REQUEST FOR PROPOSALS (RFP) 11-027F

For

ARCHITECTURAL & ENGINEERING SERVICES

CONCEPTUAL DESIGN OF PLASMA SCIENCE & TECHNOLOGY (PS&T) BUILDING

PART I

Architectural & Engineering Services For The Conceptual Design of the Plasma Science & Technology Building

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1.0 Introduction

The Princeton Plasma Physics Laboratory (PPPL) requires the Architectural & Engineering Services of a firm experienced in the design of multiple use science and technology buildings. Attachment 1 provides a PPPL estimate for a 26,150 square foot building that includes approximately 8000 square feet of High Bay space serviced by an overhead crane. Under the direction of PPPL staff, the successful firm will meet with PPPL building stakeholders and develop a detailed general requirements plan and translate the final requirements into a building concept that meets the present scientific needs and provides for adequate future expansion.

2.0 Statement of Work Activity

2.1 Define Needs

2.1.1 Successful contractor will meet with all PPPL building stakeholders as necessary to develop building general requirements, including but not limited to:

2.1.1.1 Space and access requirements
2.1.1.2 Fire & Life Safety
2.1.1.3 Special finishes
2.1.1.4 Special material handling
2.1.1.5 Radiological precautions
2.1.1.6 Electrical utility needs
2.1.1.7 HVAC and dew point requirements
2.1.1.8 Experimental cooling water requirements

2.1.2 A final Infrastructure General Requirements Document shall be developed and delivered to PPPL for final acceptance and signature of PPPL Major Stakeholders prior to the development of a conceptual building.

2.2 Design Requirements

2.2.1 Conceptual Design shall incorporate the minimum requirement of meeting LEED Gold certification.

2.2.2 Conceptual Design shall meet the requirements of High Performance Sustainable Buildings DOE G 413.3-6 (Attachment 2)

2.2.3 Where applicable, the building concept shall meet the requirements of DOE G 420.1-1 Nonreactor Nuclear Safety

Design Criteria and Explosives Safety Criteria Guide (Attachment 3)

2.2.4 The new building shall meet or exceed all applicable NJ- IBC-2006 codes.

2.2.5 The new building will be located on the area currently occupied by the Administration Building Addition and Theory Buildings.

2.2.6 The new building shall provide connection to the Administration Building on the existing first floor and the proposed 2nd and 3rd floor additions.

2.2.7 The new building, while meeting the functional needs defined in the Infrastructure General Requirements Document, must also be compatible with the existing Architecture of the surrounding buildings.

2.3 Additional Requirements

2.3.1 The Conceptual Design shall be managed by PPPL in accordance with DOE Order 413.3A. The successful contractor will be required to work in conjunction with PPPL to meet the reporting requirements of DOE O 413.3.A and achieve a successful CD-1 approval as defined by DOE O 413.3.A. (Attachment 4)

This includes but is not limited to:

2.3.1.1 Prepare and conduct PPPL conceptual design reviews as necessary to meet the requirements of DOE O 413.3.A.

2.3.1.2 Complete the disposition of PPPL conceptual design review chits and issue a CDR report.

2.3.1.3 Prepare and participate as a partner in the Lehman Conceptual Design Review.

2.3.1.4 Complete the disposition of design chits to achieve a CD-1 approval in accordance with DOE O 413.3.A.

3.0 Materials and Equipment

N/A

4.0 Environment, Safety and Health

3.1 All work shall be in accordance with PPPL ESHD 5008. The manual is available on the Internet at the following web address: http://www.pppl.gov/eshis/ESHD_MANUAL/sm.html

3.2 All contractor equipment & vehicles must be in good working condition, with no leaks of any kind. Any spills must be reported immediately to PPPL and work stopped until the spill can be cleaned up. The contractor is responsible for remediation costs caused by negligence and / or faulty equipment. PPPL Environmental Services will determine the proper method of remediation.

3.3 All work shall be in accordance with all OSHA, DOE, and PPPL requirements. Care must be taken to protect personnel, employees and surroundings.

3.4 Subcontractor workers must take and pass PPPL General Employee Training (GET) if they are to be on-site for more than 40 hours per calendar year.

3.5 The contractor must complete a PPPL Job Hazard Analysis (JHA) using a format supplied by PPPL or another format that is approved by PPPL. The JHA must be reviewed with the responsible PPPL representative as a pre-job brief.

3.6 When applicable, the contractor must comply with OSHA regulations regarding Confined Space Entry. Contractor must submit a copy of their confined space program for ES&H approval, or take confined space training on site.

3.7 A Government Issued Picture ID is required for access to the site.

6.0 Deliverables:

6.1 Infrastructure General Requirements Plan

6.2 Twelve copies of the Conceptual Design drawings, including proposed LEED planning schedule, one reproducible copy (Auto-CAD) and an electronic copy in AutoCAD.

6.3 Twelve copies of construction budget estimates, including individual trade, material, equipment, furnishings, and accessories breakouts in sufficient detail to insure a complete understanding of all costs.

7.0 Acceptance:

7.1 Successful CD-1 as defined by DOE O 413.3A (Managing Design And Construction Using Systems Engineering)

8.0 Warranty:

8.1 N/A

9.0 Selection Process

9.1 Firms wishing to be considered for the above listed design work will be evaluated on the following criteria, and should be prepared to provide evidence of the same. Interviews will be scheduled as necessary with the most competitive firms.

9.1.1 Specialized experience & technical competence of the firm including:

- Unique approaches to laboratory design
- Energy efficient commercial designs
- LEED certified buildings
- Energy efficient laboratory and science buildings

9.1.2 Specific experience and qualifications of personnel proposed for the assignment

- Architects / Engineers proposed for the project
- LEED certification experience of proposed personnel for the project(LEED AP)

9.1.3 Professional capacity of the firm in the immediate geographic (within 75 miles of project) area of the project to perform the work.

- Offices in the local area
- Engineering disciplines available in local area offices
- Areas of the project that would be subcontracted
- Names of expected subcontractors and areas expected to subcontracted.

9.1.4 Past record of performance on contracts with The U.S. Department of Energy, Federal and State Governments. Provide examples of similar projects along with owner contacts for reference.

- Work performed for DOE National Laboratories

- Projects completed under the DOE O 413.3A (Managing Design And Construction Using Systems Engineering)
- Federal / State design work similar to proposed project.

9.1.5 Demonstrated success in the use of recycled materials and achieving waste reduction and energy efficiency in facility design.

PPPL Plasma Science & Technology Building Estimated Space Requirements			
Type of Space	**Experiment**	**Room Size**	**Square Footage**
High Bay Space-Roughlt 20'-25' overhead space serviced by a bridge crane with al the necessary utilities for each experiment	Magnetic Reconnection Experiment	40' x 50'	2000
	Lithium Tokamak Experiment	40 x 50	2000
	MRI/LMX	40 x 40	1600
	Growth	40 x 50	2000
Laboratory Space-Rough Ceiling Heigt of 12'. Utilities need to be specifically identified for to accomadat each Experiment and provide for growth	MNX/FRC	40 x 40	1200
	PTSX	20 x 50	1000
	HEDP accelerator	20 x 50	1000
	LIF laser system	20 x 20	400
	Growth	20 x 40	800
	Nova Photonics Lab	20 x 40	800
	Nano particle Lab	30 x 40	1200
	Laser Laboratory	30 x 40	1200
	Plasma Material Lab	40 x 40	1600
Utility Space-Space to house Power Supplies, Pumps and necessary equipment experiments.	MRX rectifier room	20 x 40	800
	LTX power supplies	20 x 40	800
	Pump room	20 x 20	400
Lithium handling room		25 x 40	1000
Control Room-used as operations center for various experiments	Control room	25 x 40	1000
	Control room	25 x 25	625
	Control room	25 x 25	625
Technician Work Area	Technician work area	25 x 25	625
	Technician work area	25 x 25	625
	Technician work area	25 x 25	625
	Technician work area	25 x 25	625
Staging area	Staging area	40 x 40	1600
		Total Building Square Footage	26150

NOT MEASUREMENT SENSITIVE

DOE G 413.3-6
6-20-08

High Performance Sustainable Building

[This Guide describes suggested nonmandatory approaches for meeting requirements. Guides are not requirements documents and are not to be construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.]

U.S. Department of Energy
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Office of Health, Safety and Security

FOREWORD

This Department of Energy Guide is for use by all DOE elements. This Guide provides approaches for implementing the High Performance Sustainable Building (HPSB) requirements of DOE O 413.3A, *Program and Project Management for the Acquisition of Capital Assets*. DOE Guides, which are part of the DOE Directives System, provide supplemental information for fulfilling requirements contained in rules, regulatory standards, and DOE directives. Guides do not establish or invoke new requirements nor are they substitutes for requirements.

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HIGH PERFORMANCE SUSTAINABLE BUILDING

1. Background

a. DOE O 413.3A, *Program and Project Management for the Acquisition of Capital Assets,* provides the Department of Energy, including the National Nuclear Security Administration, with project management direction for the acquisition of capital assets. The goal of this order is to deliver projects on schedule, within budget, and fully capable of meeting mission performance, safeguards and security, and environmental, safety, and health standards. It contains specific provisions for the application of high performance sustainable building (HPSB) principles to the siting, design, construction, and commissioning of new facilities and major renovations of existing facilities.

b. Through the application of HPSB principles pursuant to the Order, a number of mission, energy security, and environmental benefits will be realized, including:

- reduced total (life-cycle) ownership cost of facilities;
- improved energy efficiency and water conservation;
- safe, healthy, and productive built environments; and
- inherent protection of the natural environment.

2. Purpose

This Guide highlights the DOE O 413.3A drivers for incorporating HPSB principles into Critical Decisions 1 through 4 and provides guidance for implementing DOE O 413.3A HPSB requirements.

3. Guide Scope

a. DOE O 413.3A specifies implementation of HPSB requirements into applicable capital asset acquisitions, and its Contractor Requirements Document specifically requires the application of the HPSB principles to the siting, design, construction, and commissioning of new facilities and major renovations of existing facilities.

b. The HPSB principles derive from a Memorandum of Understanding on *Federal Leadership in High Performance and Sustainable Buildings*, in which signatory agencies committed to follow a set of principles in the siting, design, construction and commissioning of federal buildings. The HPSB principles, which form the core of the Guide, are as follows:

- employ integrated design;
- optimize energy performance;

- protect and conserve water;
- enhance indoor environmental quality; and
- reduce environmental impact of materials.

c. An easy-to-read summary of the HPSB principles is provided in Table 1. Complete descriptions of the HPSB principles are found in Attachment A.

Table 1. HPSB Principles Summary

Employ integrated design principles: • Use a collaborative, integrated planning and design process. • Incorporate life-cycle cost-effective energy, water, materials, and indoor environmental quality principles throughout the design, construction, and life of the building. • Employ total building commissioning practices.
Optimize energy performance: • For new construction, reduce the energy cost budget by at least 30% compared to the baseline building performance rating per ASHRAE Standard 90.1-2004. • For major renovations, reduce the energy cost budget by at least 20% compared to a pre-renovations 2003 baseline. • Install building-level utility meters to track and continuously optimize performance.
Protect and conserve water • Use at least 20% less potable water than the indoor water use baseline calculated for the building. • Reduce outdoor potable water consumption by at least 50%; reduce storm water and polluted water runoff.
Enhance indoor environmental quality • Meet ASHRAE Standards 55-2004, Thermal Environmental Conditions for Human Occupancy, and 62.1-2004, Ventilation for Acceptable Indoor Air Quality. • Establish and implement a moisture control strategy to prevent mold contamination. • Achieve a minimum daylight factor of 2% in 75% of all space. • Specify materials and products with low or no pollutant emissions. • Protect indoor air quality during construction and prior to and after occupancy.
Reduce environmental impact of construction materials
• Use designated recycled-content and biobased-content materials and supplies. • Recycle or salvage at least 50% of the construction, demolition, and land clearing waste. • Eliminate the use of ozone-depleting compounds during and after construction.

d. In 2007, Executive Order 13423, *Strengthening Federal Environmental, Energy, and Transportation Management*, required Federal agencies to comply with the HPSB principles in new construction and major renovation of agency buildings.

e. Although this Guide pertains to DOE O 413.3A capital asset projects, it may also provide useful information on the incorporation of HPSB principles into building-related General Plant Projects and Institutional General Plant Projects at DOE sites.

f. The Guide provides recommendations and options for Federal project directors to consider when implementing HPSB requirements during the capital asset acquisition process to secure approval by the appropriate authorities; none of these recommendations is to be construed as a requirement.

4. Drivers for Incorporating HPSB into Critical Decisions 1 through 4

The following sections contain information on six key drivers for incorporating HPSB into the DOE O 413.3 Critical Decisions 1 through 4:

a. <u>DOE Directives</u>. DOE directives pertaining to HPSB include the following:

(1) DOE O 413.3A, *Program and Project Management for the Acquisition of Capital Assets.* This Order, along with its contractor requirements document, requires incorporating the HPSB principles in the project management of capital asset acquisitions involving the siting, design, construction, and commissioning of new facilities and major renovations of existing facilities.

(2) DOE O 430.2B, *Departmental Energy and Utilities Management.* This Order requires the integration of DOE energy and utilities management with other DOE facilities management processes over the life cycle of a facility, and it establishes Departmental energy efficiency leadership goals. The Order contains a requirement that capital asset construction or major renovation projects attain Leadership in Energy and Environmental Design (LEED) Gold certification. (This Guide provides a process under DOE O 413.3A that enables compliance with requirements to achieve LEED Gold certification, but the Guide itself contains no requirements.)

(3) DOE O 450.1A, *Environmental Protection Program*. This Order establishes sustainable environmental stewardship goals for DOE sites to achieve through the use of Environmental Management Systems. These Departmental goals directly relate to the acquisition of environmentally preferable products, and recycling of construction debris provisions in the HPSB principles.

