enabling assumptions, and alternative evaluations by title including, for each, a description and a unique identifier;

- the functions, requirements, enabling assumptions, and alternative evaluations cross-referenced with one another and with any interfacing functions or requirements; and

- the functions cross-referenced with their parent function and child functions.

The cross-reference: (1) identifies the parent and child relationship for each function, (2) identifies requirements associated to each function, (3) identifies any enabling assumptions applicable to each function, and (4) identifies the alternative evaluations applicable to each function.

There are many tools and methods to use in the functions and requirements process. Functional flow diagrams is one method and N^2 diagrams is another tool.

5.2.2 Requirements

In concert with functions, requirements are the next step in the systems engineering process. Every function will have at least one requirement and accurate formulation of the requirements leads to assurance that the end product will satisfy the mission need. Once defined, the requirements are the basis for many other planning elements including design criteria, specifications, work breakdown structure, cost estimates, alternative evaluations, and value engineering studies.

Requirements state <u>how</u> well an architecture must perform a function in terms of quantity (how many or how much), quality (how well), coverage (how much area, how far), timeliness (how responsive, how frequent) or readiness (availability, operational readiness). However, there are several origins/types of requirements which include:

- Those imposed on the project from external sources (constraints) such as regulations, laws, and policies;

- Those related to interfaces between functions or to external systems (interface requirements), and

- Those derived from within the project that define quantitatively how the functions must be performed (performance requirements) in support of the end product.

Unless specified otherwise, the term "requirements", as used in this Guide, includes all of the above.

The main attribute of a requirement is that it must be measurable and that it applies to the architecture. Otherwise consideration should be give to the fact it is not a requirement.

The initial, high level, set of project requirements are established during preconceptual activities. However, they are not normally of sufficient detail to produce the end product. Additional detail is developed during the conceptual and execution phases through an allocation process.

No predefined level of detail exists to which the requirements definition should be developed in any particular phase. However, the requirements from any particular phase should be the basis for the specification for the next phase. The allocation of requirements through the project phases could be similar to the following:

- **Mission Analysis** - Through a high level evaluation of project requirements, provides sufficient information to develop more detailed requirements during the conceptual and execution phases of the project.

- **Conceptual Phase** - Takes the high-level requirements developed during preconceptual activities and uses requirements allocation to determine requirements to the system and subsystem level.

- **Execution Phase** - Requirements allocation is used to determine requirements to the component level based on those developed for the system and subsystem levels during the conceptual phase.

For complex projects, a data base as described in the Functions Subsection should be established.

5.2.3 Architecture Identification

Architecture is the name given to the conceptualization of the end product at any level of allocation. The architecture at each level must perform all functions and meet all requirements for that level. Usually, several different architectures can perform functions and meet requirements for a level of allocation, and these different architectures are called alternatives. The systems approach (see subsection 3.2.2) will select the preferred architecture from the alternatives at each level of allocation before proceeding to the next level.

The architecture, like the functions, and requirements are initially very generalized or conceptual during the preconceptual activities. The objective should be to show the feasibility of the project under consideration. Risk areas should be identified with risk mitigation approaches establish as appropriate for high risk. If research and development is required, it can be initiated. Technology tradeoffs can be identified and made. The organization doing this work is usually a small focused core team.

The data being evaluated should be sufficiently complete in the cost and schedule area to allow management to make critical decision 1. The baselined architecture at this point should be treated as a recommended approach for the conceptual phase.

In the conceptual phase the architecture should be allocated to lower levels in concert with the other steps of the allocation process (see subsection 3.2.2). Some observations:

- The preconceptual activities architecture baseline is the start point for the conceptual design.
- The final conceptual design must be complete enough to establish the Total Project Cost (TPC), the Total Estimated Cost (TEC) and life cycle cost.
- The final conceptual design is generally not sufficiently complete for a construction start. The execution phase completes the design at which point it becomes the configuration.
- The conceptual phase organization generally will differ significantly from the preconceptual activities team. This requires that information files be carried forward. The same is true moving into the execution phase.

In the execution phase the architecture should be allocated to even lower levels in concert with the other steps of the allocation process (see subsection 3.2.2) until the final design is achieved.

5.3 Alternative Evaluations/Tradeoff Studies and Alternative Selection

A common term for the method of evaluating alternative architectures and selecting a preferred architecture is "alternatives evaluation". This *PEAEMP* Guide, however, defers to the terms "tradeoff study or just trade study", but recognizes and occasionally uses alternatives evaluation synonymously. The two basically follow a similar process, and are treated as the same within this Guide. A common distinction between the two is that alternative evaluations apply to the higher level (preconceptual activities and early conceptual phase) evaluation and selection process, while tradeoff studies are more appropriate at lower levels (later conceptual phase and design portion of the execution phase) where technical requirements drive the selection process. The *Engineering Tradeoff Studies* Guide, GPG-FM-003, describes a method for evaluating a set of technical alternatives and selecting the preferred alternative. Value engineering is another way to determine if the correct requirements have been specified and the resulting design is the most cost-effective and efficient to accomplish the requirements. Value engineering is discussed in detail in the *Value Engineering* Guide, GPG-FM-011.

In terms of functions, requirements, and architectures, alternative evaluations are performed to identify and evaluate potential architectures to obtain the one that best accomplishes the identified function or set of functions and satisfies the requirements. The *Systems Analysis and Assessment* Guide describes methods and factors to consider in analyzing and assessing: production, end product and operational performance; disposal methodologies; and life-cycle costs. Also, the *Productivity Tools: Automated Models and Simulations* Guide describes methods and factors to determine if the application of automated tools is appropriate, and the types of tools to be applied. Prior to evaluating the alternatives, decision criteria is established to serve as a basis for the evaluation. Decision criteria is discussed in greater detail in section 5.12. Prior to selecting the preferred alternative, the risk associated with each alternative is evaluated to establish the potential and consequences of an alternative not meeting all the requirements.

In the process of evaluating alternatives, risk analysis should be used to evaluate the probability and consequences of not satisfying the requirements and constraints associated with the selected alternative. Each alternative should be weighted in terms of the probability and consequences of failure to meet requirements and constraints. Risk is discussed further in section 7.3.

Tradeoff Studies

Alternative evaluations or trade studies should be performed during all phases of the project and program life cycles any time there are two or more options in a selection. During the preconceptual activities, trade-off studies are used to select the architecture(s) that are capable of meeting the project's end product. The evaluations conducted during this phase are typically based on summary level detail used to evaluate solutions with the best performance as measured against decision criteria such as safety, protection of human health and the environment, cost, schedule, reliability, maintainability, and supportability. Techniques such as parametric analysis, modeling, or comparisons to similar ongoing or completed DOE projects should be used in performing alternative evaluations. The *Productivity Tools: Automated Models and Simulations* Guide, GPG-FM-028, provides additional information on modeling and simulations. Setup and performance of the alternative evaluations within this phase are critical to the success of the project, since the information generated within these alternative evaluations establish the foundation upon which all subsequent tradeoff studies, and consequently decisions, are built.

Tradeoff studies are performed during the conceptual phase to further evaluate and define the selections made during preconceptual activities. The tradeoff studies are now conducted in greater technical detail. The architecture details are evaluated again using techniques such as parametric analysis, modeling, or comparisons to similar ongoing or completed DOE projects. Alternative evaluations and technical analyses are also used to evaluate any enabling assumptions passed through from the preconceptual activities.

Based on the results of the enabling assumption evaluations, changes to the architecture may be made.

During the design portion of the execution phase, further details of the architecture are developed. The results of testing programs and prototype development efforts may be incorporated with the alternative evaluation results to refine the configuration definition.

In the construction portion of the execution phase, tradeoff studies are performed to evaluate proposed changes on the end product and to support make/buy decisions. Tradeoff studies are also used to evaluate approaches to operating the end product, in preparation for the operations phase.

In the operations phase, tradeoff studies focus on refining the approach to operating the end product. Also, tradeoff studies evaluate approaches in preparation for the closeout phase.

During the closeout phase, the focus of tradeoff studies is on refining the approach to closeout generated during the operations phase.

Alternative Selection

It is difficult to describe a generic method to develop decision criteria that quantitatively combine requirements, stakeholder values, and risk because the method depends on the specific systems approach that is employed. (See the *Engineering Tradeoff Studies* Guide.) However, after the decision criteria (section 5.12) have been developed, alternative evaluations and selection could consist of the following steps:

- Select those alternatives that satisfy the requirements and constraints.
- Evaluate each alternative's performance for each of the decision criteria.
- Perform risk analysis to evaluate the probability of failure and the consequences associated with the each alternative.
- Perform sensitivity analysis to establish validity of the decision process such that minor changes won't alter the ultimate preferred architecture.
- Rank the alternatives based upon decision criteria.
- Select the preferred alternative.

Tradeoff Reports

For each alternative evaluation, a report should be generated and contain a description of the alternative evaluation performed, including:

- Identification of the scope, its applicability to the project, and its association with other evaluations or ongoing work being performed;
- The criteria and method used in performing the evaluation;
- A description of the alternatives considered;
- A detailed discussion of the outcome of the evaluation;
- Results of applying the decision criteria to the various alternatives;
- An overall evaluation of the results; and
- Recommendations.

Verification

When evaluating alternatives, verification is used to measure compliance of selected alternatives with requirements and decision criteria. The process is summarized as follows:

- Demonstrate the selected alternative performed all functions and satisfies all requirements and has been evaluated consistently by use of decision criteria.
- Ensure any enabling assumptions are valid or have defined actions to validate them. If new information invalidates any enabling assumptions, redefine the assumption or replace the assumption with valid data and repeat the evaluation with the new assumption or data.
- Submit recommendation to decision maker for approval of the selection.