(4) The Department of Energy Acquisition Regulations (DEAR). The DEAR supplements the Federal Acquisition Regulation, which codifies uniform

policies for acquisition of supplies and services by executive agencies, and contains clauses for inclusion in contracts. DEAR 970.5223-2, *Affirmative Procurement Program*, and DEAR 970.5223-1, *Integration of Environment, Safety, and Health into Work Planning and Execution*, support HPSB principles in the acquisition of capital assets.

b. *Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding*

This January 24, 2006, Memorandum of Understanding states that the Federal government is committed to designing, constructing, and operating its facilities in an energy-efficient and environmentally sustainable manner, consistent with Federal agency missions. The Memorandum of Understanding encourages the use of life-cycle concepts, consensus-based standards, and performance measurement and verification methods that lead to sustainable buildings. The Memorandum of Understanding establishes five HPSB principles that all agencies are to follow in the design, construction and commissioning of federal buildings (see Table 1 and Attachment A).

c. Executive Order (E.O.) 13423, *Strengthening Federal Environmental, Energy and Transportation Management and its Implementing Instructions*

E.O. 13423 consolidates prior "Greening the Government" Executive Orders and integrates the sustainable practices of those orders into a cohesive approach to environmental, energy, and transportation management. Executive Order 13423 requires Federal agencies to lead by example in advancing the nation's energy security and environmental performance. One of the sustainable environmental and energy practices of Executive Order 13423 is compliance with the HPSB principles of the Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding in the design, construction and/or major renovation, and commissioning of Federal Buildings.

d. Energy Policy Act (EPAct) of 2005, Pub. L. No. 109-58

Section 109 of the Energy Policy Act of 2005, *Federal Building Performance Standards*, states that if life-cycle cost-effective, "sustainable design principles are to be applied to the siting, design, and construction of all new and replacement federal buildings." It further states that each building project will "comply with third-party certification standards for high performance sustainable buildings." DOE has issued regulations (10 CFR Parts 433, 434, and 435) as required by Section 109 of the EPAct that establish revised energy efficiency performance standards for new Federal buildings.

e. Energy Independence and Security Act of 2007, Pub. L. No. 110-140

The Energy Independence and Security Act of 2007, Title IV, Subtitle C—High-Performance Federal Buildings—contains annual energy reduction goals for

Federal buildings for the years 2006 through 2015. The law requires the Secretary of Energy to identify a green building certification system and level applicable to Federal buildings, and provide input to semiannual OMB scorecards for energy management activities.

f. Office of Management and Budget Circular A-11 Guidance

Office of Management and Budget Circular A-11 addresses, among other things, the planning, budgeting, and acquisition of capital assets. Part 7 (section 300) of this Circular requires Federal agencies to report whether "sustainable design principles" have been incorporated into the project.

5. Guide Methodology

a. The following sections describe a way by which federal project directors can implement the DOE O 413.3A HPSB requirements in Critical Decisions 1 through 4 of their projects. Federal project directors can fulfill these requirements by incorporating the HPSB principles in the design, construction, and commissioning of new DOE facilities and major renovation of existing facilities.

b. Federal project directors should also be aware that a variety of background, technical, and other HPSB resource information is available from the *Whole Building Design Guide*'s Executive Order (E.O.) 13423 *Technical Guidance for Implementing the Five Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings* webpage (http://www.wbdg.org/sustainableEO/index.php). The *Whole Building Design Guide* is maintained by the National Institute of Building Sciences, with support from over 25 Federal agencies (including the Department of Energy), private-sector companies, and non-profit organizations.

6. Critical Decision-1, Approve Alternative Selection and Cost Range: Implementing HPSB requirements in *the conceptual design report and acquisition strategy.*

a. The Critical Decision-1 requirement pertaining to HPSB defined in Table 2 of DOE O 413.3A is as follows:

Document High Performance Sustainable Building considerations … in the conceptual design report and acquisition strategy, as appropriate.

b. DOE O 413.3A requires the Federal project director to identify in the conceptual design report and the acquisition strategy how the project will meet or contribute to meeting the HPSB principles. The key to successfully incorporating HPSB into a project is to use integrated design principles, as early as possible, and throughout the life of the project to both establish expectations up front and provide the framework for tracking progress throughout the project.

c. Establishing an integrated project team so that it includes members with HPSB experience, including a LEED accredited professional and a designated commissioning authority, is highly recommended. A designated commissioning authority should remain with the project through occupancy. It is also highly recommended that the architecture and engineering firms and construction firms chosen for the project have experience in constructing sustainable buildings.

d. For a list of LEED accredited professionals, see http://www.usgbc.org/LEED/AP/ViewAll.aspx.

e. The Federal project director can use the LEED building rating system to certify the project's conformance with the HPSB principles. If the project is intended to achieve a specific LEED rating level as indicated in Attachment B, Table B-1, this should be identified in the conceptual design report and the acquisition strategy. Crosswalks between the LEED new construction rating criteria and the HPSB principles can be found in Attachment B, Table B-2.

f. Discussion of HPSB is recommended as a separate section or document in the conceptual design report. One best practice is to prepare a sustainable design report to identify the sustainable building features envisioned in the preliminary design. As the project progresses, the Federal project director will update the sustainable design report to track the documentation required to certify the project under the LEED rating system. The sustainable design report thus serves as a key organizing tool to facilitate the Federal project director in tracking the project's sustainable building features. An example of a sustainable design report prepared for the Critical Decision-1 process can be found in Attachment C.

g. Federal project directors may also want to take advantage of the *Whole Building Design Guide Executive Order 13423 Technical Guidance* website (http://www.wbdg.org/sustainableEO/index.php) during the Critical Decision-1 process, and throughout the life of the project. This website offers on-line access to sustainable design resources organized around the implementation of the Executive order's sustainable building requirements and HPSB principles, including analytical tools, model contract and specification language, and reports and evaluations of construction products, processes, and materials.

h. Exemptions: The Federal project director should explain, in the conceptual design report and the acquisition strategy, the rationale for claiming any exemptions to incorporating some or all of the HPSB principles into the project. This includes buildings categorically excluded under the Energy Policy Act of 2005 for energy performance requirements, projects that are waived by the acquisition executive or building components and practices determined and documented by the integrated project team as not being life-cycle cost-effective.

7. Critical Decision-2, Approve Performance Baseline: Implementing HPSB requirements into the preliminary design review.

a. The Critical Decision-2 requirement pertaining to HPSB in Table 2 of DOE O 413.3A is as follows:

> ***Incorporate Preliminary … High Performance Sustainable Building provisions into the preliminary design and design review.***

b. During the Critical Decision-2 process, the Federal project director and the integrated project team should evaluate and document how the HPSB principles have been integrated into the preliminary design. The Federal project director and integrated project team should determine the sustainable building features that can be achieved, making tradeoffs between desired features and project realities. If the project is intended to achieve a particular LEED rating level, the Federal project director should ensure that the documentation is updated to identify the level to be achieved, including a checklist identifying the sustainable building features that contribute to achieving the certification. If the Federal project director is adopting the best practice of preparing a sustainable design report, that report should be updated to validate the sustainable building features of the preliminary project design.

8. Critical Decision-3, Approve Start of Construction: Implementing HPSB requirements into the Final Design and the External Independent Review.

a. The Critical Decision-3 requirement pertaining to HPSB in Table 2 of DOE O 413.3A is as follows:

> ***Incorporate Final … High Performance Sustainable Building provisions into the final design and the external independent review.***

b. The Federal project director should ensure that the sustainable building provisions have been incorporated into the final design and the solicitation for construction to enable the project to successfully incorporate the HPSB principles and achieve the desired LEED rating. The Federal project director should identify potential challenges, either technical or financial, that could eliminate or lessen the project's sustainable features, making sure the final design has HPSB-related specifications, such as procurement and use of environmentally preferable products including construction materials, energy-efficient systems, and a plan for recycling of construction debris and surplus materials.

c. The Federal project director should request that the external independent review or independent project review addresses the sustainable building features of the project by identifying sustainable design as a specific line of inquiry for the review team.

d. As appropriate, the Federal project director should update the sustainable design report to reflect any changes made during the final design process that might impact the project's ability to incorporate the HPSB principles and achieving the LEED rating.

9. Critical Decision-4, Approve Start of Operations or Project Completion: Implementing HPSB requirements into Issuing a Checkout, Testing, and Commissioning Plan.

a. The Critical Decision-4 requirement pertaining to HPSB in Table 2 of DOE O 413.3A is as follows:

> ***Issue a checkout, testing, and commissioning plan that identifies subtasks, systems, and equipment. The commissioning plan ensures that the equipment, systems, and facilities, including High Performance Sustainable Building systems, perform as designed and are optimized for greatest energy efficiency, resource conservation, and occupant satisfaction. The commissioning plan includes checkout and testing criteria required for initial operations.***

b. In Critical Decision-4, the Federal project director should confirm that the HPSB-related systems were included in the project's Checkout, Testing, and Commissioning Plan, and that these sustainable building features were installed correctly and are operating properly. The Federal project director compiles the data and documentation needed to establish that the HPSB principles have been successfully incorporated into the project. If the project is intended to achieve a LEED rating level, the Federal project director will document how each "point" has been obtained on the checklist in order to achieve the LEED rating. If the Federal project director is adopting the best practice of preparing a Sustainable Design Report, this report should be finalized by documenting how each sustainable design feature has been tested and validated, including any commissioning requirements.

10. Acronyms

ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
DEAR	Department of Energy Acquisition Regulations
HPSB	High Performance and Sustainable Building
LEED	Leadership in Energy and Environmental Design

11. References

a. 10 CFR Parts 433, 434, and 435, *Energy Conservation Standards for New Federal Commercial and Multi-Family High-Rise Residential Buildings and New Federal Low-Rise Residential Buildings*. Available at http://www1.eere.energy.gov/femp/pdfs/fr_notice_cfr433_434_435.pdf

b. DOE O 413.3 A, *Program and Project Management for the Acquisition of Capital Assets*.

c. DOE O 430.2B, *Departmental Energy and Utilities Management*.

d. DOE O 450.1A, *Environmental Protection Program*.

e. E.O. 13423 *Strengthening Federal Environmental, Energy, and Transportation Management*, January 26, 2007, Available at http://www.wbdg.org/pdfs/eo13423.pdf.

f. Instructions for Implementing E.O.13423 "Strengthening Federal Environmental, Energy, and Transportation Management," March 29, 2007. Available at http://www.wbdg.org/pdfs/eo13423_instructions.pdf

g. E.O. 13423 *Technical Guidance for Implementing the Five Guiding Principles for Federal Leadership in High Performance and Sustainable Buildings*, available at http://www.wbdg.org/sustainableEO/index.php. This technical guidance also includes model contract and specification language per the *Federal Green Construction Guide for Specifiers*, available at http://www.wbdg.org/design/greenspec.php. The Technical Guidance is updated periodically; therefore, it is recommended that Federal project directors and integrated project teams monitor the WBDG website for new HPSB-related resources.

h. *Federal Leadership in High Performance and Sustainable Buildings—Memorandum of Understanding*, Available at http://www.wbdg.org/pdfs/sustainable_mou.pdf.

i. Energy Star website, new building design guidance, available at http://www.energystar.gov/index.cfm?c=new_bldg_design.new_bldg_design.

j. *Office of Management and Budget Circular A-11*, Part 7, available at http://www.whitehouse.gov/omb/circulars/a11/current_year/s300.pdf.

k. US Green Buildings Council, *Leadership in Energy and Environmental Design* (LEED), available at http://www.usgbc.org.

l. Energy Policy Act (EPAct) of 2005, Pub. L. No. 109-58. Available at http://fossil.energy.gov/epact/epact_final.pdf.

m. Energy Independence and Security Act of 2007, Pub. L. No. 110-140, available at http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=110_cong_public_laws&docid=f:publ140.110.

GUIDING PRINCIPLES FOR FEDERAL LEADERSHIP IN HIGH PERFORMANCE AND SUSTAINABLE BUILDINGS

(Source: Federal Leadership in High Performance and Sustainable Buildings Memorandum of Understanding, January 2006)

I. Employ Integrated Design Principles

a. **Integrated Design**. Use a collaborative, integrated planning and design process that

- Initiates and maintains an integrated project team in all stages of a project's planning and delivery;
- Establishes performance goals for siting, energy, water, materials, and indoor environmental quality along with other comprehensive design goals; and ensures incorporation of these goals throughout the design and lifecycle of the building; and,
- Considers all stages of the building's lifecycle, including deconstruction.

b. **Commissioning**. Employ total building commissioning practices tailored to the size and complexity of the building and its system components in order to verify performance of building components and systems and help ensure that design requirements are met. This should include a designated commissioning authority, inclusion of commissioning requirements in construction documents, a commissioning plan, verification of the installation and performance of systems to be commissioned, and a commissioning report.

II. Optimize Energy Performance

a. **Energy Efficiency**. Establish a whole building performance target that takes into account the intended use, occupancy, operations, plug loads, other energy demands, and design to earn the Energy Star targets for new construction and major renovation where applicable. For new construction, reduce the energy cost budget by 30 percent compared to the baseline building performance rating per the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., (ASHRAE) and the Illuminating Engineering Society of North America (IESNA) Standard 90.1-2004, Energy Standard for Buildings Except Low-Rise Residential. For major renovations, reduce the energy cost budget by 20 percent below pre-renovations 2003 baseline.

b. **Measurement and Verification**. In accordance with DOE guidelines issued under section 103 of the Energy Policy Act of 2005 (EPAct), install building level utility meters in new major construction and renovation projects to track and continuously optimize performance. Compare actual performance data from the first year of operation with the energy design target. After one year of occupancy, measure all new major installations using the Energy Star Benchmarking Tool for building and space types covered by Energy Star. Enter data and lessons learned from sustainable buildings into the High Performance Buildings Database. (www.eere.energy.gov/femp/highperformance/index.cfm)

III. Protect and Conserve Water

a. **Indoor Water**. Employ strategies that in aggregate use a minimum of 20 percent less potable water than the indoor water use baseline calculated for the building, after meeting the Energy Policy Act of 1992 fixture performance requirements.

b. **Outdoor Water**. Use water efficient landscape and irrigation strategies, including water reuse and recycling, to reduce outdoor potable water consumption by a minimum of 50 percent over that consumed by conventional means (plant species and plant densities). Employ design and construction strategies that reduce storm water runoff and polluted site water runoff.

IV. Enhance Indoor Environmental Quality

a. **Ventilation and Thermal Comfort**. Meet the current ASHRAE Standard 55-2004, Thermal Environmental Conditions for Human Occupancy, including continuous humidity control within established ranges per climate zone, and ASHRAE Standard 62.1-2004, Ventilation for Acceptable Indoor Air Quality.

b. **Moisture Control**. Establish and implement a moisture control strategy for controlling moisture flows and condensation to prevent building damage and mold contamination.

c. **Daylighting**. Achieve a minimum daylight factor of 2 percent (excluding all direct sunlight penetration) in 75 percent of all space occupied for critical visual tasks. Provide automatic dimming controls or accessible manual lighting controls, and appropriate glare control.

d. **Low-Emitting Materials**. Specify materials and products with low pollutant emissions, including adhesives, sealants, paints, carpet systems, and furnishings.

e. **Protect Indoor Air Quality during Construction**. Follow the recommended approach of the Sheet Metal and Air Conditioning Contractor's National Association Indoor Air Quality Guidelines for Occupied Buildings under Construction, 1995. After construction and prior to occupancy, conduct a minimum 72-hour flush-out with maximum outdoor air consistent with achieving relative humidity no greater than 60 percent. After occupancy, continue flush-out as necessary to minimize exposure to contaminants from new building materials.

V. Reduce Environmental Impact of Materials

a. **Recycled Content**. For EPA-designated products, use products meeting or exceeding EPA's recycled content recommendations. For other products, use materials with recycled content such that the sum of post-consumer recycled content plus one-half of the pre-consumer content constitutes at least 10% (based on cost) of the total value of the materials in the project.

b. **Biobased Content**. For USDA-designated products, use products meeting or exceeding USDA's biobased content recommendations. For other products, use biobased products made from rapidly renewable resources and certified sustainable wood products.

c. **Construction Waste**. During a project's planning stage, identify local recycling and salvage operations that could process site related waste. Program the design to recycle or salvage at least 50 percent construction, demolition and land clearing waste, excluding soil, where markets or on-site recycling opportunities exist.

d. **Ozone Depleting Compounds**. Eliminate the use of ozone depleting compounds during and after construction where alternative environmentally preferable products are available, consistent with either the Montreal Protocol and Title VI of the Clean Air Act Amendments of 1990, or equivalent overall air quality benefits that take into account life cycle impacts.

ALIGNING THE HPSB PRINCIPLES WITH THE LEADERSHIP IN ENERGY AND ENVIRONMENTAL DESIGN NEW CONSTRUCTION (LEED-NC™) RATING SYSTEM

1. The LEED (Leadership in Energy and Environmental Design) Green Building Rating System™ is a voluntary standard that defines high performance sustainable buildings—which are healthier, more environmentally responsible, and more cost effective to operate.

2. LEED certification validates that a building is a high performing, sustainable structure. Certification also benchmarks a building's performance to support ongoing analysis over time to quantify the return on investment of green design, construction, systems, and materials.

3. LEED credits are awarded in the following categories:

   - *Sustainable Sites* (construction related pollution prevention, site development impacts, transportation alternatives, storm water management, heat island effect, and light pollution)

   - *Water Efficiency* (landscaping water use reduction, indoor water use reduction, and wastewater strategies)

   - *Energy & Atmosphere* (commissioning, whole building energy performance optimization, refrigerant management, renewable energy use, and measurement and verification)

   - *Indoor Environmental Quality* (environmental tobacco smoke control, outdoor air delivery monitoring, increased ventilation, construction indoor air quality, use low emitting materials, source control, and controllability of thermal and lighting systems)

   - *Materials & Resources* (recycling collection locations, building reuse, construction waste management, and the purchase of regionally manufactured materials, materials with recycled content, rapidly renewable materials, salvaged materials, and sustainably forested wood products)

   - *Innovation & Design Process* (LEED accredited professional, and innovative strategies for sustainable design)

4. The point-based rating system consists of a series of criteria or requirements, under each of the categories, where credits or points are earned for compliance. Although each specific credit is considered optional, <u>all</u> prerequisites need to be satisfied in order for a project to be eligible for certification. Different levels of green building certification are awarded based on the total credits earned. Table B-1 summarizes the project score

requirements and corresponding certification levels specific to the New Construction (LEED-NC™) rating system.

Table B-1: LEED-NC™ Certification Rating Requirements

Certification Level	LEED-NC™ Score Required
Certified	26-32
Silver	33-38
Gold	39-51
Platinum	52-69

As shown in the crosswalk in Table B-2, the LEED-NC™ rating system corresponds closely with the HPSB principles outlined in the January 2006 Memorandum of Understanding.

Table B-2: Crosswalk between the HPSB Principles and the LEED-NC™ Criteria

HPSB Principle	LEED Criteria
Employ Integrated Design Principles Integrated design	*Innovation & Design Process* Credit 2: LEED Accredited Professional
Commissioning	*Energy and Atmosphere* Prerequisite 1: Fundamental Commissioning of the Building Energy Systems Credit 3: Enhanced Commissioning
Optimize Energy Performance Energy Efficiency	*Energy and Atmosphere* Prerequisite 2. Minimum Energy Performance Credit 1: Optimize Energy Performance (obtain at least 7 points in this area to conform with EPAct 2005 and Executive Order 13423 requirements.)
Measurement and Verification	Credit 5: Measurement & Verification
Protect and Conserve Water Indoor Water	*Water Efficiency* Credit 3.1: Water Use Reduction: 20% Reduction
Outdoor Water	Credit 2: Innovative Wastewater Technologies Credit 1.1 Water Efficient Landscaping: Reduce by 50% Credit 1.2 Water Efficient Landscaping: No Potable Use or No Irrigation *Sustainable Sites* Prerequisite 1. Construction Activity Pollution Runoff
Enhance Indoor Environmental Quality Ventilation and Thermal Comfort	*Indoor Environmental Quality* Prerequisite 1. Minimum IAQ Performance Credit 7.1: Thermal Comfort: Design
Moisture Control	*Energy Efficiency* Prerequisite 1. Fundamental Building Systems Commissioning
Daylighting	Credit 6.1 Controllability of Systems, Lighting Credit 8.1: Daylight & Views: Daylight 75% of Spaces

HPSB Principle	LEED Criteria
Low-Emitting Materials	Credit 4.1: Low-Emitting Materials: Adhesives & Sealants Credit 4.2: Low-Emitting Materials: Paints & Coatings Credit 4.3: Low-Emitting Materials: Carpet Systems Credit 4.4: Low-Emitting Materials: Composite Wood & Agrifiber Products
Protect Indoor Air Quality during Construction	Credit 3.1: Construction Indoor Air Quality Management Plan: During Construction Credit 3.2: Construction Indoor Air Quality Management Plan: Before Occupancy
Reduce Environmental Impact of Materials Recycled Content	*Materials and Resources* Credit 4.1: Recycled Content: 10% (post-consumer + 1/2 pre-consumer)
Biobased Content	Credit 6: Rapidly Renewable Materials Credit 7: Certified Wood
Construction Waste	Credit 2.1: Construction Waste Management: Divert 50% From Disposal
Ozone Depleting Compounds	*Energy and Atmosphere* Prerequisite 3. Fundamental Refrigerant Management Credit 4: Enhanced Refrigerant Management

SUSTAINABLE DESIGN REPORT EXAMPLE

1. A sustainable design report is a living document that describes and tracks the sustainability goals of the project and provides a list of its sustainable design features. It serves as a key organizing tool that the Federal project director and integrated project team can use to monitor the project's sustainability criteria. Sites can use this best practice throughout the project to track the goals, progress towards achieving the goals, and final accomplishments with respect to the facility's sustainable design strategies and/or features in Critical Decision-1 through Critical Decision-4.

2. If the project is expected to obtain a LEED rating, the Federal project director can use the sustainable design report in Critical Decision-1 to identify the sustainable design features envisioned in the conceptual design, included in the preliminary design and then incorporated into the final design. As the project progresses, the Federal project director will update the sustainable design report to track the progress of the design documentation required to establish each point obtained under the LEED rating system.

3. When a Federal project director adopts the best practice of preparing a sustainable design report, the first iteration of this report would be developed during the Critical Decision-1 phase.

   a. The report would reflect the sustainable design features that emerge during the conceptual design process.

   b. The Federal project director would update the report in Critical Decision-2 to reflect the sustainable features of the preliminary project design, and again during Critical Decision-3 to track progress in implementing the sustainability features in the final design and external independent review.

   c. The Federal project director would finalize the sustainable design report in Critical Decision-4 to verify the incorporation of the HPSB elements in the completed project.

4. A sustainable design report contains three primary components:

   a. an introduction and overview,

   b. a matrix of the project's sustainable design features, and

   c. an evaluation of the project's LEED certification status (if the project is intended to achieve a LEED rating).

5. This attachment contains excerpts from a sample sustainable design report derived from the Experimental Sciences Complex at Sandia National Laboratory-New Mexico. The attachment is for illustrative purposes only. The Experimental Sciences Complex is a laboratory facility, so many of the specific requirements, actions, and features may not apply to office or other non-laboratory sites. The Experimental Sciences Complex project

was initially designed to achieve a LEED Gold certification level, and the excerpts in this attachment reflect the sustainable design report at the end of the Critical Decision-1 process. The matrix and LEED checklist are intended to provide helpful examples, but the actual sustainable design categories and design features should be developed and tracked for the specific building under construction. The excerpts in this attachment are presented in the following four tables:

a. Table C-1, Excerpts from Experimental Sciences Complex Sustainable Design Features Matrix. This table replicates portions of the matrix that helps ensure that the sustainable design measures identified are integrated into the project's design and can be tracked as the project progresses. Table C-1 shows the requirements for sustainable sites and energy and atmosphere —two of the five categories of design requirements for this project; the matrix in the actual sustainable design report contains the requirements for all five categories. The requirements were identified during a sustainable design planning process conducted as part of the project kickoff activities. The objectives of the matrix are the following:

   (1) Track those sustainable design features and LEED prerequisites and credits considered applicable to the project.

   (2) Track progress of the project in meeting requirements of applicable LEED prerequisites and credits.

   (3) Facilitate development of the LEED certification design phase documentation submittal so that the project can achieve the desired LEED rating.

b. Table C-2 contains excerpts from the Experimental Sciences Complex sustainable design report's LEED Certification Discussion. These include background information, a discussion of the certification status, and potential LEED points.

c. Table C-3 is the Experimental Sciences Complex LEED-NC Score Checklist. The LEED-NC Score Checklist shows each prerequisite and credit in the LEED-NC program and a determination for application to the Experimental Sciences Complex project of either "yes", "no", or "potentially."

d. Table C-4, Potentially Applicable Experimental Sciences Complex LEED Credits, lists 21 additional "potential" LEED credit points. This listing helps the Experimental Sciences Complex project team evaluate the project's ability to achieve a LEED Gold certification level and to determine which potential LEED credit points warrant further evaluation for application to Experimental Sciences Complex.

Table C-1: Excerpts from Experimental Sciences Complex Matrix of Sustainable Design Features

	SD Category	Description of Requirement	Responsible Discipline/ Actions Required/ Status	Features Included in Design
Sustainable Sites (SS)	*Erosion & Sedimentation Control (SSp-1)*	Erosion and Sediment Control Plan	Construction Contractor	Sandia Specification 01065 will be included as part of the ESC construction documents and requires the development and implementation of an erosion and sediment control plan according to U.S. EPA document no. EPA 832/R-92-005, "Storm Water Management for Construction Activities," Chapter 3. This specification will ensure satisfaction of the LEED SS prerequisite, construction activity pollution prevention (SSp-1). The plan will be prepared by the construction contractor and referenced as applicable. The plan will be summarized and referenced in the final SD Report.
	Site Selection (SSc-1)	Avoid development of inappropriate sites	SNL	The site selected for the ESC project is a previously developed area within Technical Area 1. This site meets the criteria for the LEED SS credit, site selection (SSc-1)
	Development Density & Community Connectivity (SSc-2)	Meet a 60,000 square feet per acre development density	SNL	• Selection of the ESC project location within TA 1 definitely meets the intent of this credit, as defined in the LEED-NC Application Guide for Multiple Buildings and On-Campus Buildings. Documentation requirements will include: 1) showing ESC was located in a previously developed area with existing development and infrastructure; 2) verifying the project location is within a designated dense campus growth area; and 3) that the project is resulting in increased development density that meets or contributes to the goals of the campus mater plan.
	Brownfield Redevelopment (SSc-3)	Rehabilitate and develop an environmentally damaged site	SNL	The ESC project site has no history of environmental contamination requiring restoration or rehabilitation. Although the building previously occupying the ESC project site may have required removal of materials that posed potential risk to the environment (such as asbestos or PCBs) prior to demolition, no environment damage to the site surface or subsurface is known to have occurred. This LEED credit will not apply to the ESC project

	SD Category	Description of Requirement	Responsible Discipline/ Actions Required/ Status	Features Included in Design
Sustainable Sites (SS)	*Alternative Transportation (SSc-4.1/4.4)*	Adopted features that promote the use of alternative transportation.	SNL	Access to Public Transportation (SSc-4.1): Although there are Albuquerque City Bus Transit System stops all around Tech Area 1, the location of the ESC project appears to be just beyond the ¼ mile requirement of the credit. There are a total of 5 bus routes with one or more stops outside Tech Area 1 in the vicinity of the ESC project site. A more detailed distance assessment will be required to make a final determination for the applicability of this credit to the ESC project. Bicycle Commuter Provisions (SSc-4.2): The ESC design will incorporate a bicycle storage rack located near the entrance to the building (see ESC 100% Title 1 Dwg 748AS4001) and provide a single shower facility in both the women's and men's restrooms (see ESC 100% Title 1 Dwg 748AE1101) . Low-Emitting Vehicle Availability (SSc-4.3): The ESC design will incorporate parking and recharging stations for (2) SNL electric vehicles (see ESC 100% Title 1 Dwg 748AS1001). Parking Capacity (SSc-4.4): The ESC design will not provide new parking for personal owned vehicles and will therefore satisfy the Option 4 requirements for this credit. The ESC design will achieve at least three of the four LEED Alternative Transportation credits (SSc-4.1/4.4)

	SD Category	Description of Requirement	Responsible Discipline/ Actions Required/ Status	Features Included in Design
Sustainable Sites (SS)	*Storm water Management (SSc-6.1/6.2)*	Approaches and implemented measures that mitigate storm water flow or improve storm water quality relative to site development.	Civil and Landscape Design	Due to the limited landscape area associated with the ESC project, there is limited opportunity to manage storm water on site. Currently, roof-top runoff is direct to the east side of the ESC building. The landscape plan includes a storm water retention feature (4” to 6” deep) in the south east corner of the site (see ESC 100% Title 1 Dwg 748CG1001 and Dwg 748LI1001). However, the majority of site runoff is directed to storm drain inlets located on H and G Avenues. The capacity of the retention feature is currently be evaluated relative to the pre- and post-development runoff quantities and rates. In addition, treatment of storm water runoff using a chambered storm water manhole to remove suspended solids is under consideration.
	Heat Island (SSc-7.1/7.2)	Landscape and exterior design features that reduce the heat island effect	Architecture/Landscape Design	The ESC project has limited exterior areas available to shade exterior hardscape surfaces such as walkways, services roadways and parking area. Landscape trees and building structure features will shade the hardscape surfaces surrounding the ESC building to some extent. Evaluation of the LEED Heat Island credit for shading site hardscape surfaces (SSc-7.1) is ongoing. ESC 100% Title 1 Dwg 748LP1001 illustrates the landscape design for ESC and Dwg 748CS1002 illustrates the development footprint and associated hardscape surfaces for ESC. The ESC design will incorporate a white, cool-roof membrane meeting the Solar Reflectance Index (SRI) requirement of 78 or greater over much of the laboratory spaces. In addition, the standing seam metal roof system over the high bay area will also meet the SRI requirement. Since the entire roofing system will meet the SRI requirement, an Innovation Credit point may also be obtained due to the resulting 100% roof coverage meeting the SRI requirement.

	SD Category	Description of Requirement	Responsible Discipline/ Actions Required/ Status	Features Included in Design
	Light Pollution Reduction (SSc-8)	Adopted measures that reduce the amount of light leaving the site at night.	Electrical Design	The ESC design has limited exterior lighting requirements, due to the absence of a parking area and limited area surrounding the building. The LEED light pollution reduction credit (SSc-8) should be relatively straight forward to achieve. The exterior lighting design for ESC remains under evaluation for LEED credit compliance. The ESC 100% Title 1 design indicates night sky compliant wall-pak metal halide fixtures will be installed over exterior doors.
Energy & Atmosphere (EA)	*Fundamental Commissioning (EAp-1)*	Verify the building's energy related systems are installed, calibrated and operate as intended	Commissioning Authority	Although commissioning specifications have been included in the 100% Title I design phase documents, a commissioning authority has not been identified and the start of commissioning activities has not been established. However, fundamental commissioning of ESC has been identified as an activity to be performed. The LEED fundamental commissioning credit (EAp-1) should be relatively straight forward to achieve.