Interfaces

Alternative evaluations performed as part of project evaluation and selection need to be integrated with activities that support NEPA documentation. Specifically, Environmental

Assessment (EA) and Environmental Impact Statements (EIS) are generated to comply with the NEPA requirements under 10 CFR 1021 for the evaluation of major Federal action(s). To efficiently and effectively accomplish this, evaluations prepared in support of the EIS/EA must be integrated. This is accomplished by ensuring the tradeoff studies provide the same information to the staffs responsible for the end product and the NEPA program. Using the same trade study would be cost effective. The *Environmental Interfaces* Guide, GPG-FM-021, describes environmental considerations and processes to integrate with project planning and execution.

5.4 Design Documentation

Design documentation includes the design specifications, design drawings and calculations, and the drawings and specifications used to build or construct. During the conceptual phase, emphasis is on early design activities such as process flow diagrams, site layout and utility needs. As the design evolves during the execution phase, the documentation includes detailed design drawings, construction drawings and construction specifications as well as finalized design calculations. During construction, the design and construction documents are modified, as necessary, to reflect the actual construction. At the completion of construction, the design documentation is reviewed to verify it is consistent with the as-built configuration and transferred to the operations organization.

5.5 Safety Assessments

An assessment of hazards associated with project facilities or end product should be performed. Its purpose is to minimize the likelihood of the occurrence and the consequences of a hazard by identifying, evaluating, and controlling the events that could lead to adverse consequences. The relationship of safety assessment development to the life cycle is shown in Figure 5.5-1.

The hazards associated with facilities, operations, or the end product should be assessed concurrently with the inception of projects to initiate new, or to modify existing, facilities, operations, or products. In this context, hazards implies threats to safety, and safety implies freedom from harm to persons, equipment, facilities, and insults to the environment.

For certain nuclear facilities, DOE guidance requires the preparation of a Preliminary Safety Evaluation early in the consideration of any project affecting that facility. With whatever preliminary information exists, the Preliminary Safety Evaluation identifies hazards, proposes scenarios of accidents that would trigger the hazards, and analyzes the accidents for the severity of potential consequences and the probability of their occurrence. Similar safety assessment products can be prepared for the hazards associated with projects for non-nuclear facilities.

Safety assessments are used by both management and engineering to assist in the evaluation of alternatives. The Preliminary Safety Evaluation is also used as the safety basis for preparing an Environmental Assessment (EA). The EA helps to determine the extent of environmental impact and discriminates between a "Finding of No Significant Impact" and the need for an Environmental Impact Statement. Preliminary Safety Evaluations are refined as more definitive information becomes available. An important iterative relationship is maintained during project design as: (1) the safety assessment dictates criteria for safety and (2) the designers exercise their ingenuity to meet the criteria.

Safety assessments are generated by engineers, or similarly qualified staff, with a knowledge of the project functions and requirements, and experience in hazards analysis. Lacking appropriate staff, commercial nuclear licensing contractors are ideally qualified for this task.

The safety assessment or the Preliminary Safety Evaluation, is used as the basis for Safety Analysis Reports for nuclear facilities. The Preliminary Safety Analysis Report is required prior to the Approval to Start Construction Critical Decision and the Final Safety Analysis Report is required prior to the Start of Operations Critical Decision. Draft DOE O 420, FACILITY SAFETY, and the *Safety Analysis* Guide, GPG-FM-023, describe methods, factors, and requirements to consider in determination and minimization of safety hazards in facility design and execution.

5.6 Interface Control Documents (ICDs)

Inter-group coordination is discussed in section 5.11 and methods and factors to consider for continuity and compatibility of design components are discussed in the *Interface Management* Guide. This section discusses a subset of interface management: Interface Control Documents (ICDs). ICDs are used to identify the functional and physical requirements and constraints at a common boundary between two (or more) functions or components. Interfaces result from interaction between functions, components, or products. Functional interfaces are the relationships between actions. Physical interfaces are the relationships between components. The development of ICDs is a continuous process throughout the life cycle and is initiated in the early phases of a project.

An ICD is the design and management tool formalizing an agreement between two or more entities having resources that functionally and physically connect. An ICD may be

Figure 5.5-1. Safety Assessment Related to the Life Cycle.

Definitions of Terms for Figure 5.5-1

CD	Critical Decision
NEPA	National Environmental Policy Act
TSR	Technical Safety Requirements
SR	Safety Requirements
PSAR	Preliminary Safety Analysis Reports
FSAR	Final Safety Analysis Report
EA	Environmental Assessment
DEIS	Draft Environmental Impact Statement
FEIS	Final Environmental Impact Statement
ROD	Record of Decision
MAP	Mitigation Action Plan

either a drawing or document of a standardized form and content. For complex projects, interfaces are often defined through the use of Interface Control Working Groups (ICWGs). Within these groups, representatives from both sides develop documentation that establishes the requirements to which the interface will be designed and developed. This should be of a form and format dependent on the complexity of the interface and the guidelines established by the project interface management plan. The interface management plan should include, but not be limited to, the following information:

- The definition of different types, or classes, of interfaces and how each will be handled;
- The process that will be followed in defining interfaces;
- The documentation that will be generated in defining interfaces and its correlation to the different classes of interfaces;

- If applicable, the function and responsibilities of the Interface Control Working Group, its charter and method of operating within the various levels of the project's organization;
- The relationship between the interface definition effort and the configuration management effort;
- The process to be followed in changing established interface definitions.
- A schedule defining the interface definition effort.
- Identification of what other documentation, will be necessary to manage and establish the interface definition effort.

To track interface definitions, a data base should be established that contains, at a minimum, the following information:

- ICD number,
- Identification of the interfacing actions or components,
- The individual responsible for generating the ICD,
- The individuals responsible for concurring with the interface definition,
- The type, or class of the interfaces,
- The revision level of the ICD, and
- The status of the ICD's development.

ICDs and the tracking data base should be placed under configuration control. The ICWG should not have the authority to approve changes to ICDs. Change approval authority should be integral with the process established in the project's configuration management plan.

5.7 Test and Evaluation

The objective of test and evaluation (T&E) is to provide a demonstrable measure that the end product complies with the specified project requirements. The T&E effort includes the complete set of activities necessary to demonstrate compliance. This set is generally a combination of analysis, review, inspection, and testing activities. The T&E effort is initiated on a project by reviewing the project requirements and ensuring measures exist for each requirement to be used in demonstrating compliance with the requirement. Where acceptable measures can not be established for a requirement, the requirement must be questioned and if acceptable measures can not be established, the requirement must be eliminated. Generally, the final activity in the T&E effort is to evaluate the results from all T&E activities, as a set, against the project requirements to ensure the results demonstrate compliance. This evaluation activity should be documented as appropriate.

The extent of the T&E effort will depend on the complexity of the end product. All projects should, however, have some appropriate level of T&E activities. The level of activities should be established as a part of planning with the results of the planning documented in a T&E plan. On a complex project, the T&E plan could be a significant document or a series of planning documents. However, on projects with less complex end product, the T&E planning may be documented in a short section in the project execution plan.

T&E activities should be initiated during the preconceptual activities and continued throughout the project life cycle. As a part of the preconceptual activities, the developed architecture for the end product should be verified against the project requirements. As development of the project architecture continues during conceptual, preliminary, and detailed design, the project team must systematically verify the developing architecture against the requirements through the use of reviews, analysis and where appropriate, selective development testing. At the initiation of construction, the T&E activities evolves to inspection and construction verification testing activities. The T&E activities generally peak during the execution turnover subphase as the functional and operational turnover testing is initiated. During the project life cycle, any changes in the project requirements, end product, or the evolving project architecture must be incorporated into the T&E planning. Additional T&E activities resulting from the changes should be planned, completed, and the results integrated into the previous T&E results.

T&E activities are generally completed by engineering with the appropriate level of support from management. During construction, this would include construction engineering and quality control staff performing the construction verification testing and inspection activities respectively. If the end product includes facilities involving significant operations, the facilities future operations staff should be involved in the functional and operational turnover testing activities. For projects being completed by a DOE contractor(s), the DOE project manager's involvement in T&E may be limited to ensuring the T&E effort is specified in the contract SOW and performing oversight activities.

Products resulting from the T&E effort are generally documents which may include test and evaluation plans, analysis, review reports, testing procedures, inspection reports, test reports, and assessment reports. On projects with a complex end product, a key product would be the final T&E assessment report. Additional information on the T&E area is included in the DOE guidance document, *Test and Evaluation* Guide.

5.8 Operations and Maintenance Requirements Documentation

As part of transition to operations, the project must provide requirements on operation and maintenance of the facility. This documentation could include operating limits, operating procedures, vendor equipment documentation, and maintenance requirements, both preventative and corrective.

5.9 Turnover Documentation

Turnover documentation is the sum total of documentation that is transferred from the project to the operations organization at the end on the execution phase. It is comprised of Design Documentation (section 6.4), Tests and Evaluation (section 6.7) and Operations and Maintenance Requirements Documentation (section 6.8).

5.10 Specifications

The allocation of the functions and requirements (section 6.3) proceeds to a point where good management dictates that an identified part of the work be handed off to a new organization to proceed with the next level of allocation. The new organization may be another part of DOE; i.e., a Program Office or Site, or a contractor. The documentation required at the hand off should include a specification. The specification serves as a control method for establishing the technical scope baseline and a quantitative record of the input to the next level of work to be performed. Specifications are not all the same but they share common attributes of:

- Identification of the Mission Need element being satisfied.
- Functions that must be accomplished,
- Quantitative requirements that must be met,
- A recommended architecture for the next level of allocation, and
- Any other technical constraints that may affect the completion of the work segment.