	SD Category	Description of Requirement	Responsible Discipline/ Actions Required/ Status	Features Included in Design
	Minimum Energy Performance (EAp-2) *Optimize Energy Performance (EAc-1.1/1.10)*	Comply with mandatory provisions and prescriptive requirements of ASHRAE 90.1-2004 1) Results of energy analysis, including projected energy use index (BTU/GSF/yr) of selected design. 2) Performance metrics (such as lighting watts/SF, AFUE, CFM/peak fan kW). 3) Cross Reference with the design basis and design analysis. 4) Summary and Recommendation s	Mechanical Design	The ESC 100% Title 1 design identifies a number of energy efficiency measures incorporating into the building design, including: • HVAC system design with two partial load boilers that match heating capacities; full economizer controls to allow seasonal free-cooling; and high efficiency motors. • Heat pipe heat recovery system to recovery heat from exhaust air for preheating outside air entering the building. • Building envelope design with specification of R-19 wall cavity insulation, R-30 roof insulation; and insulating glass units with thermally broken frames. • Building fenestration design with horizontal mullion extension shading devices. • Occupancy sensors for lighting control in corridors, bathrooms, conference room, break room, and throughout the interior office spaces. An energy conservation report will be prepared for ESC and will be included as an appendix once available. An energy simulation model for ESC has been developed to evaluate energy efficiency opportunities as well as energy performance relative to ASHRAE 90.1-2004 for LEED Optimize Energy Use credit (EAc-1.1/1.10) results. Currently ESC building simulation results (using Trane Trace 700) indicates a 32% reduction compared to ASHRAE 90.1, resulting in 7 of 10 possible LEED points for energy efficiency. The LEED Minimum Energy Efficiency prerequisite (EAp-2) should be relatively straight forward to achieve as ASHRAE 90.1-2004 compliance is a project requirement.

	SD Category	Description of Requirement	Responsible Discipline/ Actions Required/ Status	Features Included in Design
Energy & Atmosphere (EA)	*Refrigerant Management (EAp-3)* *Enhanced Refrigerant Management (EAc-4)*	Reduce use of ozone depleting refrigerants	Mechanical Design	No CFC refrigerants will be specified for ESC HVAC&R systems. As a result, the LEED Refrigerant Management prerequisite (EAp-3) should be straight forward to achieve. The chillers specified for ESC at the 100% Title I design phase will use either R-407-C or R-134A refrigerants. The fire suppression system for ESC is water based. As a result, the Enhanced Refrigerant Management credit (EAc-4) will also be straight forward to achieve. However, calculations demonstrating credit compliance will be required.
	On-Site Renewable Energy (EAc-2.1/2.3)	Implement renewable energy sources	Mechanical Design	The ESC mechanical design team is evaluating the feasibility of implementing a solar hot water heating system for domestic hot water. Details for this evaluation will be included when available. Initial evaluations indicated unfavorable economics; however, a more detailed analysis is ongoing. The LEED On-Site Renewable Energy credit (EAp-2.1/2.3) will not likely be satisfied, as the renewable energy source must account for a minimum of 2.5% of the building energy cost (as determined for EAc-1).

	SD Category	Description of Requirement	Responsible Discipline/ Actions Required/ Status	Features Included in Design
Energy & Atmosphere (EA)	*Enhanced Commissioning (EAc-3)*	Initiate commissioning activities early in the design process and perform additional commissioning activities.	Commissioning Authority	Although commissioning specifications have been included in the 100% Title I design phase documents, a commissioning authority has not been identified and the start of commissioning activities has not been established. Although fundamental commissioning of ESC has been identified as an activity to be performed, initiating commissioning activities prior to development of the construction documents has been identified as an excessive cost element. The ESC design team is currently evaluating the cost associated with enhanced commissioning and the potential for Sandia to perform the enhanced commissioning activities. The LEED Enhanced Commissioning credit (EAc-3) is not likely to be achieved as of 100% Title I design phase.
	Measurement and Verification (EAc-5)	Provide for ongoing accountability of building energy consumption over time	Mechanical Controls Design	Continuous monitoring and control equipment have not yet been defined for such systems as lighting; constant and variable motor loads; variable frequency drive operation; chiller efficiency at variable loads; air and water economizer and heat recovery cycles; air distribution static pressures and ventilation air volumes; boiler efficiencies; building-related process energy systems and equipment; indoor water risers and outdoor irrigation systems. The LEED Measurement and Verification credit (EAc-5) requires development and implementation of an M&V Plan following the International Performance Measurement & Verification Protocol, Volume III: Concepts and Options for Determining Energy Savings in New Construction, April 2003. M&V details for ESC are under development and the requirements for this LEED credit should be evaluated further as the ESC design progresses.

Table C-2. Excerpts from Experimental Sciences Complex's LEED Certification Discussion

Introduction

The Leadership in Energy and Environmental Design for New Construction (LEED-NC) Green Building Rating System™ has become the industry standard for design, construction, and operation of high performance green buildings. The Experimental Sciences Complex project has been registered with the US Green Building Council (USGBC) for certification under version 2.2 of the LEED-NC rating system. The Experimental Sciences Complex project has committed to achieving a minimum certification level of LEED Silver, and to strive for a certification level of LEED Gold. This section of the Sustainable Design report provides the status of progress towards LEED certification for the Experimental Sciences Complex project.

Certification Status

The LEED-NC rating system is a point-based approach to assign a score to a building. A LEED-NC Score Checklist has been developed for the Experimental Sciences Complex project; this will be maintained throughout the design process to track each LEED prerequisite and credit considered applicable to the Experimental Sciences Complex building project (see Table C-3 of this attachment). The LEED-NC Score Checklist shows each prerequisite and credit in the LEED-NC program and a determination for application to the Experimental Sciences Complex project of either "yes", "no", or "potentially" (indicated by a question mark, "?", on the checklist). A "yes" determination indicates all the requirements associated with the credit or prerequisite can and will be satisfied. A "no" determination indicates that one or more specific aspects of the requirements associated with the credit or pre-requisite is either not applicable or simply will not be satisfied by the Experimental Sciences Complex project. A "potentially" (?) determination indicates that the credit or prerequisite could potentially be satisfied, but requires additional evaluation for applicability to Experimental Sciences Complex and ability to satisfy the credit or prerequisite requirements.

> ***Discussion:*** *Table C-3 contains the LEED-NC Score Checklist for the Experimental Sciences Complex*

Potential LEED Points

The Experimental Sciences Complex LEED-NC Score Checklist indicates that a total of 33 points are considered achievable at the 100% Title I design phase of the Experimental Sciences Complex project. The checklist also indicates that another 21 points are considered to be potentially achievable. Although 33 points would achieve a LEED Silver certification level, loss of any credit points due to unforeseen future circumstances (such as changes to the project scope or value engineering measures) could jeopardize the certification level achievable by the project. In addition, the Experimental Sciences Complex project is striving to attain a LEED Gold certification level. Therefore, satisfying at least some of the 21 LEED credit points designated as "potentially" achievable is important to preserving the LEED Silver certification level and essential to obtaining the LEED Gold certification level.

Discussion: *Table C-4 of this attachment lists the additional 21 "potential" LEED credit points and provides an evaluation of the 21 "potential" LEED credit points to determine those considered more likely (greater than 50% probability) to be applicable and achievable by the Experimental Sciences Complex project and those considered unlikely (less than 50% probability) to be applicable and achievable by the Experimental Sciences Complex project. This information helps the Experimental Sciences Complex project team evaluate the ability to achieve a LEED Gold certification level and to determine which potential LEED credit points warrant further evaluation for application and benefit to Experimental Sciences Complex. The information provided in the Sustainable Design Result Matrix. (Table C-1 of this attachment provides the basis for these determinations.)*

TABLE C-3: LEED-NC Checklist

LEED-NC

Experimental Sciences Complex LEED-NC (Ver 2.2) Score Checklist

Experimental Sciences Complex
Sandia National Laboratories/New Mexico

Yes	?	No				
6	5	3	**Sustainable Sites**			**14 Points**
Y			Prereq 1		**Construction Activity Pollution Prevention**	Required
1			Credit 1		**Site Selection**	1
	1		Credit 2		**Development Density & Community Connectivity**	1
		1	Credit 3		**Brownfield Redevelopment**	1
	1		Credit 4.1		**Alternative Transportation**, Public Transportation Access	1
1			Credit 4.2		**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
1			Credit 4.3		**Alternative Transportation**, Low-Emitting and Fuel-Efficient Vehicles	1
1			Credit 4.4		**Alternative Transportation**, Parking Capacity	1
		1	Credit 5.1		**Site Development,** Protect of Restore Habitat	1
		1	Credit 5.2		**Site Development,** Maximize Open Space	1
	1		Credit 6.1		**Stormwater Design,** Quantity Control	1
	1		Credit 6.2		**Stormwater Design,** Quality Control	1
	1		Credit 7.1		**Heat Island Effect,** Non-Roof	1
1			Credit 7.2		**Heat Island Effect,** Roof	1
1			Credit 8		**Light Pollution Reduction**	1

Yes	?	No				
3		2	**Water Efficiency**			**5 Points**
1			Credit 1.1		**Water Efficient Landscaping**, Reduce by 50%	1
		1	Credit 1.2		**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
		1	Credit 2		**Innovative Wastewater Technologies**	1
1			Credit 3.1		**Water Use Reduction**, 20% Reduction	1
1			Credit 3.2		**Water Use Reduction**, 30% Reduction	1

Yes	?	No				
8	5	4	**Energy & Atmosphere**			**17 Points**
Y			Prereq 1		**Fundamental Commissioning of the Building Energy Systems**	Required
Y			Prereq 2		**Minimum Energy Performance**	Required
Y			Prereq 3		**Fundamental Refrigerant Management**	Required

7	2	1	Credit 1	**Optimize Energy Performance**	1 to 10
	1	2	Credit 2	**On-Site Renewable Energy**	1 to 3
	1		Credit 3	**Enhanced Commissioning**	1
1			Credit 4	**Enhanced Refrigerant Management**	1
	1		Credit 5	**Measurement & Verification**	1
		1	Credit 6	**Green Power**	1

continued…

Yes	?	No			
5	3	5	**Materials & Resources**		13 Points
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
		1	Credit 1.1	**Building Reuse**, Maintain 75% of Existing Walls, Floors & Roof	1
		1	Credit 1.2	**Building Reuse**, Maintain 100% of Existing Walls, Floors & Roof	1
		1	Credit 1.3	**Building Reuse**, Maintain 50% of Interior Non-Structural Elements	1
1			Credit 2.1	**Construction Waste Management**, Divert 50% from Disposal	1
1			Credit 2.2	**Construction Waste Management**, Divert 75% from Disposal	1
		1	Credit 3.1	**Materials Reuse**, 5%	1
		1	Credit 3.2	**Materials Reuse**,10%	1
1			Credit 4.1	**Recycled Content**, 10% (post-consumer + ½ pre-consumer)	1
1			Credit 4.2	**Recycled Content**, 20% (post-consumer + ½ pre-consumer)	1
	1		Credit 5.1	**Regional Materials**, 10% Extracted, Processed & Manufactured Regionally	1
	1		Credit 5.2	**Regional Materials**, 20% Extracted, Processed & Manufactured Regionally	1
	1		Credit 6	**Rapidly Renewable Materials**	1
1			Credit 7	**Certified Wood**	1

Yes	?	No			
10	4	2	**Indoor Environmental Quality**		15 Points
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
	1		Credit 1	**Outdoor Air Delivery Monitoring**	1
1			Credit 2	**Increased Ventilation**	1
1			Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
1			Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
1			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
1			Credit 4.2	**Low-Emitting Materials**, Paints & Coatings	1
1			Credit 4.3	**Low-Emitting Materials**, Carpet Systems	1
1			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber Products	1
1			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
1			Credit 6.1	**Controllability of Systems**, Lighting	1
	1		Credit 6.2	**Controllability of Systems**, Thermal Comfort	1
	1		Credit 7.1	**Thermal Comfort**, Design	1

Yes	?	No	Credit	Description	Points
1			Credit 7.2	**Thermal Comfort**, Verification	1
	1		Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
		1	Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes	?	No			
1	4			**Innovation & Design Process**	**5** Points
	1		Credit 1.1	**Innovation in Design**: Provide Specific Title	1
	1		Credit 1.2	**Innovation in Design**: Provide Specific Title	1
	1		Credit 1.3	**Innovation in Design**: Provide Specific Title	1
	1		Credit 1.4	**Innovation in Design**: Provide Specific Title	1
1			Credit 2	**LEED® Accredited Professional**	1

Yes	?	No		
33	21	16	**Project Totals (pre-certification estimates)**	**69** Points

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

TABLE C-4: "Potentially" Applicable Experimental Sciences Complex LEED Credits

LEED-NC Credits Identified as Potentially ("?") Applicable to Experimental Sciences Complex	Probability of Credit Applicability	
	Likely (>50% Possibility)	Unlikely (<50% Possibility)
SSc-2: Development Density & Community Connectivity	1	
SSc-4.1: Alternative Transportation, Public Transportation Access	1	
SSc-6.1: Storm Water Management, Quantity Control		1
SSc-6.2: Storm Water Management, Quality Control		1
SSc-7.1: Heat Island, Non-Roofs	1	
EAc-1.8/1.10: Optimize Energy Performance		2
EAc-2.1: On-Site Renewable Energy		1
EAc-3: Enhanced Commissioning		1
EAc-5: Measurement and Verification		1
MRc-5.1: Regional Materials, 10% Extracted, Processed & Manufactured Regionally	1	
MRc-5.2: Regional Materials, 20% Extracted, Processed & Manufactured Regionally		1
MRc-6: Rapidly Renewable Material		1
EQc-1: Outdoor Air Delivery Monitoring	1	
EQc-6.2: Controllability of Systems: Thermal Comfort	1	
EQc-7.1: Thermal Comfort, Design	1	
EQc-8.1: Daylight & Views: Daylight 75% of Spaces	1	
IDc-1.1/1.4: Innovation in Design	4	
Total	12	9

Note: This table indicates 12 of the 21 "potentially" applicable LEED-NC credit points are considered to have a greater than 50% probability of being satisfied by the Experimental Sciences Complex project. This assumes the Experimental Sciences Complex project will be able to establish all four credits for innovation in design. An additional 12 points would increase the overall score for Experimental Sciences Complex to a total of 45, resulting in a LEED Gold certification level. A target LEED-NC score of 45 points for Experimental Sciences Complex also provides a 6-point cushion for maintaining a Gold certification level in the event unforeseen circumstances eliminate credit points. See Table C-1 of this Attachment for further discussion of each credit point.