The mission needs are divided by an engineering process into manageable functional units. Each unit should be defined by technical requirements and design criteria and documented in a specification. The range of differences is between the top-level specification for a Site cleanup task, which may focus more on the level of cleanup, and a functional path to follow, to a component-level specification for a pump selected from the vender product description sheet. Selecting the level of specification best suited for the application is a difficult task for a project team. This section of the Guide describes several levels of specifications, but the project team will have to grade the best selection for their project.

5.10.1 Specification Levels

Project/System, Level - 1 (Type A): The level 1 specification sets the top level requirements for the Program or Project. Depending on the program/project allocation, more than one Level 1 specification may be needed. Also, an intermediate Level 1 specification may be needed when the allocation requires complex subsystems.

Subsystems, End Product, Procurements, and Components, Level - 2 (Type B): Level 2 specifications are the documents used to specify a component to be designed and built or to accompany a procurement package detailing the requirements to which the subject component is to be developed or produced. The details of the level 2 specification flow from the requirements found in the Level 1 specifications(s). The number of Level 2 specifications depends on the number of subsystems, or components required to make up an end product and the way in which pieces are grouped for procurement. These Level 2 components may be further divided at this level as specific requirements dictate. Subsystems and components can include software.

As-built Subsystems, End Product, and Components, Level - 2 (Type C): As the construction for a project is completed, there is a need for specifications that reflect the as-built configuration of the end product. These specification generally result from the configuration management effort to keep the Level 2 specifications up to date with as-built configuration.

Note: The SSC Project had a good set of specifications in work. Examples are available from SSC Laboratory records transferred to the Federal Record Center in Fort Worth, Texas.

5.10.2 Specification Processing

During development, specifications should undergo periodic progress reviews by cognizant managers. Final drafts should be subjected to reviews presented to all appropriate organizations. Comments and corrections should be incorporated prior to forwarding for approval and release. Formal review and approval of each document should be recorded. Final versions of specifications should be provided to the Document Control Center for reproduction and distribution. Later inputs, such as from calibration requirements summaries, trade studies, and cost analyses, may call for re-examination of requirements. Changes, approved by the configuration control board/panel, will be implemented by a specification change notice distributed by the Document Control Center to all persons holding a copy of the specification.

5.10.3 Format and Style

The basic format for preparation of the Level - 1, 2, and 3 specifications may be selected to best meet the user's needs. Design parameters for the DOE Mission will be developed in these Level - 1, specifications and will flow down to the Level - 2 specifications. Level - 1 and 2 specifications will generally be released to industry for procurement. It is recommended that MIL-STD-490A format be used as a guide. Exceptions to the use of that format may occur for vendors not familiar with MIL-STD-490A requirements or when a specific item specification has been prepared and successfully used in the past. Such exceptions should be graded to a format to meet the required use, ensuring the requirements are complete and understandable, and the objectives are met.

5.10.4 Subcontractor Generated Specifications

DOE generated draft specification may be provided to a contractor to establish a baseline from contractor go-ahead until a contractor-generated specification is approved during the development phase. Contractor specifications are approved in accordance with contract requirements.

5.10.5 Types of Level 2 Specifications

Five types of Level - 2 specifications are suggested:

1. **Development and Performance Specification**. Each hardware and software development specification establishes the performance, design, development, and test requirements for project items under configuration management.

2. **Product Specification**. Development and preparation of a product specification begins as the design stabilizes at each level of iteration. After approval of the corresponding development activities, a product specification containing fabrication requirements, is generated.

The product specification contains a) a detailed description of the parts, parts selection criteria, and subassemblies of the product, usually by prescribing compliance with a set of drawings; and b) those performance requirements and corresponding acceptance tests and inspections necessary to assure proper fabrication, adjustment, and assembly techniques.

3. **Process Specifications**. These are provided to define manufacturing processes which must be invoked. They identify manufacturing requirements, equipment, materials, procedures and operations, and any certifications required.

4. **Material Specifications**. These are provided as needed to identify the specific materials by requirement, character, quality, or formulation.

5. **Design Requirements Document**. The technical description for each of the constructed facilities should be documented in the Design Requirements Document.

6. SPECIALTY ENGINEERING INTEGRATION PRODUCTS

This section describes how the following Engineering Specialties should be integrated into project management to ensure their inclusion in both the requirements definition and conformance verification functions.

- Integrated Logistics Support
- Life-Cycle Cost
- Environment, Safety & Health
- Human Factors Engineering
- Safeguards and Security
- Risk Management
- NEPA Documentation
- Value Engineering
- Reliability, Availability, and Maintainability
- Constructability, Operability and Survivability Reviews
- Quality Assurance
- Regulatory Compliance
- Environmental, Socioeconomic, and Institutional

Specialty Engineering disciplines are most effective when used early in the design effort. Aggressive planning to use these disciplines is needed to achieve the greatest impact. Specialty engineers should participate in all design, review, and evaluation activities as an integral part of the project execution phase. The Project Execution Plan should describe the activity to manage and integrate these specialty engineering disciplines into the project development program. This plan should describe the objectives and identify the responsibilities of specialty engineering at the project level and provide specialty engineering guidance to the projects.

6.1 Integrated Logistics Support

The main objectives of the Integrated Logistics Support (ILS) are to ensure that required support and readiness characteristics are designed into the project and that resources necessary for project readiness are identified and available when required. To achieve these objectives, reliability, maintainability, supportability and readiness requirements must be defined early in the engineering process, included in system and subsystem specifications, and considered in the formal review process prior to critical decisions. Attainable supportability characteristics are developed throughout the design process using design tradeoff efforts involving all applicable logistic disciplines. The logistic disciplines include: maintenance planning, personnel, training, supply support, technical documentation, support equipment, computer resources, facilities, packaging, handling, storage, and transportation. ILS should be one of the specialty engineering activities specifically addressed in the Project Execution Plan.

ILS is the name given to several of the specialty disciplines indicated above. In grading the approach to ILS, one can write to ILS and skip the specific disciplines, or bypass ILS and focus on the discipline most applicable to the unique project need.

6.2 System Life-Cycle Cost

Life-cycle cost is the name given to a summation of all cost associated with a project that has gone through all of the phases of the life cycle model shown in Figure 3.1-1. The project life cycle cost is usually about 10 to 20 percent of the total life-cycle cost, the closeout cost is usually about 5 to 10 percent of the total life-cycle cost, and the rest is operations and maintenance. Almost all of the operations and maintenance cost is establish by the design decision made during the preconceptual activities, conceptual phase, and the design part of the execution phase. Project cost is reported as Total Estimated Cost (TEC) and includes Total Project Cost (TPC) but does not track life-cycle cost. Having life-cycle cost as a parameter in the trade off decision criteria will affect the design.

Design considerations should include cost parameters that achieve a desirable balance among performance, reliability, supportability, schedule, and cost attributes and comply with safety and technical requirements. Life-cycle cost estimates should be made using engineering cost analyses and coordinated with formal total system life cycle cost estimates used to support outlays. The approach to establishing the life-cycle cost should be discussed in the Project Execution Plan. The *Systems Analysis and Assessment* Guide, GPG-FM-029, provides additional information on life-cycle cost analysis and assessment, including determination of facility costs from preliminary design through closure and disposal.

6.3 Environment, Safety & Health (ES&H)

A comprehensive ES&H program should be established. The ES&H program should interface with the regulatory compliance program for engineering support for the preparation of the Safety Analysis Reports. The program for a given project should be described in the Project Execution Plan. The description should explain how to incorporate ES&H requirements in the engineering process and how to include them in the verification activities. It should include the following:

- Plan and document an ES&H effort for each project;
- Perform hazard analysis during all life-cycle design phases;
- Conduct ES&H reviews as an integral part of all design and technical reviews.

Key references:

- **Draft DOE O 420, FACILITY SAFETY**, describes methods, factors, and requirements to consider when determining and minimizing the safety hazards in facility design and execution.

- ***Environmental Interfaces* Guide** describes factors, considerations and processes to integrate with project planning and execution.

- ***Safety Analysis* Guide** describes methods and factors to consider when determining and minimizing the safety hazards in facility design and project execution.

- ***Waste Minimization/Pollution Prevention* Guide** describes methods and factors to consider when identifying and mitigating excessive waste creation and pollution production.

6.4 Human Factors Engineering

Human Factors Engineering is used to reduce the potential for human error in system operation and ensure system safety, operational efficiency, ease of maintainability, and reliability. The Human Factors Engineering effort involves:

- Examining regulations and codes to identify those with Human Factors Engineering implications;
- Deriving requirements and specifications that consider human physical and cognitive capabilities and limitations, as applied to system design;
- Allocating the functional requirements to a person and/or machine;
- Ensuring that Human Factors Engineering considerations are adequately reflected in project training programs; and
- Participating as an integral part of all audits and design and technical reviews.

Human Factors Engineering should address subsystem design and the relationships of system elements to each other and how they can be optimized. Human Factors Engineering should also be addressed in the design process by incorporating operational considerations into the design to achieve the objectives of system safety, operational efficiency, reliability, availability, and maintainability. Tradeoff studies should be made to accomplish this optimization. The Human Factors Engineering approach for each project application should be described in the Project Execution Plan. Responsibility for Human Factors Engineering implementation rests with the engineering activity at each project; coordination and guidance are provided by project management. The *Human Factors Engineering* Guide, GPG-FM-027, further describes the methods and factors to be considered.

6.5 Safeguards and Security

The Project Execution Plan should describe the safeguards and security program to be defined, documented, and implemented at the project level. Issues affecting the development of the technical baseline should be identified and documented to ensure that appropriate engineering actions may be accomplished during system development. This should include identifying the need for requirements and specifications and suggested methods for verifying conformance with those requirements.