DOE G 420.1-1

Approved: 3-28-00

NONREACTOR NUCLEAR SAFETY DESIGN CRITERIA AND EXPLOSIVES SAFETY CRITERIA GUIDE *for use with* DOE O 420.1, FACILITY SAFETY

U.S. DEPARTMENT OF ENERGY

Office of Environment, Safety and Health

Distribution:
All Departmental Elements

Initiated By:
Office of Environment, Safety and Health

FOREWORD

This Guide provides guidance on the application of requirements for nonreactor nuclear facilities and explosives facilities of Department of Energy (DOE) O 420.1, FACILITY SAFETY, Section 4.1, Nuclear and Explosives Safety Design Criteria. The following guidelines were established for the development of this Guide.

- This Guide provides guidance on implementing the requirements stated in DOE O 420.1, Section 4.1, as they apply to the design aspects for nuclear safety of nonreactor nuclear facilities and safety requirements for explosives facilities. The guidance provided in this Guide is restricted to the requirements identified in DOE O 420.1, Section 4.1. This Guide does *not* establish requirements.

- Safety analyses performed in accordance with DOE-STD-3009-94 establish the identification, function, and performance of safety structures, systems, and components (SSCs) and must be conducted early in the design process.

- Applicable current Rules, Standards, and Orders will be referenced herein and text and requirements from these documents will not be repeated.

- Same-subject information will be grouped in a single section and cross referenced elsewhere as required.

- Management and policy requirements will *not* be included in this document.

Throughout this Guide, the words “must” and “should” are used to identify actions that need to be accomplished to meet this guidance. The word “must” denotes actions that are required to comply with this Guide. The word “should” is used to indicate recommended practice (DOE-STD-1075-94).

Users are encouraged to submit suggestions for improving this Guide to the office of Nuclear Safety Policy and Standards.

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GLOSSARY

NOTE: Origins of the definitions are indicated by references shown in brackets, [ ], although in some cases the referenced Orders are being replaced. If no reference is listed, the definition originates in this Guide and is unique to its application. Terms used within this Guide that are not defined in the Glossary carry their definition from the referenced documents.

Accident. An unplanned sequence of events that results in undesirable consequences. [DOE-STD-3009-94]

Accident analysis. For the purposes of properly implementing the Unreviewed Safety Question Order, the term "accident analysis" refers to those bounding analyses selected for inclusion in the Safety Analysis Report. These analyses refer to design basis accidents (DBAs) only. [DOE 5480.21]

Accident analysis has historically consisted of the formal development of numerical estimates of the expected consequence and probability of potential accidents associated with a facility. For the purposes of this Guide, accident analysis is a follow-on effort to the hazard analysis, not a fundamentally new examination requiring extensive original work. As such, it requires documentation of the basis for assignment to a given likelihood of occurrence range (e.g., 1/y to 10^{-2}/y, 10^{-2}/y to 10^{-4}/y, 10^{-4}/y to 10^{-6}/y) in hazard analysis and performance of a formally documented consequence analysis. Consequences are compared with offsite evaluation guidelines to identify safety-class structures, systems, and components. [DOE-STD-3009-94]

ALARA. As low as reasonably achievable.

Confinement barriers.

- **Primary confinement.** Provides confinement of hazardous material to the vicinity of its processing. This confinement is typically provided by piping, tanks, gloveboxes, encapsulating material, and the like, along with any offgas systems that control effluent from within the primary confinement.

- **Secondary confinement.** Consists of a cell or enclosure surrounding the process material or equipment along with any associated ventilation exhaust systems from the enclosed area. Except in the case of areas housing glovebox operations, the area inside this barrier is usually unoccupied (e.g., canyons, hot cells); it provides protection for operating personnel.

- **Tertiary confinement.** Typically provided by walls, floor, roof, and associated ventilation exhaust systems of the facility. It provides a final barrier against the release of hazardous material to the environment.

Construction. Any combination of engineering, procurement, erection, installation, assembly, or fabrication activities involved in creating a new facility or altering, adding to, or rehabilitating an existing facility. It also includes the alteration and repair (including dredging, excavating, and painting) of buildings, structures, or other real property.

Decommissioning. The process of closing and securing a nuclear facility or nuclear materials storage facility to provide adequate protection from radiation exposure and to isolate radioactive contamination from the human environment. [DOE 5480.30]

Decontamination. The act of removing a chemical, biological, or radiological contaminant from or neutralizing its potential effect on a person, object, or environment by washing, chemical action, mechanical cleaning, or other techniques. [DOE 5480.30]

Design basis. Information that identifies the specific functions to be performed by a structure, system, or component of a facility, and the specific values or range of values chosen for controlling parameters as reference bounds of design. These values may be (1) restraints derived from generally accepted "state of the art" practices for achieving functional goals, or (2) requirements derived from analyses (based on calculations and/or experiments) of the effects of a postulated accident for which a structure, system, or component must meet its functional goals. [10 CFR 50.2]

Design basis accident. An accident postulated for the purpose of establishing functional and performance requirements for safety structures, systems, and components. [DOE-STD-3009-94]

Effluent monitoring. The collection and analysis of samples or measurements of liquid and gaseous effluents for the purpose of characterizing and quantifying contaminants, assessing radiation exposures of members of the public, providing a means to control effluents at or near the point of discharge, and demonstrating compliance with applicable standards and permit requirements. [DOE 5400.1]

Evaluation guideline. Radiation dose value against which the safety analysis evaluates. Offsite evaluation guidelines are established for the purpose of identifying and evaluating safety-class structures, systems, and components.

Explosives facility. Any facility or location used for storage or operation with explosives or ammunition.

Facility. For the purpose of this Guide, the definition most often refers to buildings and other structures, their functional systems and equipment, and other fixed systems and equipment installed therein to delineate a facility. However, specific operations and processes independent of buildings or other structures (e.g., waste retrieval and processing, waste burial, remediation, groundwater or soil decontamination, decommissioning) are also encompassed by this definition. The flexibility in the definition does not extend to subdivision of physically concurrent operations having potential energy sources that can seriously affect one another or which use common systems fundamental to the operation (e.g., a common glovebox ventilation exhaust header). [DOE-STD-3009-94]

Fail safe. A design characteristic by which a unit or system will become safe and remain safe if a system or component fails or loses its activation energy.

Hazard. A source of danger (i.e., material, energy source, or operation) with the potential to cause illness, injury, or death to personnel or damage to an operation or to the environment (without regard for the likelihood or credibility of accident scenarios or consequence mitigation). [DOE 5480.23]

Hazard analysis. The determination of material, system, process, and plant characteristics that can produce undesirable consequences, followed by the assessment of hazardous situations associated with a process or activity. Largely qualitative techniques are used to pinpoint weaknesses in design or operation of the facility that could lead to accidents. The Safety Analysis Report hazard analysis examines the complete spectrum of potential accidents that could expose members of the public, onsite workers, facility workers, and the environment to hazardous materials. [DOE-STD-3009-94]

Hazard classification. Evaluation of the consequences of unmitigated releases to classify facilities or operations into the following hazard categories. [DOE 5480.23]

- **Hazard Category 1:** Shows the potential for significant offsite consequences.
- **Hazard Category 2:** Shows the potential for significant onsite consequences.
- **Hazard Category 3:** Shows the potential for only significant localized consequences.

DOE-STD-1027-92 provides guidance and radiological threshold values for determining the hazard category of a facility. DOE-STD-1027-92 interprets Hazard Category 1 facilities as Category A reactors and other facilities designated as such by the Program Secretarial Officer. [DOE-STD-3009-94]

Hazardous material. For the purpose of this Guide, any solid, liquid, or gaseous material that is not radioactive but is toxic, explosive, flammable, corrosive, or otherwise physically or biologically threatening to health.

Nonreactor nuclear facility. Those activities or operations that involve radioactive and/or fissionable materials in such form and quantity that a nuclear hazard potentially exists to the employees or the general public. Included are activities or operations that—

- produce, process, or store radioactive liquid or solid waste, fissionable materials, or tritium;
- conduct separations operations;

- conduct irradiated materials inspection, fuel fabrication, decontamination, or recovery operations;

- conduct fuel enrichment operations; and

- perform environmental remediation or waste management activities involving radioactive materials.

Incidental use and generating of radioactive materials in a facility operation (e.g., check and calibration sources, use of radioactive sources in research and experimental and analytical laboratory activities, electron microscopes, and x-ray machines) would not ordinarily require the facility to be included in this definition. [DOE 5480.23]

Public. All individuals outside the DOE site boundary. [DOE-STD-3009-94]

Risk. The quantitative or qualitative expression of possible loss that considers both the probability that an event will occur and the consequence of that event. [DOE 5480.23]

Safety analysis. A documented process: (1) to provide systematic identification of hazards within a given DOE operation; (2) to describe and analyze the adequacy of the measures taken to eliminate, control, or mitigate identified hazards; and (3) to analyze and evaluate potential accidents and their associated risks. [DOE 5480.23]

Safety Analysis Report. A report that documents the adequacy of safety analysis to ensure that a facility can be constructed, operated, maintained, shut down, and decommissioned safely and in compliance with applicable laws and regulations. [DOE 5480.23]

Safety basis. The combination of information relating to the control of hazards at a facility (including design, engineering analyses, and Administrative Controls) upon which DOE depends for its conclusion that activities at the facility can be conducted safely. [DOE 5480.23]

Single-failure criterion. Safety systems must perform all required safety functions for a DBA in the presence of the following.

- Any single detectable failure within the safety systems concurrent with all identifiable but undetectable failures.

- All failures caused by the single failure.

- All failures and spurious system actions that cause, or are caused by, the DBA requiring the safety function.

The single failure could occur prior to, or at any time during, the DBA for which the safety system is required to function. [ANSI/IEEE Standard 379-1994, Chapter 4]

Site boundary. A well-marked boundary of the property over which the owner or operator can exercise strict control.

ABBREVIATIONS AND ACRONYMS

AC/DC	alternating current/direct current
ACGIH	American Conference of Governmental Industrial Hygienists
ACI	American Concrete Institute
AISC	American Institute of Steel Construction
ALARA	as low as reasonably achievable
ANS	American Nuclear Society
ANSI	American National Standards Institute
API	American Petroleum Institute
ASHRAE	American Society of Heating, Refrigeration, and Air-Conditioning
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
CFR	Code of Federal Regulations
DBA	design basis accident
DoD	Department of Defense
DoDESB	Department of Defense Explosives Safety Board
DOE	Department of Energy
DOE O	Department of Energy Order
DOE G	Department of Energy Guide
DOE-STD	DOE Standard
EIA	Electronic Industries Association
ERDA	Energy Research and Development Administration (predecessor to DOE)
HEPA	high-efficiency particulate air (filter)
IAEA	International Atomic Energy Agency
I&C	instrumentation and control
IEEE	Institute of Electrical and Electronic Engineers
IES	Illumination Engineering Society
ISA	Instrumentation Society of America
MOI	maximally exposed offsite individual
NCRP	National Council on Radiation Protection
NEPA	National Environmental Policy Act
NFPA	National Fire Protection Association
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
NUREG	Nuclear Regulatory Guide
OSHA	Occupational Safety and Health Administration
QA	quality assurance
RAM	reliability, availability, and maintainability
RCRA	Resource Conservation and Recovery Act
SMACNA	Sheet Metal and Air Conditioning Contractors National Association
SSC	structures, systems, and components

1. INTRODUCTION

1.1 General

This Implementation Guide provides an acceptable approach for satisfying the requirements of Department of Energy (DOE) Order (O) 420.1, Facility Safety, Section 4.1, Nuclear and Explosives Safety Design Criteria. The objective of the Guide is to provide a methodology for selecting industry codes and standards for nuclear safety aspects of nonreactor nuclear facility design. The Guide stresses that safety design should be driven by safety analysis and provides interpretive guidance on the performance-level requirements of the Order. A successful safety design depends on the quality of the safety analysis and on engineering judgment in the transformation of this guidance to the final design.

This Guide is not intended to be all inclusive with respect to the nuclear/radiological safety requirements and guidance for designing a DOE nonreactor nuclear facility. Where other DOE Orders, Rules, and national and industry codes and standards contain requirements and supporting guidance pertaining to safety of nuclear facilities, such guidance will not be repeated in this document. Instead, a short discussion will point to the relevant document. Examples are found in the areas of natural phenomena hazards mitigation, fire protection, criticality safety, and explosives safety.

1.2 Applicability

The requirements of DOE O 420.1, Section 4.1, are applicable to the design and construction of new nonreactor nuclear facilities and for modifications to existing nonreactor nuclear facilities when the modifications significantly increase the probability or consequence of a nuclear accident or require a change in the Technical Safety Requirements of a facility. It is intentionally left to the judgment of the proposing contractor and the approving DOE authority to define "significant." In part, this is intended to allow upgrading of existing safety equipment or installation of minor new improvements without subjecting the process to onerous procedural requirements and thus discouraging improvements.

Modifications to facility design and construction during the design and construction phase must conform to the design requirements for new facilities.

All new construction must, as a minimum, conform to the model building codes applicable for the state or region, supplemented with additional safety requirements associated with the hazards in a facility in a graded manner.

1.3 Content

This Guide is structured to represent the progressive logic of design. Section 1, Introduction, provides a general statement regarding the intent and applicability of the Guide. The following sections provide guidance for nuclear safety design concepts or assurances, elements of design for nuclear safety, functional design criteria, and criteria for safety structures, systems, and components (SSCs).

Contained within Section 2, Safety Analysis and Design Process, are nuclear safety design concepts that when implemented along with specific criteria should ensure a safe facility design. This section addresses the importance of starting the safety analysis as early as possible in the design and maintaining an interrelationship between the design process and the safety analysis, as they both evolve. The section provides explicit guidance for the application of the offsite evaluation guideline for the proper classification of safety class SSCs. Other concepts addressed under this section are defense in depth, system engineering, and quality assurance (QA). These are nuclear safety design concepts and strategies to be applied at the beginning and throughout the design process to ensure safety concerns are addressed and incorporated into the design as necessary.

Section 3, Elements of Design for Nuclear Safety; Section 4, Functional Design Criteria; and Section 5, Supplementary Design Criteria for Safety Structures, Systems, and Components, describe specific criteria that are to be applied, as applicable, to the facility under design. The guidance within these sections relates to safety as it applies to the overall facility and its impact on facility design.

Section 3 addresses nuclear safety criteria that should be considered during the design process such as siting, natural phenomena, architecture, accessibility and maintainability, human factors, and decontamination and decommissioning.

Section 4 is more specific to the safety function(s) that are to be performed within or by the facility under design. These nuclear safety criteria include nuclear criticality, radiation protection, hazardous material protection, effluent monitoring and control, waste management, fire protection, emergency preparedness and emergency communications, and explosives criteria and their applicability to the safety of the facility, depending on the function or mission of the facility.

Section 5 provides guidance for specific criteria requirements for the SSCs that are identified, via the safety analysis, to function as safety-class or safety-significant SSCs. These criteria are applied to those specific elements within the facility.

1.4 Compliance with DOE O 420.1 Requirements

This section provides a correlation of the requirements contained in DOE O 420.1, Section 4.1, to this Guide. The objectives of DOE O 420.1, Section 4.1, Nuclear Safety, are covered in the Introduction section defining the intent and applicability to DOE design activities.

The requirements for the development process of the safety analysis are set forth in DOE O 420.1, Section 4.1.1.1, General Requirements. Also contained in DOE O 420.1, Section 4.1.1.1, and DOE O 420.1, Section 4.1.1.2, Design Requirements, are the requirements pertaining to the implementation of defense in depth and the quality level requirements for facility design and construction. Section 2, Safety Analysis and Design Process, of this Guide provides guidance for performing the safety analysis and maintaining an interrelationship with the design process. This Guide section also contains guidance for nuclear safety design concepts such as defense in depth, system engineering, and QA to meet the requirements set forth in DOE O 420.1, Section 4.1.

Guidance for the additional nuclear safety design requirements set forth in Section 4.1.1.2 of DOE 420.1 are addressed in detail in Section 3, Elements of Design for Nuclear Safety, Section 4, Functional Design Criteria, and Section 5, Supplementary Design Criteria for Safety Structures, Systems, and Components, of this Guide. Requirements related to the overall facility design (e.g., siting; natural phenomena; architecture; reliability, accessibility, and maintainability; and decontamination and decommissioning) are provided in Section 3 of this Guide. Section 4of this Guide provides guidance to meet the nuclear safety functional requirements of DOE O 420.1, Section 4.1.1.2, as they pertain to as low as reasonably achievable (ALARA), waste management, and other functional operations. The guidance to meet the requirements for safety SSCs to be designed so they can perform their safety functions when called upon to operate and to be designed and fabricated under a QA program as defined in Section 4.1.1.2 of DOE O 420.1 are addressed in Section 5 of this Guide.

Guidance to comply with the requirements contained in Section 4.1.2, Explosives Safety, of DOE O 420.1, Section 4.1, are provided in Section 4.8, Explosives Criteria, of this Guide.

2. SAFETY ANALYSIS AND DESIGN PROCESS

2.1 Design Process and Safety Analysis Relationship

In this section, the relationship between the facility design process and the parallel development of the facility safety analysis is discussed. Continuous coordination is necessary between these two activities throughout the project to ensure that the final design meets the mission requirements and includes the required safety features and to ensure that the principles of integrated safety management systems as described in DOE P 450.4 and DOE G 450.4-1A are implemented. The safety analysis must be performed in accordance with the guidance in DOE-STD-3009-94 and the requirements of DOE 5480.23 to develop and validate the functional and performance requirements for the safety SSCs. One of the objectives of the hazard and accident analyses is to identify the complete suite of safety SSCs for a facility and to designate them as safety class or safety significant, as appropriate to their importance and role. From the Introduction to DOE-STD-3009-94, the techniques for hazard analysis provide methodologies for comprehensive definition of the accident spectrum for workers and the public. Throughout the evaluation process, preventive and mitigative SSCs and pertinent elements of programmatic controls are identified. This identification also establishes functional requirements for SSCs, which will subsequently delineate the technical information needed to establish performance criteria. The most significant aspects of defense in depth and worker safety are subject to definition as safety-significant SSCs and coverage by Technical Safety Requirements. Safety-class designation is reserved for SSCs needed for public protection and carries with it the most stringent requirements. Demonstration of compliance with the nuclear facility design requirements of DOE O 420.1 in accordance with the guidance for performing safety analyses DOE-STD-3009-94 (Chapters 3 and 4 of the Standard) and this Implementation Guide must be shown in the Preliminary Safety Analysis Report (or a Safety Analysis Report for significant modifications to existing facilities), DOE approval of which must be received before construction can begin.

Selection and design of safety SSCs is an important part of the overall facility design process. As the facility design progresses from conceptual design through the finalization of design, designers and safety analysts must exchange information in an iterative process. Early in the conceptual design, a hazard analysis must be conducted based on the anticipated physical and chemical processes to be used in support of the overall facility mission, external human-induced hazards, and natural phenomena hazards. The hazards associated with processes may influence the design (e.g., alternative physical layouts, segmentation of facilities to isolate particularly hazardous processes, or the use of multistage or parallel processes to reduce the hazardous material in any particular process step). Natural phenomena hazards must be considered in accordance with DOE O 420.1, Section 4.4, Natural Phenomena Hazards Mitigation, and the associated Guide. External human-induced hazards peculiar to the site (such as pipelines and hazardous materials storage) must be considered.

The results of the hazard analysis must be used to identify the design basis accidents (DBAs) that in turn must be used to define the functional and performance requirements of the facility safety

SSCs. Safety SSCs required to prevent or mitigate accidents whose consequences approach or exceed offsite evaluation guidelines must be defined as safety-class SSCs. Safety-significant SSCs must be selected for worker protection and to provide defense in depth.

The defense-in-depth concept, described in Section 2.3 of this Guide, must be integrated into the facility design process. The application of the defense-in-depth concept to the facility design will help identify potential safety features to be included in the facility design. Consideration should be given to prevent or mitigate accident consequences from contaminating the environment, even when direct public or worker safety is not an issue.

Sufficient hazard and accident analyses must be completed during the preliminary design to verify and finalize the selection of safety SSCs. These hazard and accident analyses must be sufficiently complete to determine the design environmental and load conditions for safety SSCs. Accident analysis examines a limited subset of accidents (DBAs) derived from the hazard analysis. The accident analysis forms the basis for evaluating the ability of the safety SSCs to perform their safety functions. The identification of DBAs is therefore based on the hazard analysis to ensure that a reasonable spectrum of potential accidents are considered for the design. DBAs should be analyzed conservatively using the applicable deterministic phenomonological methods. During the design process, the accident analysis should also be used to establish design requirements that minimize or eliminate potential hazards. Therefore, prevention and control of potential hazards through early and iterative interaction with the design process should be a primary objective of the hazard and accident analyses.

2.1.1 Functional Classification of Safety SSCs

In Sections 2.1.2 and 2.1.3 the classification of safety SSCs as safety class or safety significant is discussed. The concept of using an evaluation guideline for identifying safety class SSCs is introduced. The use of the evaluation guideline is only one element in a larger safety SSC functional classification process that is intended to contribute to "adequate safety." Other operational contributors are disciplined conduct of operations, training, and safety management programs such as a radiation protection program, emergency response program, etc. Some principles that should be incorporated in a functional classification process are:

- Protection of the public is contributed to by all facets of safety in design, including safety class SSCs as well as safety significant SSCs, and, in many DOE cases, by remote siting. The expectation is that public design basis accident dose consequences (considering the protection provided by safety systems) would generally be a small fraction of the evaluation guideline.

- Protection of the public is predominant in safety design; protection of workers is no less important. However, the degree of protection for facility workers achievable by SSCs is limited. Other factors such as disciplined conduct of operations, training, and safety management programs are no less important in assuring worker safety.

- In prioritization of items for a facility safety strategy:

  - Minimization of hazardous materials (material at risk) is the first priority.
  - Safety SSCs are preferred over Administrative Controls.
  - Passive SSCs are preferred over active SSCs.
  - Preventative controls are preferred over mitigative controls.
  - Facility safety SSCs are preferred over personal protective equipment.
  - Controls closest to the hazard may provide protection to both workers and the public.
  - Controls that are effective for multiple hazards can be resource effective.

2.1.2 Application of Offsite Evaluation Guidelines for Safety-Class SSCs

A computational construct using the concepts of an unmitigated accident release and an evaluation guideline has been developed to aid in the designation of safety class SSCs. The process uses the same initiating events as identified in the hazard and accident analyses discussed in Section 2.1, but for the purposes of showing which SSCs are sufficiently important to classify as safety class, it presumes that the candidate safety systems are not functional (unmitigated release). Other parameters of the analyses should conservatively reflect physical realities; e.g., energies driving the release, release fractions, etc. If the resulting site boundary dose approaches the evaluation guideline, then the candidate SSCs need to be evaluated to see if their effectiveness in preventing or mitigating the accident justifies one or more of them being designated as safety class. These analyses and evaluations should be retained as backup information to support the designations of safety class SSCs.

The evaluation guideline has been set at 25 rem total effective dose equivalent. The dose estimates compared to it are those which would be received by a hypothetical maximally-exposed individual at the site boundary from an unmitigated accidental release of radionuclides during a finite period, nominally 2 hours, but no longer than 8 hours. The time limitation is solely for the purpose of limiting the calculation to time periods for which a significant release rate might be expected and to provide a stable basis for the calculation. The 25 rem level was chosen to be representative of a potential release that could impact the offsite public and warrant special consideration of preventative and mitigative measures. The intended function of the evaluation guideline is strictly to identify safety SSCs that should be given the special designation of safety class and be subject to more rigorous design criteria as described in Section 5 of this Guide. Because of uncertainties in analysis and design parameters before final design, the 25 rem value should not be regarded as a “bright line.” If unmitigated dose results are in the rem range, then serious consideration should be given to identifying related safety SSCs as safety class. In most cases it will be found that mitigating safety class SSCs effectively reduce offsite doses far below 25 rem. Especially considering this, it should emphatically be understood that 25 rem is not an acceptance criterion for safety design.

If a postulated bounding accident for any accident scenario type could be expected to occur during facility operations, then, in addition to the evaluation guideline discussed above, it must also be considered as part of normal operations, which is governed by 10 CFR 835, Occupational Radiation Protection; unintended releases of sufficiently high frequency as considered a part of normal operations would also be governed by this regulation. This is not to imply, however, that safety SSCs should be identified based on compliance with 10 CFR 835. Any accidents that have a significant consequence potential to the public or workers, independent of likelihood, must be thoroughly evaluated, including the identification of appropriate safety SSCs and Administrative Controls.

The relevant factors for dose calculation are discussed below, and guidance is given for each.

Dose Calculation Location

For the purposes of comparison to the evaluation guideline, the comparison point is taken to be the location of a theoretical maximally exposed offsite individual (MOI) standing at the site boundary. This location can also be beyond the DOE site boundary if a buoyant or elevated plume is not at ground level at the DOE site boundary. In such cases, the calculation location is taken at the point of maximum exposure, typically where the plume reaches ground level. With regard to members of the public who may be on-site, DOE's position on this issue is that individuals on-site, both workers and public, come under the emergency response plans and capabilities of the site. This protection, along with implementation of defense-in-depth and worker safety philosophy through safety SSCs and DOE's safety management programs address on-site safety. However, an annual assessment of any changes in the site boundary and potential effects on safety SSC classification should be performed, in association with the required annual update of the Safety Analysis Report for a facility. These may be affected by privatization and site turnover initiatives.

Atmospheric Dispersion

The 95th percentile of the distribution of doses to the MOI, accounting for variations in distance to the site boundary as a function of direction, is the comparison point for assessment against the evaluation guideline. The method used should be consistent with the statistical treatment of calculated X/Q values described in regulatory position 3 of Nuclear Regulatory Commission (NRC) Regulatory Guide 1.145 for the evaluation of consequences along the exclusion area boundary. The determination of distance to the site boundary should be made in accordance with the procedure outlined in position 1.2 of Regulatory Guide 1.145. NRC Regulatory Guide 1.23 presents acceptable means of generating the meteorological data upon which dispersion is based. Accident phenomenology may be modeled assuming straight-line Gaussian dispersion characteristics, applying meteorological data representing a 1-hour average for the duration of the accident. Accident duration is defined in terms of plume passage at the location of dose calculation, for a period not to exceed 8 hours. Prolonged effects, such as resuspension, need not be modeled. It is important to note, however, that the calculation requires MOI immersion in the main body of the plume for a period representative of its passage (subject to the 8-hour restriction). The accident progression should not be defined so that the MOI is not substantially exposed (i.e., using a release rate that is specifically intended to expose the MOI to only a small fraction of the total material released, or defining time and windspeed so that the plume has not reached the MOI). The exposure period begins from the time the plume reaches the MOI.

For ground releases, the calculated dose equates to the centerline dose at the site boundary. For elevated, thermally buoyant, or jet releases, plume touchdown may occur beyond the site boundary. As noted in the discussion of receptor location, these cases should locate the dose calculation at the point of maximum dose beyond the site boundary, which is typically at the point of plume touchdown.

Accidents with unique dispersion characteristics, such as explosions, may be modeled using phenomenon-specific codes more accurately representing the release conditions. Discussion should be provided justifying the appropriateness of the model to the specific situation. For accident phenomena defined by weather extremes, actual meteorological conditions associated with the phenomena may be used for comparison to the evaluation guideline.

Source Term

The radioactive airborne source term is typically estimated as the product of five factors: (1) material-at-risk, (2) damage ratio, (3) airborne release fraction, (4) respirable fraction, and (5) leakpath factor. Detailed discussion of these parameters is provided in DOE-HDBK-3010-94, *Airborne Release Fractions/Rates and Respirable Fractions for Nonreactor Nuclear Facilities*.

Material-at-Risk. The material-at-risk values used in hazard and accident analysis should represent documented maximums for a given process or activity. While DOE-STD-1027-92, Change 1, September, 1997 excludes material in qualified containers from consideration for the purposes of hazard classification, such material can be excluded in the source term for the applicable accident scenarios, only if the containers can be shown to perform their functions under the accident environments (per the Standard).

Damage Ratio. The damage ratio is that fraction of material actually impacted by the accident-generated conditions. DOE-HDBK-3010-94 notes that some degree of ambiguity can result from overlapping definitions of material at risk and damage ratio in various applications. One consistent means of definition should be used throughout.

Airborne Release Fractions and Respirable Fractions. Bounding estimates for radionuclide airborne release fractions and respirable fractions for a wide variety of material at risk and release phenomena are systematically presented in DOE-HDBK-3010-94. In those cases where there may be significant direct shine contribution to dose, that contribution should be evaluated without use of the respirable fraction.

Leakpath Factor (LPF). The leakpath factor is the fraction of material passing through some confinement deposition or filtration mechanism. Several leakpath factors may be associated with a specific accident; e.g., fraction passing from a glovebox, fraction passing from a room, fraction passing through filtration vis-a-vis door leakage. (For unmitigated accident calculations, LPF = 1.0.)

2.1.3 Safety-Significant SSCs

The following paragraphs constitute the definition of safety significant SSCs as first presented in DOE-STD-3009-94. Together with the discussions of defense in depth of Section 2.3 of this Guide, they provide guidance for the identification of safety significant SSCs.

Safety-significant structures, systems, and components (safety-significant SSCs) are structures, systems, and components not designated as safety-class SSCs, but whose preventive or mitigative function is a major contributor to defense in depth (i.e., prevention of uncontrolled material releases) and/or worker safety as determined from hazard analysis.