6.6 Risk Management

Risk Management (RM) is the method used to identify, analyze, and mitigate hazards and potential deviations from technical, cost, and schedule parameters. RM is integrated with established engineering management techniques such as contingency planning, test and evaluation, technical performance measurement, and performance assessment. RM includes several related actions:

- **Risk Planning** is the process of organizing an approach to identifying and then eliminating, minimizing, or containing the effects of undesirable occurrences.

- **Risk Assessment** is the process of identifying areas of potential risk and prioritizing these risks.

- **Risk Analysis** requires conducting an analysis to determine the probability of events and the consequences associated with the potential actions. The purpose of risk analysis is to discover and quantify the cause, effects, and magnitude of the risk perceived, and to develop and examine alternative options. Risk analysis is frequently used to examine alternative architectures/options.

- **Risk Abatement** includes techniques and methods developed to reduce or control the risk.

- **Risk Monitoring** is continual review of changes to system functions, requirements, and architecture to ensure that these risks remain visible and/or understood and managed to the extent that the event or consequence may be abated in a timely manner.

Risk assessments provide management with information to aid in the decision-making process. The initial risk assessment should be performed during the preconceptual activity and should be updated as the project progresses through each phase of the life cycle and at major project milestones. Risk Management should begin during the conceptual phase and continue through execution, operation, and closeout.

A Risk Management Plan to define the process for planning and managing technical, cost, and schedule risks should consider the following types of risk: risks common to more than one project, risks concerned with the interfaces between projects, risks associated with new and unproven technologies, and risks with potential consequences that exceed predetermined thresholds. The Project Execution Plan should be clear on the scope and to bound the Risk Management Plan.

Risk assessments are generally performed on approach options, that are proposed to meet the imposed requirements for the project's end product. They are also performed to evaluate programmatic risks, which include the process being used to define the end product. These evaluations support the decision making process by providing decision makers with the probability that the selected approach would satisfy requirements or attain a logical solution. Risk assessments generally consider two basic factors:

- Probability of failure - which considers an option's technical risks associated with its potential for failure to achieve technical performance specifications.

- Consequence of failure - which considers the impacts of an option's failing to achieve its technical, cost, or schedule requirements.

Risk can be assigned categories; this is very subjective, and the use of no more than three categories is suggested. The definition of the categories may be more important than which risk falls in which category. Three basic categories result from the risk assessment:

- High - Likely to cause significant disruption of schedule, increase in cost, or degradation of performance.

- Medium - Has the potential to cause some disruption to schedule, increase in cost, or degradation of performance.

- Low - Has little potential to cause disruption to schedule, increase in cost, or degradation of performance.

Because risk evaluations are important to the decision making process, it is necessary to continually evaluate risks throughout a project's duration, and to establish a program to manage the risks inherent in the selected approaches. The goal of the risk management program should be to have all items in the low risk category. The objectives of the risk management effort are to:

- Identify potential sources of technical and programmatic risk and identify the risk drivers.

- Assess (quantitatively, if possible) risks and their impacts on cost, schedule and project product or process technical performance.

- Determine sensitivity of interrelated risks.

- Determine alternative approaches to handle moderate and high risks.

- Take actions to avoid or control each risk.

- Ensure risk is factored into decision analysis and is identified to the decision makers.

- Identify sources of risk associated with enabling assumptions.

Risk management effort should generate the following documents:

- Risk management plan - Describes how risks should be identified, assessed, reduced, and managed. If the cognizant DOE organization does not request that a risk management plan be generated, the risk management approach should be defined within the performing contractor's planning documentation.

- Risk sensitivity analysis - identifies how sensitive a project is to variations in risk in terms of cost and schedule.

- Risk handling plan - Generated for each high level risk item and submitted to the cognizant DOE organization for approval. This plan should include:

  - a statement and assessment of the risk,

  - consequence of failure,

  - alternatives considered,

  - recommended risk reduction methods,

  - impact of implementing the risk reduction approach (cost, schedule, technical),

  - responsible organizations/individuals for risk handling,

  - risk reduction implementation start date and key milestone schedule,

  - criteria for reducing an item's risk level,

  - decision points, and

  - fall-back positions, with associated costs.

- Risk reduction report - submitted to the cognizant DOE organization, describing the status of each medium and high risk item, as specified by DOE.

- All risk documents should be placed under configuration control.

This subject is discussed further in the *Project Risk Management* Guide.

6.7 NEPA Documentation

Recognizes the effect of the NEPA required assessments on the facility/system design and coordinates the effects of the final record of decision (ROD).

6.8 Value Engineering

Value engineering is a facilitating process to determine if the correct requirements have been specified and the resulting design is the most effective and efficient to accomplish the requirements. It should be noted that value engineering can be applied any time throughout the life cycle including operations. Value engineering is discussed in detail in the *Value Engineering* Guide. Value engineering is an organized effort to analyze the functions of systems, equipment, facilities, services, and supplies for the purpose of achieving the essential functions at the lowest life cycle cost while maintaining required performance, reliability, availability, quality, and safety. value engineering answers five questions about the project's end product:

- What is it?

- What does it do?

- What else will do the job?

- How much will it cost?

- Can we do it less expensively?

The goal of value engineering is to improve product/service value in one of four ways:

- Increase performance and decrease cost;

- Maintain performance and decrease cost;

- Increase performance and maintain cost; or

- Increase performance in greater proportion than cost increases.

Value engineering helps develop a technical scope that meets project requirements and addresses stakeholder needs, while providing the best value for DOE.

The Project Manager should arrange to have either a team of value engineers brought in on a contract basis for a short period of time to facilitate the study or use in-house personnel when the needed expertise is available. The duration of the study may vary from 1 to 5 days in most cases but is dependent upon the complexity and magnitude of the project.

VE can be applied at any point in the life cycle of a project. In the preconceptual activities, a VE-like process using rough-order-of-magnitude cost estimates can be used to compare alternatives to the proposed project. value engineering has high value during the conceptual phase to reduce project life cycle costs. During the execution phase, value engineering provides reduced cost at detailed design and construction.

Application of value engineering is most beneficial during the preconceptual activities and conceptual phase. Waiting to apply value engineering during the execution phase may require changes in systems already completed, hence incurring costs for changing those systems as well as the system on which the value engineering was originally conducted.

6.8.1 Federal Requirements for Value Engineering

OMB Circular A-131 requires Federal Departments and Agencies to use value engineering as a management tool, where appropriate, to reduce program and acquisition costs. It requires that value engineering be applied to projects greater than $1 million. DOE guidelines for implementing the circular are specified in DOE O 4010.1, VALUE ENGINEERING. The circular requires Federal Departments and Agencies to:

- Designate a senior management official to monitor and coordinate value engineering efforts, and grant waivers as appropriate.

- Develop criteria and guidelines for both in-house and contractor personnel to identify programs/projects with the most potential to yield savings from the application of value engineering techniques. Criteria and guidelines must include:

    - Measuring the net life-cycle cost savings from value engineering,

- Dollar thresholds for applying value engineering (thresholds must be no higher than $1 million),
- Criteria for granting waivers to conduct value engineering studies (in FAR 48.201(a)), and
- Requirements that construction programs/projects consider environmentally-sound and energy efficient alternatives and results.

- Provide training in value engineering techniques to appropriate staff who monitor, coordinate, conduct, or review value engineering studies.
- Ensure that necessary funds are available to conduct VE.
- Maintain documentation of projects, including results of value engineering studies, why value engineering proposals recommendations were not followed, whether waivers were granted and why.
- Adhere to requirements of FAR, including value engineering clauses in Parts 48 and 51.
- Develop annual plans for using value engineering in the Department or Agency.
- Report annually to OMB on value engineering activities.

6.8.2 Other Terminology for Value Engineering

- Value engineering applied to the study of something that has already been designed or produced is sometimes referred to as Value Analysis.
- Value engineering applied to studies related to the construction process only is sometimes referred to as Constructability Analysis.
- Value engineering is also referred to as value management as a comprehensive term for all applications of value engineering principles.

6.9 Reliability, Availability and Maintainability Reviews

Reliability, availability, and maintainability (RAM) is critical to the development of design criteria and the design decision making process. The program should address the development, allocation, review, revision, and monitoring of RAM goals/parameters to ensure the attainment of project availability requirements. The goals/parameters should be identified in a comprehensive plan that provides policy, objectives, methodologies, requirements, and minimum levels of tasks to be performed during various acquisition stages. The plan should also address the required verification and validation standards that must be complied with to ensure availability. The project should include RAM as one of the engineering specialty activities to be integrated into the project. The *Reliability and Maintainability Planning and Control* Guide, GPG-FM-004, further describes methodologies, tools and techniques to effectively design, build and operate facilities and engineered systems.

6.10 Constructability, Operability, and Survivability Reviews

This section should address the effects of constructability, operability, and survivability on the design of the facilities/system.

6.11 Quality Assurance

Quality assurance (QA) requirements for the project should comply with the Program Quality Assurance Requirements Document (QARD), Quality Assurance Program Description (QAPD) document and applicable program, field element, and contractor QAPDs. The QAPDs incorporate and supplement the applicable quality assurance program requirements from DOE Orders and CFRs.

The QA program provides for both the achievement of quality and the verification of that achievement. The line organization is responsible for achieving quality. The QA organization achieves quality assurance through overview activities such as audits, surveillance, and reviews.

Audits include objective evaluations of work areas, quality affecting activities, processes, procedures, and instructions to determine the effectiveness of the QA program and the technical adequacy of work being performed. Surveillance includes observation of activities or review of documentation to evaluate compliance with approved procedures. Milestone reviews are conducted in accordance with the respective procedures to ensure that performance complies with requirements.

QA procedures are prepared and implemented for activities performed by Headquarters and the field office that affect quality. Typically, field office and the project office work to the same procedures. The project should develop and implement QA procedures that are specific to their scope of work. These procedures should be consistent with the QAPD.

When working to the QA program, applicable field office and project procedures should apply; when working to the contractor's QA program, applicable contractor procedures should apply. The contractor's QAPD must meet the requirements of upper-tier QAPDs for the scope of work assigned. The QAPD details the contractor's quality affecting responsibilities, interfaces, and management controls to meet upper-tier requirements. Implementation procedures include the technical, management, and operating instructions to ensure implementation of functional requirements.

Both the DOE and the contractor adopt a QA approach in which the extent of QA and procedural control is graded to items and activities, according to the relative importance of the item or activity to safety or project objectives. The extent to which QA and procedural control should be applied depends on fundamental considerations such as the consequence of item failure, importance of data, complexity of design and fabrication, the degree to which functional control can be demonstrated by inspection or test, quality history, and economic considerations. The graded approach should be defined in the QAPD. All procedures and equipment important to safety should be subject to QA. The *Quality Assurance/Quality Control* Guide,GPG-FM-017, further describes methods for applying QA principles to ensure successful results.

6.12 Regulatory Specialty Integration

Numerous laws and regulations governing public safety and the environment must be integrated into the engineering process so that they can be evaluated, defined, imposed, tracked, and verified as being addressed in the design requirements. Laws and regulations, though considered binding constraints in the systems approach, are subject to change and the impact of such change must then be traced through the project requirements.

The engineering organization must ensure that regulatory requirements, institutional constraints, and issues related to public acceptability are translated into architecture and engineering terms and hard requirements with verifiable performance measures. To help accomplish these objectives, these regulatory specialty activities should be integrated into the engineering process. The *Public Participation* Guide, GPG-FM-022, describes methods to effectively include the public in project planning and execution.

6.12.1 Regulatory Compliance

Regulatory compliance activities should facilitate coordination with regulatory agencies to ensure that any license application fully addresses the required data sufficient to provide the license. Compliance must be made with mandates of the Federal environmental laws and regulations, with regulatory requirements of the EPA, with Federal health and safety regulations, with applicable DOE Orders, and with applicable State and local regulations and agreements. This should include a sequencing of major design and project milestones, definition of required data sets, and identification of what needs to be done, when, and by whom. The engineering and design milestones should be managed in conjunction with the regulatory milestones. These efforts should be incorporated in the Project Execution Plan to describe how compliance should be achieved, to provide interpretation of the applicability of the regulatory requirement on the project, to identify what technologies or models should be used, how data and analyses should be verified, and to depict the flow of data and analyses into the regulatory documentation.

6.12.2 Environmental, Socioeconomic, and Institutional

Environmental and socioeconomic activities must facilitate the timely compliance with applicable Federal, State, and local environmental requirements, including those specified in environmental laws, regulations and standards, to ensure that design, construction, and operation occur on schedule. Environmental requirements are generally quantifiable and objective, and must be treated as project constraints. Socioeconomic and institutional considerations are to be applied in alternative design evaluations and selection decisions. Stakeholders (including, States, Indian Tribes, local governments, public interest groups, the general public and others, such as review boards) values should be elicited and used in systems trade studies. Single-point solutions (averaging) of stakeholder values are to be avoided, rather the effects and impacts of differing stakeholder values and weights are to be considered in the decision making. Stakeholder participation in the engineering process is to be encouraged to the greatest extent practical.

Project level socioeconomic activities should be planned and conducted in accordance with plans provided in site specific documents. Implementation of the considerations set forth in this document should ensure that issues are handled adequately, that data and resources are integrated, and that risks and liabilities are properly addressed.

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7. PROJECT REVIEWS

The review should be an important tool of management and the supporting staff to determine accomplishment on a project. There are many types of reviews; however, they all have the central theme of communicating information on current status, progress, completeness, correctness, or work completion. Reviews are held between customer and supplier, management, different organizations, and among peers.

The DOE *Project Reviews* Guide, GPG-FM-015, discusses the different types of reviews in detail. Additional discussion on reviews is found in the Test and Evaluation section of this Guide. Table 7-1 gives a list of recommended reviews, a description of each, and the time frame when the review should be performed. The list may be used during the planning activities to establish an appropriate set of reviews for the project.

Reviews are performed to determine if a product is correct, will perform the intended functions, and meets allocated requirements. These reviews are performed on the products discussed in this Guide that represents a part or all of the end product such as drawings, analysis, and specifications. These correctness reviews are generally peer reviews or internal reviews and are an integral part of the project test and evaluation effort and should be planned as such. This allows the project team to assess the set of verification activities from a completeness and redundancy standpoint. The test and evaluation section discusses planning, performance, and the products from the verification review activities.

Reviews are performed to determine the current condition of a project item or activity. The reviews could look at progress toward completion, compliance status, or readiness to proceed. Items being reviewed could be the project baseline, requirements, subsystem, or the project end product. Examples of activities could include planning, design, or construction. These reviews generally involve management, and/or the customer. Products from these reviews should include review plans, review reports, action item lists, and action item resolution reports.

Some reviews are generally performed by team members with participants in the reviews including technology experts, project manager, engineering management, senior management, the end product customer, and other appropriate project stakeholders. These reviews are generally completed using a committee/meeting format. The review should have a specific objective and the performers should plan the review to meet the objective. The review information is generally presented in a meeting setting with the review participants questioning the presenters as needed for a thorough understanding of

Table 7-1. Project Reviews

REVIEW	REVIEW DESCRIPITON
Preconceptual Design Review	Review the completeness of the established customer requirements and identified project configurations. The review should establish the bases for accepting the mission need analysis and approval of the project.
Requirement Allocation	These reviews involve the review of specifications that specify requirements for components, subsystem, systems (including facilities), or activities for clarify, completeness and correctness. The reviews are generally completed by an individual capable of having completed the requirements allocation. These reviews should follow the preparation of project specifications specifying project requirements. These reviews could be initiated during the preconceptual activities if project specifications are prepared as a part of the preconceptual effort. However, most of these reviews will be completed as a part of the conceptual and preliminary design activities.
System Requirements Review	This review (s) shall be conducted to: a. determine that customer requirements have been analyzed and translated into system specific functional and performance requirements. b. assess progress and directio of completed and on-going technology verifications and demonstrations. c. assess progress in risk identification, quantification, and risk management actions and approaches. d. identify and assess key technologies essential to system success. e. assess the degress of convergence on viable system requirements. Assessments include interfaces associated with the primary functions. f. review the draft system specification. These reviews should be an integral part of the functional decomposition and requirements allocation activities. The reviews should be closely coordinated with and provide input to the System Functional Reviews (see review description below). These activities are generally completed during the conceptual and preliminary design effort.
System Functional Review	This review shall be conducted to: a. ensure that the process used to arrive at functional and performance requirements for the system is complete in that: primary function products and processes are addressed; a balanced and integrated approach to the development of the functional and performance requirements is demonstrated; an audit trail is established from customer requirements reviewed at SSR; and any requirement changes made since SRR are substantiated.

Table 7-1. Project Reviews (continued)

REVIEW	REVIEW DESCRIPITON
System Functional Review (continued)	b. verify critical product and process technology performance, availability and design suitability. c. assess the system's configuration and draft allocated configuration documentation to determine the adequacy, completeness and achieviability of proposed system functional and performance requirements. d. assess the implementation requirements for the technology strategy. e. assess pre-planned product and process improvement and evolutionary acquisition strategies. f. assess the risk handling approach recommended for the next phase or engineering effort. These reviews should be an integral part of the functional decomposition and requirements allocation activities. The reviews should be closely coordinated with and use the out put from the System Requirements Reviews (see review description above). These reviews should be held near the end of the functional decomposition activities during the conceptual and/or preliminary design effort.
Conceptual Design Review	Should be performed near the end of the conceptual phase of the project: a. evaluate the optimization correlation, completeness, and risks associated with the allocated project requirements. b. ensure a technical understanding among all participants on the updated project configuration and completed system (or system segment) specifications, and other systems definition effort, products and plans. c. summarily assess the system engineering process which produced the allocated system requirements as well as the engineering planning for the next phases. The results of the review should establish the bases for accepting the conceptual design and approval of the baseline.
Alternative System Review	Alternative system reviews will be conducted to examine, and reach an understanding on, each system concept's ability to satisfy identified customer needs and objectives and to assess factors essential to continued development. Information to be reviewed shall include: a. systems engineering outputs and traceability to the initially identified customer needs and requirements. b. system effectiveness of the concept. c. life cycle resource requirements, risks, timing to need and other factors deemed appropriate by the Government. d. recommended cost, schedule and performance objectives. e. product and process technology verifications needed. f. tentative risk management approach. g. recommended technical exit criteria for the next phase or continued engineering effort. h. the current physical architecture, tentative specification tree, and project work breakdown structure.

Table 7-1. Project Reviews (continued)

REVIEW	REVIEW DESCRIPITON
Alternative System Review (continued)	These reviews should be completed as an integral part of the trade studies that are completed as a part of the functional decomposition. These reviews should provide input into and support the decision in selecting the project configuration. These reviews are generally conducted during the conceptual and/or preliminary effort but on some projects, the reviews may be conducted during the preconceptual activities.
Preliminary Design Review (PDR)	The review should be conducted near the end of the preliminary design to ascertain if the preliminary design is to be committed to detailed design. The review should: a. ensure that the process used to arrive at the functional and performance requirements is complete in that all products and processes have been addressed and that trade studies and allocations are complete and are incorporated into the design approach; that a balanced and integrated approach to the design of product and process was demonstrated and that an audit trail is established from the functional baseline and customer requirements. b. ensure that critical design approaches are confirmed and that the risk management actions and results of risk closure activities are evaluated. c. assess the design configuration and design approach (and available designs) to determine the adequacy, completeness and realism of achieving the functional and performance requirements in the development specifications and any proposed changes. d. assess functional hierarchical to ensure that "segments" satisfy the segmented portion of the functional decomposition. e. assess any pre-planned product and process improvement and evolutionary acquisition strategy requirements.
Drawing Preparation Checks	These reviews involve the review of drawings that present the design to determine if the design approach will perform the intended functions and complies with specified requirements. The reviews are generally completed by an individual capable of having completed the design and should be completed as an integral part of the preparation of a given drawing. These reviews are generally performed during the preliminary and detailed design activities. Drawing prepared as a part of the preconceptual and conceptual activities that reflect the design bases, should be reviewed as a part of the preliminary design activities.