As a rule of thumb, safety-significant SSC designations based on worker safety are limited to those systems, structures, or components whose failure is estimated to result in a prompt worker fatality or serious injuries (e.g., loss of eye, loss of limb) or significant radiological or chemical exposures to workers. This rule of thumb is neither an evaluation guideline nor a quantitative criterion. It represents a threshold of concern for which safety-significant SSC designation may be warranted. Estimates of worker consequences for the purpose of a safety-significant SSC designation are not intended to require detailed analytical modeling, due to the uncertainties in analyses, especially for facility workers. Considerations should be based on engineering judgment of possible effects and the potential added value of safety-significant SSC designation. Experience has shown that safety-significant SSCs identified through defense-in-depth considerations also provide safety for workers.

2.2 External Design Constraints

The primary inputs for facility design include the DOE mission requirements, DOE O 420.1, and externally imposed regulatory inputs from Federal [e.g., Occupational Safety and Health Administration (OSHA), Environmental Protection Agency, etc.], State, and local governments where the facility is located (e.g., a stack monitor to record releases to comply with local environmental monitoring requirements), and DOE O 430.1A, LIFE CYCLE ASSET MANAGEMENT, which calls for the use of national consensus codes and standards. As a minimum, design and construction must conform to the model building codes applicable for the state or region, supplemented with additional safety requirements associated with the hazards in the facility in a graded manner.

2.3 Defense in Depth

Defense in depth includes conservative siting, minimization of material at risk, the use of conservative design margins and QA, the use of successive physical barriers for protection against the release of hazardous materials, the provision of multiple means to ensure critical safety functions (those basic safety functions needed to control the processes, maintain them in a safe state, and to confine and mitigate hazardous materials associated with the potential for accidents with significant public impact), the use of equipment and Administrative Controls which restrict deviations from normal operations and provide for recovery from accidents to achieve a safe condition, means to monitor accident releases required for emergency response, and the provision of emergency plans for minimizing the effects of an accident.

With respect to factors within the influence of the facility designer, defense in depth is a safety design concept or strategy that must be applied at the beginning and maintained throughout the facility design process. This safety design strategy is based on the premise that no one layer of protection is completely relied upon to ensure safe operation. By applying this safety strategy, the DOE O 420.1 objective of providing multiple layers of protection to prevent or mitigate an unintended release of radioactive material to the environment can be achieved. Conceptually, there are three levels of defense in depth.

The first level of defense consists of a well-designed facility with process design to reduce source terms, reliable SSCs that are simple to operate and maintain and resistant to degradation, and personnel well trained in operations and maintenance and committed to a strong safety culture.

The second level recognizes that failures of systems and components and human failures cannot be entirely eliminated and that protective features (e.g., engineering design features and Administrative Controls) are required. These features are provided to ensure a return to normal operation or to bring the facility to a safe condition in the event of postulated abnormal events. These features may provide automatic system response to such events or may be monitors that alert operators to the necessity of taking manual action. Such response to off-normal conditions can effectively halt the progression of events toward an accident.

The final level of defense consists of conservatively designed safety SSCs to prevent or mitigate the consequences of accidents that may be caused by errors, malfunctions, or by events that occur both internal and external to the facility.

The following are elements of defense-in-depth related to safety design and construction that must be objectives during the design process.

- **Siting.** Consider site locations that reduce the need to provide design measures to alleviate potentially hazardous conditions or to protect surrounding populations. For example, consideration of ground instability, flooding, and hazards due to nearby installations or activities.

- **Material at risk.** Apply facility and process design and Administrative Controls to minimize and control inventories of radioactive materials and their forms.

- **Conservative design.** Design conservative margins that may allow operations to deviate from normal conditions before requiring corrective actions and taking into consideration the potential degradation of elements and operational errors.

- **Quality assurance (QA).** Use QA practices for the design and construction of safety SSCs whose stringency is commensurate with anticipated hazards, including but not limited to the assurance of qualified design and construction personnel, traceability of design decisions and procurements, and documentation of changes in design and construction.

- **Physical barriers.** Design physical barriers to confine radioactive material and thereby prevent uncontrolled releases.

- **Critical safety functions.** Design to provide multiple ways for safety functions to control processes, to maintain processes in a safe state, and to confine radioactivity when accidents could have the potential for significant public radiological impact.

- **Equipment and Administrative Controls.** Include features to control process variables to values within safe conditions, to alert operating personnel of an approach toward conservative process limits, to allow timely detection of failure or malfunction of critical equipment, and to allow for the imposition of Administrative Controls assumed in the hazard analysis, and/or accident analysis.

- **Emergency features.** Include alarms and monitors to alert workers and the public to the existence of unsafe conditions and to record the sequence and severity of an accident. Evacuation considerations incorporated into the facility design are to be coordinated with the development of the emergency plan.

The detailed design criteria requirements for these defense-in-depth elements that must be used are defined in Section 3, Elements of Design for Nuclear Safety; Section 4, Functional Design Criteria; and Section 5, Supplementary Design Criteria for Safety Structures, Systems, and Components, of this Guide.

2.4 Systems Engineering

The systems engineering process covers a broad range of activities that involves the design and management of a total facility. For the purpose of this Guide, the focus will be on those elements of systems engineering that relate to nuclear safety and should be considered as part of the overall facility system engineering activities. The systems engineering activities relating to nuclear safety include the following:

- identifying and integrating facility nuclear safety requirements;

- coordinating multidisciplinary teamwork in implementing facility safety requirements;

- providing nuclear safety-related interface management;

- providing configuration management to include the establishment of baseline configuration; and

- coordinating technical reviews of the facility nuclear safety features.

The application of systems engineering activities to the nuclear safety aspects of facility design should be graded and commensurate with the facility hazards and complexity. The goal is to ensure that the systems engineering activities include consideration of the appropriate facility safety features. Electronic Industries Association Interim Standard, System Engineering, and the applicable Guides for DOE O 430.1A should be used for guidance in developing systems engineering actives to enhance the facility safety design.

2.5 Quality Assurance

As required by 10 CFR 830.120, Quality Assurance Requirements, nuclear facilities must develop and implement a QA program that meets the requirements contained therein. Supplemental information and acceptable methods for implementing these requirements are found in Implementation Guide For Use with 10 CFR 830.120, G-830.120. QA encompasses all those planned and systematic actions and controls necessary to ensure that risk to the public health and safety and the environment are controlled and that the safety, reliability, and performance are realized through the application of effective management systems. The "graded approach" should be applied when identifying QA requirements for SSCs; that is, the scope and breadth of the requirements contained within the QA program should be adjusted to reflect the importance of the safety function of the SSCs.

The degree of implementation of the QA Program should evolve concurrently with the project through its life cycle. Specifically, the QA requirements identified for the design, fabrication, construction, and modification of an SSC must be documented and supported by the facility's safety analysis.

Document and change control for project design documents and supporting documentation must be provided by the design activity during the design. By the start of construction, document and change control must be provided by an appropriate QA configuration management program. Subsequent changes to project design and supporting documents must be made by means of a formal change control program in accordance with 10 CFR 830.120. Additional QA criteria for safety SSCs are found in Section 5, Supplementary Design Criteria for Safety Structures, Systems, and Components, of this Guide.

3. ELEMENTS OF DESIGN FOR NUCLEAR SAFETY

3.1 General

This section provides design guidance and identifies key documents that contain safety design requirements for the design and construction of DOE nonreactor nuclear facilities. The predominant model building codes in the region must govern on issues not covered in this Guide. Section 4.2, Fire Protection, of DOE O 420.1 must apply for fire protection and life safety criteria.

When developing the safety aspects of the facility design, there is a logical sequence of design considerations to follow. First, the radioactive and/or hazardous material inventory should be minimized and material forms considered. Next, conservative design margins should be applied as appropriate. Finally, appropriate preventive and mitigative features should be considered. Successful application of these principles and features into the facility design will result in a safe facility design.

3.1.1 Radioactive and/or Hazardous Material Inventory

The basic and most effective means of controlling the hazards inherent in the facility is the restriction of inventories and forms of radioactive and/or hazardous materials. Emphasis should be placed on limiting the quantities of radioactive and/or hazardous materials in both process and storage areas. Material may be rendered less hazardous by maintaining it in more stabilized and less dispersible forms. For example, a quantity of plutonium stored in metal form presents less of a hazard than the same quantity stored in its oxide form.

3.1.2 Conservative Facility Design

The next area of emphasis should be conservative design margins that account for deviations from normal process parameters. The facility design also should accommodate means such as monitors and automatic and manual controls to restrict deviations from normal operations and to assist recovery during the early stages of an accident sequence. Conservative design features apply to safety SSCs as described in Section 5.1.1.1 of this Guide.

3.1.3 Preventive Features

To prevent abnormal facility conditions from progressing to accidents, preventive features should be considered in the design. The objective of these features is to provide a return to normal operation or return to a safe condition. These features may provide automatic system response to such events or may be monitors that alert operators to the necessity of taking manual action. Such response to off-normal conditions can effectively halt the progression of events toward an accident.

3.1.4 Mitigating Features

Safety SSCs must be provided to mitigate consequences of accidents that may still occur despite the application of the preceding conventions. The safety SSCs must be identified through the safety analysis (see Section 2.1 of this Guide).

3.2 Siting Criteria Development

The following factors should be considered in determining facility site suitability and in establishing facility safety design criteria:

- the site boundary and land-use characteristics of the site surroundings, including properties at risk from accidental exposures, public exclusion zones (access control), population-center distances, and population density;

- proximity of services such as the fire department and emergency medical centers;

- utility systems essential to support safety class SSCs;

- physical characteristics of the site, including topography, meteorology, and hydrology;

- geological and subsurface elements such as earthquake loading, soil bearing design capacity, rock or other bearing stratum, and groundwater elevations;

- natural phenomena hazards as discussed in Section 3.3, Natural Phenomena Hazards, of this Guide and DOE O 420.1, Section 4.4, Natural Phenomena Hazards Mitigation, including seismic activity, wind, hurricane, tornado, flood, hail, volcanic ash, lightning, and snow;

- emergency response considerations, including population sheltering or shielding parameters and evacuation delay times and rates for the public and colocated workers;

- potential human-induced hazards from nearby facilities or activities such as industrial and military facilities, aircraft impacts, pipelines, and transportation routes;

- proximity and hazard to other facilities (from the proposed facility); and

- site-related assumptions of the Environmental Impact Statement.

For the purpose of this Guide, a radiological siting criterion of 25 rem, 50-year total effective dose equivalent must be used, from releases over the course of postulated design basis accidents from uptakes at the site boundary that could be delivered during a one year period.

3.3 Natural Phenomena Hazards

3.3.1 General Application

Safety SSCs must be designed and constructed to withstand the effects of natural phenomena hazards. Fundamental requirements for natural phenomena hazards are specified in the regional model building codes. The natural phenomena design requirements for safety SSCs as specified in DOE O 420.1, Section 4.4, and the associated DOE Standards must apply to safety SSCs as determined by the methodology described in DOE-STD-3009-94. The safety-class or safety-significant designation is the basis for selecting the specified natural phenomena design requirements found in the referenced DOE Standards.

3.3.2 Primary Applicable Requirements

- DOE O 420.1, Section 4.4, and its Guide
- DOE-STD-1020-94, *Natural Phenomena Hazards Design and Evaluation Criteria for Department of Energy Facilities*
- DOE-STD-1021-93, *Natural Phenomena Hazards Performance Categorization Guidelines for Structures, Systems, and Components*
- DOE-STD-1022-94, *Natural Phenomena Hazards Site Characterization Criteria*
- DOE-STD-1023-95, *Natural Phenomena Hazards Assessment Criteria*
- DOE-STD-1024-92, *Guidelines for Use of Probabilistic Seismic Hazard Curves at Department of Energy Sites for Department of Energy Facilities*

3.3.3 Other Considerations

Design considerations for volcanic eruption and ash fall, lightning strikes, range fires, snow loads, and extreme temperatures are not provided in DOE O 420.1, Section 4.4, and other associated standards. Criteria for the assessment and mitigation of these hazards must be developed on a site-specific basis and approved by DOE prior to use. Lightning protection systems must be considered for buildings and structures that contain, process, and store radioactive, explosive, and similarly hazardous materials. Lightning protection systems must be designed to comply with National Fire Protection Association (NFPA) 780. (See DOE O 420.1, Sections 4.3 and 4.4.)

Design considerations should be given to the interaction of more than one event, particularly those more likely to occur simultaneously. For example, heavy rains usually accompany tornadoes or high winds; excessive roof loads may result from rain and accumulated volcanic ash; and upstream dams may fail due to seismic events.

3.4 Architectural

The type and level of hazards should be determined for each functional area, the attendant degree of risk established, and the possibility of cross contamination considered. Wherever possible, work areas with compatible contaminants should be located together to simplify design criteria related to air supply and exhaust, waste disposal, decontamination, and cross contamination.

Radioactive and hazardous material contamination control requirements should be considered in the design to minimize the potential for contamination spread.

Office areas should be located in common-use facilities (e.g., data computation and processing, word processing, etc.) and away from process areas to minimize risks to workers of exposure to radioactive and/or hazardous materials.

3.4.1 Building Layout

The building layout should provide protection from the hazards associated with handling, processing, and storing of radioactive and/or hazardous materials. In addition, the following items should be considered in the facility safety design.

- Additional space should be provided for temporary or additional shielding in the event radiation levels are higher than anticipated.

- The arrangement and location of hazardous process equipment and its maintenance provisions should provide appropriate protective and safety measures as applicable.

- The building design should accommodate prompt return to a safe condition in emergencies and allow ready access for and protection of workers in areas where manual corrective actions are required and in areas that contain radiation monitoring equipment readouts.

- Facility layout should provide specific control and isolation, if possible, of quantities of flammable, toxic, and explosive gases, chemicals, and other hazardous materials admitted to the facility.

3.4.2 Access Control

The facility design should accommodate the requirements for safeguards and security, emergency egress, and area access control for worker protection. Where these requirements may appear to conflict, life safety must take precedence. For example, safeguards and security requirements would minimize the number of entrances and exits, but for worker safety, the emergency-egress requirements would provide an adequate number of exits. Specific requirements for access control must be implemented as specified by 10 CFR 835 for radiological hazards, by the Resource Conservation and Recovery Act (RCRA) for hazardous waste treatment, storage, and disposal facilities, and by 29 CFR 1910 and 1926 (OSHA) for hazardous material locations within operating facilities and construction sites.

Where access control is provided for control rooms that contain safety-class SSC controls and monitoring, the same level of qualification must be considered for the access control features. Access controls must not prevent operator actions required to achieve and maintain a facility in a safe condition.