Table 7-1. Project Reviews (continued)

REVIEW	REVIEW DESCRIPITON
Software Specification Review (SSR)	SSR shall be performed to evaluate the following: a. functional overview of the software system, including inputs, processing, and outputs of each function. b. overall software system performance requirements, including those for execution time, storage requirements, and similar constraints. c. control flow and data flow between each of the software functions that comprise the software system.
Software Specification Review (SSR) (continued)	d. all interface requirements between the software system and all other software systems. e. qualification requirements that identify applicable levels and methods of testing for the software requirements that comprise the software system. f. any special delivery requirements - for the software system. g. quality factor requirements; i.e., correctness, reliability, efficiency, integrity, usability, maintainability, testability, flexibility, portability, reusability, and interoperability. h. mission requirements of the system and its associated operational and support environments. i. functions and characteristics of the computer system within the overall system. j. milestone schedules. k. updates to all software deliverables since the SSR. l. any actions or procedures deviating from approved plans. It is recommended that the SRR be a combination of verification and status reviews where the software specifications receive a Requirements Allocation Review (see review description above). This review (or reviews) should be completed as an integral part of completing the software specification. The reviews should establish the bases for approving initiation of design of the software modules and detailed coding and are generally completed during the detailed design effort.
Detailed Design Reviews	These reviews are conducted in order to: a. determine that the detail design satisfies the performance and engineering specialty requirements of the development specifications. b. establish the detail design compatibility among the items of components, subsystems, sytems (including facilities), computer programs, and personnel. c. assess productivity and risk areas (on a technical, cost, and schedule basis). d. review the preliminary product specifications. If these reviews are completed as verification review, the reviews may be performed as a combination of Design Approach and Requirement Allocation reviews described above. These reviews should be performed periodically during the detailed design effort.

Table 7-1. Project Reviews (continued)

REVIEW	REVIEW DESCRIPITON
System Verification Reviews	See Design Approach and Requirements Allocation reviews above. These are generally peer level reviews performed as a part of the detailed design activities that reviews all the design documents (drawings, analysis and specifications) for a component, subsystem, and system (including facilities) for compatibility and completeness. These reviews should be completed near the end of the given system design effort. The results of these reviews are significant input to the Critical Design Review (see review description below).
Critical Design Review (CDR)	This review shall be conducted when detailed design is nearing completion. The result of successfully completing this review shall be the release of the detailed design documentation for manufacturing and /or construction. The purpose of this review will be to: a. determine that the detailed design drawings comply with the requirements specifications. b. determine the design compatibility. c. determine that the detailed design includes all products and processes. d. determine that functional and performance requirements have been complied with. e. evaluate risk management activities and risk closure actions and results. f. determine if the project configuration management system is in place to control field changes.
Test Readiness Review	This review (s) is held near the end of construction to assess the completion of the construction activities; assess the preparation of the components, subsystems and/or system (s) for acceptance testing; training of the test operators; safety precautions planned during testing; and the process used to prepare, review and approve the testing procedures. This review should lead to an agreement to initiate the acceptance testing in the project.

Table 7-1. Project Reviews (continued)

REVIEW	REVIEW DESCRIPITON
Physical Configuration Audit	These reviews are the final Drawing Preparation Check (see review description above) to assure the final as built drawings are complete and correct. These reviews should be completed as the construction of subsystems and systems (including facilities) are completed. The scope and results of these reviews should be input to the Project Completion Review (see review description below). The reviewed as built drawings should be input to the configuration management data base.
Functional Configuration Audit	These reviews are the final Design Approach Review (see review description above). It is completed on the as built drawings to assure the as built configuration will preform the functions allocated to the subsystems or systems (including facilities). These reviews should be completed near the end of construction. The scope and result of these reviews should be input to the Project Completion Review (see review description below).
Project Completion Review	This review is held to: a. assess the adequacy of the constructed facility in performing its required function. The Functional Configuration Audit (see above noted review) should provide the input for this item. b. evaluate operator training and skill levels to determine if they are prepared to perform the necessary functions in operating the facility in a safe and efficient manner. c. assess the safety of the facility and the planned safety procedures. d. evaluate the as-built system to ensure conformance with regulatory considerations and support the key decision readiness review for facility operation approval. The Physical Configuration Audit (see above review description) should provide input to this item. e. assess configuration management procedures to ensure that the as-built design is maintained over the life of the facility or system in order that D&D activities may be properly addressed at closeout. This review should support turn over of the facility to the customer. Some of the above scope items for this review may not be in the project work scope (such as operator training) and therefore may not be included in the review. This review should be coordinated with the organizational element charged with performing the DOE O 5480.31 mandated Operations Readiness Review if this review is planned. The coordination should eliminate duplicated activities and assure the results of this review are documented to support use of the results in supporting operation readiness issues.

the material. Issues unresolved during the review should be placed on an action item list and the action assigned to an individual for resolution within a specific performance period. A review report should be prepared that summarizes the results of the review including a list of the unresolved issues. Resolution of the unresolved issues noted during the review should be documented. The results of the reviews are generally used by the project team, management, and the customer to assess progress in meeting project milestones or to establish readiness to proceed. Reviews should be scheduled and performed throughout the project life cycle and during the preconceptual activities. In the preconceptual activities, a review should be scheduled to review the established project requirements and preconceptual architecture. This review should support the mission need decision. During the project life cycle a number of important reviews should be performed. A conceptual design review should be performed near the end of the conceptual phase to support acceptance of the conceptual design and approval of the project baseline. The critical design review is held during the execution design subphase to assess the status of the design and to approve the initiation of construction. Additional reviews that should be considered are listed in Table 7-1.

Reviews are an important project activity and should be planned as an integral part of the project during the planning activities. Reviews should be planned based on the complexity and the duration of the project. The objective of the review should be specified as a part of the planning effort. These reviews should be scheduled to precede critical decision points and/or as requested by both the customer and management to assess baseline progress. Care should be taken to ensure that sufficient reviews are scheduled to keep the stakeholders informed on the progress. The project manager should establish a reasonable balance between the need to inform and the overall cost of reviews. The customer may, at any time, call for an in-process or unscheduled review when a need is identified. When possible, these unscheduled reviews should be integrated with a planned review. Requests for an unscheduled review should consider funds availability before the review is committed to.

If the project is being completed by a prime contractor, the DOE project manager must pass the review responsibility and scope on to the contractor. The review requirements should be specified as a part of the contract statement of work. In this case additional reviews may be necessary for the DOE to receive interactive status updates on the projects. DOE should participate in the contractors reviews to limit the number of reviews required and the costs.

8. GRADED APPROACH

This Guide presents planning, management, engineering, engineering specialty, and review products that apply to a large and highly complex project and expects a graded approach to be used for less complex projects. As applied to this Guide, the DOE definition for a graded approach is:

> "The planning, management, engineering, engineering specialty review products required, and the magnitude of resources expended for a particular product should be tailored to be commensurate with the elements relative importance to safety, environmental compliance, safeguards and security, programmatic importance, magnitude of the hazard, financial impact, and/or other project specific requirements."

Specific factors to consider when applying the graded approach include life cycle phase, size and complexity, technical issues, dollar value, visibility, uncertainties, and risk. From a project viewpoint, there are two distinct and different areas where a graded approach needs to be applied:

(1) determining requirements and products for control of the project and project management risk, and

(2) determining requirements and products for the control of the end product and project's technical risk.

Products for controlling project risk are defined by the planning, management, engineering, and engineering specialty products discussed in this Guide. Products for controlling the project's technical risk are defined by the engineering and specialty engineering products defined in this Guide. Review products are used to control both project and technical risk.

8.1 Controlling Project Risk - Grading Planning, Management Engineering, Engineering Specialty, and Review Products

A risk-based graded approach should be used to determine which planning, management, engineering, engineering specialty, and review products and tools should be applied to ensure efficient and successful project completion. The *Risk Analysis and Management* Guide, GPG-FM-007, provides additional information on applying a risk-based graded approach.

Implementation of the risk-based graded approach is a two-step systematic process:

1. Determine Risk Factors. Identify and assess (i.e., grade) project risks (Table 8-1).

2. Select Products. Select appropriate planning, management, engineering, engineering specialty, and review products and tools and the degree of application for controlling risks (Table 8-2).

8.1.1 Step 1. Determine Risk Factors

Risk analysis consists of two phases: (1) Identifying project risk factors and (2) assessing degree of project risk. Risk analysis may need to be performed at the overall project level, by specific project phases, by lower WBS levels, or by contract. Risk analysis is performed during the planning stages of the project and updated throughout project execution to translate the degree of application of guideline products into contractor system requirements.

- **Identifying Project Risk Factors** is simply the identification of project-related risks. Unfavorable outcome of a risk will normally affect one or more project baselines. Risks are additive; each risk identified increases overall project complexity. The left column of Table 8-1 provides examples of many risk areas common to DOE projects as well as factors that increase project complexity.

- **Assessing Degree of Project Risk** involves determining, qualitatively, the magnitude of each identified risk. The magnitude of risk (i.e., low, medium, and high) is assessed by evaluating the possibility of an unfavorable outcome and the potential impact. Table 8-1 provides project attributes that categorize common risk areas.

8.1.2 Step 2: Select Products

Once project risks and complexities have been assessed and each project risk factor has been graded, the DOE project manager selects the rigor of application for each planning, management, engineering, engineering specialty and review product that is suitable to control the risks identified in Step 1.

Table 8-2 provides a grading of planning, management, engineering, engineering specialty and review products. As the risk increases, the number of products and rigor of application increases. The intersection of a category (row) and level of application (column) are system attributes. Table 8-2 is not intended as a prescriptive list. It does not provide a grading for medium risk because of the wide range of products that will fall in this risk category.

Table 8-1. Examples of Graded Approach Project <u>and</u> Contract Risk Areas/Complexity Factors.

RISK/COMPLEXITY FACTOR	LOW RISK	MODERATE RISK	HIGH RISK
Technology	Common/off-the-shelf technology Civil/conventional construction	Proven/state-of-the-art technology Engineered equipment Testing	Unproven technology New system High engineered equipment R&D or investigative requirements Extensive testing Nuclear facility
Time	Ample time to perform work	Reasonable time to perform work (tight but possible)	Compressed time frame to perform work DOE commitments with other agencies (e.g., DoD, NASA, EPA, NRC), states, etc.
Interfaces	No major impact on site operations, other contractors, projects, programs, etc.	Potential impact on site operations, other contractors, projects, projects, etc.	Potential major impact on site operations, other contractors, projects, programs, etc.
Number of Key Participants	1	2-3	3 or more
Contractor Capabilities	Proven track record	Limited experience	Newly acquired capabilities
Magnitude and Type of Environmental Contamination	Hazardous or low-level waste, fully characterized	Hazardous or low-level waste, moderately characterized	High-level or mixed waste, regardless of characterization
Regulatory Involvement	None	EPA, NRC, or states	EPA, NRC, or states
NEPA Enviornmental Permits (RCRA, CWA, CAA, etc.) or Licensing	Categorical Exclusion and No permitting	Environmental Assessment and Ordinary permitting required	Environmental Assessment or Environmental Impact Statement or Unique permitting required
Number of Locations Site Ownership Site Improvement/ Access	1 DOE property No infrastructure/improvements required and accessible	2-3 Government, State, or participant property Minor infrastructure/improvements required and accessible	4 or more Private property Major infrastructure/improvements required or difficult access
Labor Skills Availability Staff Build-up Productivity	Low or moderate skill labor Readily available Gradual Low or average productivity assumed and low schedule risk	Moderate or higly skilled labor Availability restricted Measured or phased Low or average productivity assumed and moderate schedule risk	Moderate or highly skilled labor Availability severely restricted Rapid Average or high productivity assumed and moderate or high schedule risk
Quality Requirements	Large quality tolerance and low productivity risk	Moderate quality tolerances (rework likely) and moderate productivity risk	Precision work (re-work expected) and moderate or high productivity risk NEA1

RISK/COMPLEXITY FACTOR	LOW RISK	MODERATE RISK	HIGH RISK
Funding	Less than 1-year duration Small project (e.g., GPP size)	2-3 year duration Other Line Item Project size	2 or more year duration Other Line Item, MP, MSA, size
Political Visibility	None	Minor	Major
Cost Sharing* Number of contributors in addition to DOE	None	1	2 or more
PUBLIC INVOLVEMENT	None	Minor	Independent oversight
Overall Complexity	Low technology Low schedule risk 1 contractor 1-2 subcontractors 1 location No interfaces or dependencies with other participants, projects, programs, etc. No regulatory involvement CX or minor EA etc.	Low or moderate technology risk Low or moderate schedule risk 1-2 major prime contractors 2-3 major subcontractor 1-2 locations Few interfaces or dependencies with other participants, projects, programs, etc. Some regulatory involvement EA etc.	Moderate or high technology risk Moderate or high schedule risk 2 or more major prime contractors Multiple subcontractors 2 or more locations Several interfaces or dependencies with other participants, projects, programs, etc. EA or EIS etc.

The selection of the appropriate mix of products is a balance between effectiveness and economy. All requirements have a price. The benefits of additional requirements to increase control must be evaluated against the increased cost. Excessive applications should be avoided. Selection of planning, management, engineering, engineering specialty and review products should be apparent once project risks have been analyzed. For further assistance, however, several general criteria for selecting attributes from Table 8-2 are listed:

Suggested Criterion 1 - For projects (or subprojects) less than $10 million Total Project Cost (TPC) or participants with work scope less than $10 million, eliminate the "high" column (as appropriate)

Suggested Criterion 2 - For projects (or subprojects) greater than $10 million TPC or participants with work scope greater than $10 million, eliminate the "low" column (as appropriate)

Effort spent on risk analysis should be in proportion to both the TPC or participant's portion of the project Total Estimated Cost (TEC) and the potential impact to the Government. Risk analysis for developing project requirements is not a complex process. This effort should be performed internally by the DOE project manager and staff. Outside consultants should not be required. With the guidance provided in the *Risk Analysis and*

Management Guide, risk analysis can be easily performed and project control system specifications developed in 1-2 days on large, complex projects and in less time for less-complex projects. A periodic review of project risks and planning, management, engineering, engineering specialty and review products should be performed at key decisions or at the start of major phases of each project.

Guideline applications to manage and control projects should be summarized in the Project Execution Plan.

8.2 Controlling Technical Risk - Grading Engineering and Engineering Specialty Products

A graded approach is used to determine the appropriate engineering and engineering specialty products and tools that should be applied when defining a project's end product. For a highly complex and costly project such as a major environmental clean-up activity, which could potentially have serious off-site personnel safety consequences, most of the products and tools discussed in this Guide would be developed. At the other extreme, for a low-hazard project, such as an office complex, where the greatest hazard is localized (that is, offsite personnel and workers at other facilities on the site are unaffected), fewer products would be expected.

For engineering and engineering specialty products, the graded approach is based on hazard associated with the end product. Hazard is related to the worst possible accident, without regard for either the physical components or the administrative projects (such as safety reviews, QA projects, procedures, and training) intended to prevent, detect, or mitigate potential accidents. Hazard considers the material types, quantities, forms, locations, dispersibility, and interaction with available energy sources that could cause harm to personnel or the environment. Hazard is a measure of the unmitigated consequences of source terms; it provides an indication of the importance of having components and administrative controls that prevent, detect, or mitigate accidents.

In contrast, risk is a measure of the combination of the probability of the occurrence and the consequences of such an occurrence. In risk assessments, the components and administrative controls are assumed to function. By providing these components and administrative controls, the risks associated with the operation of hazardous end product become acceptably small. Risk is a measure of both the hazard and the effectiveness of the components and administrative controls. Because the purpose of grading often relates to the value of improvements, it is appropriate to use hazard, or unmitigated risk, rather than risk to gauge importance.

In keeping with its established policy that safety be given priority over programmatic considerations, DOE has focused initial development of the grading process on nuclear hazards. DOE-STD-1027-92, *Hazard Categorization and Accident Analysis Techniques for Compliance with DOE 5480.23, Nuclear Safety Analysis Reports,* provides guidance for evaluating facility hazards. Chemical and other hazards are also being considered. DOE recognizes that at some nuclear facilities, the dominant hazard may not be a nuclear hazard but rather some other type of hazardous material, such as sulfuric acid or chlorine. The hazard category of any facility, nuclear or nonnuclear, should be based on the dominant hazard.

The degree of implementation necessary to maintain adequate safety varies with facility size and complexity. Large, complex facilities generally have more components and therefore more opportunities for failure than less complex facilities. Similarly, if a facility is small and uncomplicated, its safety may depend more heavily on manual actions than on automatic safety actions. In situations that depend heavily on manual safety decisions and actions, the man-machine interface becomes more important.

Pending the development of detailed DOE guidance, judgment should be used to estimate the relative complexity of the facility. Those estimates would then be merged with the hazard category to arrive at an overall facility importance grade.

Table 8-2. Graded Application of *PEAEMP* Products.

PRODUCT	HIGH	LOW
PLANNING	Preconceptual Development Plan	Planning for the preconceptual phase (Note 1)
	Conceptual Development Plan	Planning for the conceptual phase (Note 1)
	Project Execution Plan	Project Execution Plan
	Transition Plan	Planning for transition to operations (Note 2)
	Closeout Plan	Planning for closeout (Note 2)
MANAGEMENT	Justification of Mission Need	Justification of Mission Need
	Project Organization	Project Organization (Note 2)
	Management/Engineering Processes	Management/Engineering Processess (Note 1)
	Training	Training (Note 1)
	Planning Documentation	Planning Documentation (Note 2)
	Federal Budget Cycle	Federal Budget Cycle
	Monitoring/Control/Oversight	Monitoring/Control/Oversight (Note 2)
	Contract Management	Contract Management
	Configuration Management	Configuration Management (Note 2)
	Baesline Management	Baseline Management
	Construction Management	Construction Management (Note 2)
	Inter-Group Coordination	Inter-Group Coordination (Note 1)
	Decision Criteria	Decision Criteria (Note 1)
ENGINEERING	Mission Analysis	Mission Analysis (Note 1)
	Functions & Requirements	Functions & Requirements (Note 1)
	Alternative Evaluations	Alternative Evaluations (Note 1)
	Alternative Selections	Alternative Selections (Note 1)
	Design Documentation	Design Documentation
	Safety Assessments	Safety Assessments
	Interface Control Documents	Interface Control Documents
	Test & Evaluations	Test & Evaluation
	Oprations/Maintenance Requirements Documentation	Operations/Maintenance Requirements Documentation
	Specifications	Specifications
SPECIALTY ENGINEERING	Integrated Logistics Support	Integrated Logistics Support (Note 2)

PRODUCT	HIGH	LOW
	System Life Cycle Cost	System Life Cycle Cost
	Environment, Safety & Health	Environment, Safety & Health (Note 2)
	Human Factors Engineering	Human Factors Engineering (Note 2)
	Safeguards & Security	Safeguards & Security (Note 2)
	Risk Management	Risk Management (Note 2)
	NEPA Documentation	NEPA Documentation (Note 2)
	Value Engineering	Value Engineering (Note 2)
	Quality Assurance	Quality Assurance
	Regulatory Compliance	Regulatory Compliance
	Environmental, Socioeconomic & Institutional	Environmental, Socioeconomic & Institutional (Note 2)
REVIEWS	Preconceptual Design Review	Preconceptual Design Review
	Alternative System Review	
	Requirement Allocation Review	
	System Requirements Review	
	Conceptual Design Review	Conceptual Design Review
	System Functional Review	System Functional Review
	Design Approach Reviews	Design Approach Reviews
	Design Analysis Reviews	Design Analysis Reviews
	Preliminary Design Review	
	Instruction Reviews	Instruction Reviews
	Drawing Preparation Checks	Drawing Preparation Checks
	Software Specification Reviews	
	Detailed Design Review	
	System Verification Reviews	
	Critical Design Review	Critical Design Review
	Test Readiness Reviews	
	Physical Configuration Audits	Physical Configuration Audits
	Functional Configuration Audits	
	Project Completion Reviews	Project Completion Reviews

Table 8-2 Notes:

1. If applicable, activity should be performed, but does not require formal documentation.
2. If applicable, activity planning should be included in the Project Execution Plan.

9. MEASURING FOR RESULTS

A systematic measurement program is required to ensure that timely, meaningful, and action-oriented information is available to support the decision making process essential to effectively manage both projects and the organizations that are responsible for the project.

Almost every organization does some measurement. For example, a project manager must continually be aware of, as a minimum, cost, schedule, and technical performance so that he can assess that the work planned has been accomplished for the cost planned. Several Good Practice Guides (GPGs) discuss processes to provide the project manager with the needed information. These Guides include GPG-FM-006, *Performance Analysis and Reporting*; GPG-FM-008, *Work Scope Planning*; and GPG-FM-009, *Baseline Change Control*.

However, many organizations do not:

- systematically and regularly collect data and develop information for assessing progress and evaluating risks;

- have an organizational memory, i.e., an experience data base (they rely on individual experience); or

- regularly use quantitative information to support decisions.

A systematic measurement program addresses the quantitative information needs of both the management and engineering organizations in implementing the project processes. These processes continually interact during the life cycle of a project. The "messages" between them are often quantitative in nature.

This section will focus on a few basic considerations that should support the other guides and provide a systematic measurement program.

A systematic measurement program:

- is a planned, organized, integrated, and ongoing effort to provide information for management and engineering decisions;

- institutionalizes the development and use of quantitative information as a basic component of the management and engineering processes;

- provides the collection, analysis, integration and reporting of quantitative information at the development level to support the attainment of project and organizational goals;
- identifies the impact of possible management actions; and
- is an integral part of modern business practice.

A systematic measurement program consists of various activities, including:

- establishing and maintaining an organizational experience data base;
- collecting and validating data;
- quantifying end product and process characteristics;
- providing estimates of end product size, cost, schedule, and quantity;
- monitoring projects and determining status and earned value as required;
- determining and assessing potential and actual process and project risks;
- measuring process status (including technical performance) and improvement;
- estimating the potential impact of possible technology/process changes;
- measuring quality and identifying the impact of possible management actions;
- providing training in metrics analysis, estimation, etc.; and
- developing metrics standards.

Every systematic measurement program will probably not perform all of these activities. At a minimum the three step theme of this Guide should be used:

1. <u>PLAN</u> the performance of the effort that produce the product,
2. <u>PERFORM</u> the plan,
3. <u>VERIFY</u> the correct performance of the plan.

The term “product,” as used above and elsewhere in this section, refers to the products suggested in this Guide.

The key item above is verify. To be effective in verifying that performance has been successful performance measures or metrics should be established along with the planning. There is much debate ongoing, concerning what constitutes good metrics. While the answer may vary from one organization to another, there are some attributes shared by all. A "good metric":

- has value to its customer or end user;
- provides insight into how well goals and objectives are being met;
- is simple, understandable, repeatable, and measurable;
- shows trends, rather than a one-time status point;
- is unambiguously defined;
- is economical to collect;
- is timely; and
- drives appropriate actions.

This Guide recommends that consideration be given to the selection of performance measures or metrics during the planning efforts for each subtask that supports the project. Subtasks metrics should be rolled up to task metrics and tasks up to project performance indicators. Many projects select their performance indicators but do not allocate them down to the subtask level. Hence when a subtask falls behind there is no correlation to the project status and the program is surprised that there is some concern. Table 9-1 gives some examples of metrics. It will be necessary to select the set of metrics graded to the projects needs as well as the end-users needs.

The metrics process should be an integral part of the project, which must include the derivation and usage of both technical and management metrics. Technical metrics may include technical performance measures or system complexity indices. Management metrics may include productivity metrics, defect rates, and risk indices.

The outcomes of the metrics process should include: (1) empirically based project planning; (2) decisions based on historical data and lessons learned; (3) validated process improvement; and (4) problem avoidance based on trend detection and correction. The generalized metrics process thus includes:

- **Planning** - The initial activity in the process involves the planning for a metrics program, and the subsequent refinements to the program at regular iterations. The planning phase should consider all pertinent issues, support needed, metrics to be collected for each task/work product, and the tools and techniques to be used. The selection of metrics should be linked to planned products and processes to be used.

- **Implementing** - The implementation phase involves the activities from collection to transformation of raw data into usable metrics. The implementation will be an iterative process which will typically occur at regularly scheduled intervals or at the completion of a work product or life cycle phase.

- **Validating** - Once metrics are generated, an important, yet often neglected step is the validation of the metrics results. This may include an inspection activity, comparison of results against expectations, and comparison to industry benchmarks or analogous results.

- **Action Taking** - Once a set of validated metrics is produced, the results must be first analyzed and then provided as feedback to the appropriate project management or process improvement teams, to be utilized in the intended manner. The results must also be stored in the appropriate repository for future use, and any defects or improvement suggestions should be fed forward to the planning efforts for the next metrics application.

These lessons learned should be considered in a systematic effort to measure for results:

- Planning is key. Thoroughly explore the goals prior to defining metrics. Understand who will use the metrics and why. Measure only that from which decisions can be made.

- Select or deselect specific metrics based both on the project phase and needs of the end user.

- Executive management support is essential, and "buy-in" by all involved participants should be achieved.

Table 9-1. Metrics Examples

CLASS	DATA	EXAMPLE METRICS
Completion: A completion metric is any indicator used to measure the status of a specific effort.	• % requirements allocated per phase • % of tests remaining • % of traced requirements	• requirements allocation • requirements coverage • requirements traceability
Complexity: Any metric used to assess the complexity or difficulty of current task to a previous similar task is a complexity metric.	• number of system interfaces • % functions reused	• complexity index • reuse index
Compliance: A compliance metric provides an indicator of process or product conformance to customer or internal standards.	• non-compliant requirements • non-compliant process requirements	• requirements compliance • process compliance
Customer Satisfaction: A metric indicating satisfaction with process or products.	• survey results • number of complaints	• customer satisfaction • responsiveness index
Productivity: A productivity metric is a measure of the ability of an organization to produce a system against plan.	• planned versus actual dates • labor hours per task	• on-time delivery rate • requirements productivity
Quality: Quality metrics are amy measurements of product or process quality.	• defects per requirement • number of trouble reports • defects found in inspections	• defect rate • defect density • inspection effectiveness
Technical Stability: A technical stability metric is an indicator of convergence or divergence in an engineering, manufacturing or test effort.	• change of derived requirements • change in time for task • risk data • technical parameter values	• requirement stability • cycle time • risk index • technical performance • technical performance measures

- Well designed data collection forms or menus encourage completeness and correctness. Effort expended in developing an effective means to collect data will reduce problems associated with collection. Initially, collection should be phase in, beginning with a couple of projects, and expanded to include all projects.

- Carefully design the metrics repository data base to allow change and growth. Design the format of reports in parallel with the structure of the data base.

Capture lessons learned with a prototype data base for future use in planning for a fully automated system.

- Use care in structuring metrics. For example, one's derived requirements can be someone else's baseline requirements which would require careful consideration in how requirements-based metrics are analyzed and used.

- Present data whenever possible, as trend analysis (for senior management, present data graphically). Make the end metrics product accessible and meaningful to both the intended recipients of the data and the sources of data.

- Whenever possible, leverage the data stores/repositories of other groups, including finance, configuration management and quality assurance.

- Significant challenges exist for measurement of DOE project life cycle products. Challenges must be recognized and incorporated into the overall metrics program and its goals.

When establishing and then conducting a program of systematic measurement, it is important to keep in mind that:

- Measurement is not an end in itself. The prime goal of a systematic measurement program is better management, not just better measurement.

- An organization's systematic measurement program should be tailored to its resources, culture, and needs.

- There is a need for rigor in the development and application of metrics.

- The best management practice depends on metrics.

- The metrics used should be accurate and relevant. Relevance means that a metric must measure the process or product attribute intended.

- The metrics selected should support organization and project goals.

- Every metric selected should satisfy a need for quantitative information stated for a particular consumer, i.e., program/project managers.

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10.8 Good Practice Guides

A summary of the Good Practice Guides can be found in the *Guide to the Guides*.

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11. DEFINITIONS

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12. ASSISTANCE

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13. RELATED TRAINING

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APPENDICES