3.5 Accessibility and Maintainability

Section 4.1.1.2 of DOE O 420.1 requires that facilities be designed to facilitate inspection, testing, maintenance, and repair and replacement of safety SSCs to assure their continued function, readiness for operation, and accuracy. The facility design must include provisions for accessibility and maintainability that include but are not limited to the following:

- Surveillance equipment should be located and sufficient space provided for relative ease of routine testing and maintenance activities.
- Accessible inspection covers to allow for visual inspection should be provided and located such that necessary routine inspections can be conducted with minimum disruption to the facility or equipment operation. Examples include ducting and process piping systems.
- The facility design should include features that provide for ease of routine maintenance without a subsequent mission reduction. Examples include providing sufficient clearance around equipment to accommodate change out of large components and providing permanent ladder(s) and platform(s) access to lubrication and equipment areas.

A Reliability, Availability, and Maintainability (RAM) program should be established in accordance with the guidance of DOE RELIABILITY, AVAILABILITY, AND MAINTAINABILITY GUIDELINES (Draft) and graded as to the complexity and hazards of the facility. The purpose of a RAM program is to help ensure that the project will be free of RAM-related problems that could prevent achieving health, safety, environmental, performance, schedule, and economic goals.

3.6 Human Factors Engineering

Appropriate human factors engineering principles and criteria should be integrated into the design, operation, and maintenance of DOE facilities. The human factor elements that should be considered include, but are not limited to, the following: equipment labeling, workplace environment (temperature and humidity, lighting, noise, vibration, and aesthetics), human dimensions, operating panels and controls, component arrangement, warning and annunciator systems, and communication systems. The applicable criteria found in Nuclear Regulatory Guide (NUREG) 0700, MIL-STD-1472D [Department of Defense (DoD)], and American

National Standards Institute (ANSI)/Institute of Electrical and Electronic Engineers (IEEE) 1023 should be considered in the design of these elements.

3.7 Design to Facilitate Deactivation, Decontamination, and Decommissioning

3.7.1 Deactivation

Deactivation is the process of removing hazardous materials and neutralizing hazardous conditions at the end of a facility's life or mission prior to decontamination and decommissioning. Design to facilitate deactivation would incorporate facility features that aid in the removal of surplus radioactive and chemical materials; storage tank cleanout and maintenance; stabilization of contamination and process materials; and the removal of hazardous, mixed, and radioactive wastes. In general, these features would reduce the physical risks and hazards associated with facility decontamination and decommissioning and would also be called for when designing for ease of maintenance during operation.

3.7.2 Decontamination

In accordance with DOE O 420.1, the facility design must incorporate measures to simplify decontamination of areas that may become contaminated with radioactive or hazardous materials. Items such as service piping, conduits, and ductwork should be kept to a minimum in potential contamination areas and should be arranged to facilitate decontamination. Walls, ceilings, and floors in areas vulnerable to contamination should be finished with washable or strippable coverings. Metal liners should be used in areas that have the potential to become highly contaminated. Cracks, crevices, and joints should be filled and finished smooth to prevent accumulation of contaminated material. The facility design should incorporate features that will facilitate decontamination to achieve facility decommissioning, to increase the potential for other uses, or both.

3.7.3 Decommissioning

Design features consistent with the requirements of DOE O 435.1, RADIOACTIVE WASTE MANAGEMENT, should be developed during the planning and design phases based on decommissioning requirements or a conversion method leading to other facility uses. The following design principles should be considered:

- Use of localized liquid-transfer systems with emphasis on localized batch solidification of liquid waste to avoid long runs of buried contaminated piping. Special provisions should be included in the design to ensure the integrity of joints in buried pipelines.
- Location of exhaust filtration components of the ventilation systems at or near individual enclosures to minimize long runs of internally contaminated ductwork.
- Equipment, including effluent decontamination equipment, that precludes, to the extent practicable, the accumulation of radioactive or other hazardous materials in relatively

inaccessible areas, including curves and turns in piping and ductwork. Accessible, removable covers for inspection and cleanouts are encouraged.

- Use of modular radiation shielding in lieu of or in addition to monolithic shielding walls.

- Provisions for flushing and/or cleaning contaminated or potentially contaminated piping systems.

- Provisions for suitable clearances, where practical, to accommodate remote handling and safety surveillance equipment required for future decontamination and decommissioning.

- Use of lifting lugs on large tanks and equipment.

- Piping systems that carry contaminated or potentially contaminated liquid should be free draining via gravity.

4. FUNCTIONAL DESIGN CRITERIA

4.1 Nuclear Criticality Safety

4.1.1 Conditions that Initiate Requirements of this Section

Any DOE facility that may produce, process, store, transfer, dispose, or otherwise handle sufficient quantities of fissionable material that present a concern for accidental criticality must be designed to meet the requirements of DOE O 420.1, Section 4.3, Nuclear Criticality Safety.

4.1.2 Primary Applicable Requirements

DOE O 420.1, Section 4.3, contains requirements that facilities be designed in such a manner that the probability of a criticality accident is acceptably low and, to the extent practical, the public, the workers, and the environment are protected from damaging effects and undue hazards that may arise from a criticality accident as required; that no single credible event or failure must result in a criticality accident having unmitigated consequences; and that criticality accident alarm systems and criticality detection systems be included. See DOE O 420.1, Section 4.3, and its supporting standards for details.

4.2 Radiation Protection

4.2.1 Primary Applicable Requirements

The control of radiological exposures of workers, the public, and the environment must be in accordance with Section 4.1.1.2 of DOE O 420.1, 10 CFR 835, and 10 CFR 834 (Proposed). Additional guidance is contained in the *DOE Radiological Control Manual* (DOE/EH-0256T).

4.2.2 General Application

The primary objective of radiological protection is to minimize personnel external and internal exposures to radioactive materials; provide adequate radiation posting, sampling, monitoring, and notification or alarm capabilities; and apply ALARA principles. Radiation protection should be provided through facility physical design (e.g., shielding, remote handling, area layout, equipment layout, confinement, and ventilation) and supplemented by cautionary systems. ALARA principles to minimize personnel exposures must be applied to all equipment and facility designs.

Specific criteria for monitoring and entry control systems, posting and labeling of radioactive materials, nuclear accident dosimetry, and ALARA applications must be applied as required by 10 CFR 835.

Offsite dose limits used to assess acceptability of the facility safety design during normal operations and anticipated operational occurrences must comply with 10 CFR 834 (Proposed).

Physical layout and details of proven radiological equipment designs are contained in the DOE adopted IAEA Safety Series 30 Standard and Faust (1988).

The projected dose rates must be based on occupancy, duration, and frequency of exposure and must not exceed values specified in 10 CFR 835. This may require that shielding be provided for areas requiring normal and intermittent access, such as those for preventive maintenance, component changes, or adjustment of systems and equipment. The type of shielding should be determined by the characteristics of the radiation, structural requirements, fire protection requirements, and radiation damage potential. Shielding should also be installed to minimize nonpenetrating external radiation exposures to the skin and lens of the eye where required. In most cases, confinement barriers or process equipment provide this function. Where shielding is an integral part of the facility structure, it must be designed and installed to at least the same level of natural phenomenon qualification as the facility structure. Additional guidance is contained in ANSI/ANS 6.4.2. Where shields are identified as safety class, the additional requirements stated in Section 5 of this Guide.

Occupied operating areas for normal operating conditions must be designed not to exceed the airborne concentration limits of 10 CFR 835. Respirators should not be required under normal operating conditions except as a precautionary measure. Engineered controls and features should be designed with consideration of contaminant chemical forms to minimize potential inhalation of radioactive materials.

Devices to monitor individual exposures to external radiation and to warn personnel of radioactive contamination must be used in accordance with 10 CFR 835. Air sampling equipment should be placed in strategic locations to detect and evaluate airborne contaminant conditions at work locations. Continuous air monitors with preset alarms should be provided to give early warning of significant releases of radioactive materials. Air monitoring and warning systems must comply with the requirements of 10 CFR 835 with consideration for additional guidance contained in ANSI N13.1.

Breathing-air supply systems, if required, must comply with 29 CFR 1910.134.

4.2.3 Special Considerations and Good Engineering Practices

American Nuclear Society document ANS 11.16 contains guidance on functional designs based on both DOE and NRC experiences. DOE/EH-0256T provides details on radioactive material identification, storage, and transport. These documents provide descriptions and details of use-proven principles and designs and identify considerations that affect configuration, hardware selection, installation, maintenance, and controls that can be used in developing a sound functional design.

Shielding should be designed to limit the total external dose during normal operations to the annual exposure limit values as specified in 10 CFR 835. Design of facilities and shields applicable to machines and sources is summarized as good practices in NCRP Report 49. Additional guidance is contained in ANSI N43.2.

Guidance on ventilation design is provided by an ACGIH document (ACGIH 2092-1998) and ERDA 76-21. Alarms for loss of ventilation or differential pressure must be provided on primary confinement systems (gloveboxes or hoods) and should be considered on secondary confinement systems (rooms). ANSI/ASME N509 contains requirements for the design of nuclear facility air cleaning systems and ANSI/ASME N510 contains requirements for testing air cleaning systems.

Change rooms for changing into and out of protective clothing should be designed to ensure that clean clothing (personal clothing) and contaminated clothing (protective clothing) are segregated. The design objective is to ensure that storage of contaminated protective clothing will control contamination so that it does not spread beyond the storage container. The change room exhaust air should be high-efficiency particulate air (HEPA) filtered as applicable if dispersible radionuclides are handled in the process areas it serves.

Personnel decontamination facilities should be located close to areas that are potential sources of contamination. Safety showers may be used if water collection from their use is controlled. Portable personnel decontamination equipment should be considered for facilities with no permanent structures.

Respiratory protection should be provided to maintenance personnel where potentially significant exposures exist for maintenance operations and design constraints preclude the ability to perform maintenance either remotely or in a glovebox. However, every reasonable effort should be made to allow routine maintenance activities to be conducted without the need for respiratory protection.

4.3 Hazardous Material Protection

This section provides functional design guidance for hazardous material protection other than radioactive material protection. While not controlled by DOE O 420.1, Section 4.1, directly, these considerations may indirectly relate to nuclear safety in that hazardous material releases may cause or exacerbate nuclear accidents. The hazard analysis must establish any potential for hazardous material release accidents that cause or exacerbate a nuclear accident. This potential must be considered in the accident analysis and the selection of safety SSCs.

4.3.1 Conditions that Initiate Requirements of this Section

Any facility where personnel could potentially be exposed to hazardous materials listed in 29 CFR 1910 at concentrations approaching the listed permissible exposure limits (8-hour, time-weighted average, normal operations) must comply with the requirements of the applicable laws for hazardous material protection.

4.3.2 Primary Applicable Requirements

Requirements for design of engineered controls for hazardous material protection are contained in 29 CFR 1910, Subparts G, H, and Z.

4.3.3 General Application

Ventilation systems are engineering controls commonly used to prevent worker exposure to hazardous materials and are used in combination with personal protective equipment and operational procedures. 29 CFR 1910, Subpart G, 1910.94, requires that where ventilation is used to control worker exposures, it must be adequate to reduce the hazardous material concentrations of air contaminants to the degree that the hazardous material no longer poses a health risk to the worker (i.e., concentrations at or below the permissible exposure limits). 29 CFR 1910, Subpart Z, 1910.1000, requires that wherever engineering controls are not sufficient to reduce exposures to such levels, they must be used to reduce exposures to the lowest practicable level and supplemented by work practice controls. The design should ensure that respirators are not required for normal operating conditions or routine maintenance activities except as a precautionary measure.

Ventilation systems for hazardous material protection should use exhaust hoods to control concentrations of hazardous materials from discrete sources, or should control the number of air changes per hour for an entire room or bay. Air flow and other design requirements for specific types of systems must comply with 29 CFR 1910, Subparts G and H. 29 CFR 1910, Subpart Z, provides requirements for monitoring and alarm systems for facilities that manage or use specific hazardous materials. Additional guidance on design of ventilation systems for hazardous material protection is provided in ANSI Z9.2 and ASHRAE 62. Decontamination facilities, safety showers, and eyewashes to mitigate external exposures to hazardous materials must be provided where mandated by 29 CFR 1910, Subparts H and Z. These systems must be designed in accordance with the requirements of ANSI Z358.1 and ANSI Z124.2.

4.3.4 Special Considerations and Good Engineering Practices

Facilities with hazardous material exposure concerns should be designed to minimize personnel exposures, both external and internal, and to provide adequate monitoring and notification capabilities to inform workers of unsafe conditions. Hazardous material protection should be provided through facility design (e.g., remote handling, area and equipment layout, spill-control features, confinement, ventilation, etc.). Occupied spaces should be designed to preclude locations where low oxygen content or air displacement may occur or where reactive, combustible, flammable, or explosive gas, vapor, or liquid accumulation might occur.

Safety controls and features should be designed to consider contaminant chemical forms and minimize the potential for inhalation and contact under all conditions. Directed ventilation flow paths should be used to move contaminants away from worker breathing zones. The design should ensure that ventilation flow will cascade from clean areas to contaminated areas to preclude contamination spread. Uniform distribution of incoming air and/or air mixing equipment should be provided to ensure that no pockets of stagnant air exist in areas where workers are present.

4.4 Effluent Monitoring and Control

4.4.1 Applicability

This section applies to any DOE facility that produces airborne or liquid radioactive and/or hazardous material effluents, including contaminated storm water, under normal operating conditions.

4.4.2 Special Considerations and Good Engineering Practices

Liquid process wastes containing radioactive and/or hazardous material should be collected and monitored near the source of generation before batch transfer via appropriate pipelines or portable tanks to a liquid-waste treatment facility. Waste storage tanks and transfer lines must be designed and constructed so that any leakage should be detected, contained, and collected for removal before it reaches the environment. Double-walled transfer pipelines or multiple encasements should be used for high-level radioactive liquid wastes and other liquid wastes that have the potential to cause significant localized consequences as defined by safety analysis, or significant exposures during the implementation of mitigating measures in the event of an accidental release. Provisions should be made for the collection, removal, and appropriate disposition of infiltration into the annulus of double-walled pipelines. Radioactive- and hazardous-waste collection, transfer, and storage systems must be designed to avoid the dilution of radioactive or hazardous waste by waste of lower concentrations of radioactivity, toxicity, or other hazard. Emphasis should be placed on reducing radioactive constituents in liquid effluents released to surface waters or soil columns to levels ALARA.

All airborne effluents from areas in which hazardous or radioactive materials are managed other than in closed containers should be exhausted through a ventilation system designed to remove particulate material, vapors, and gases, as necessary, to comply with applicable release requirements and to reduce releases of radioactive materials to levels ALARA. The design of airborne-effluent systems should preclude holdup of particulate materials in offgas and ventilation ductwork and include provisions to continuously monitor buildup of material and material recovery. The design of systems must also preclude the accumulation of potentially flammable quantities of gases generated by radiolysis or chemical reactions within process equipment.

The design capacity for effluent monitoring and control systems must be consistent with the needs for handling process effluents during normal operations, anticipated operational occurrences, and DBA conditions. Alarms must be provided that will annunciate in the event concentrations of radioactive or hazardous materials above specified limits are detected in the effluent stream. Appropriate manual or automatic protective features must be provided to prevent an uncontrolled release of radioactive and/or hazardous material to the environment or the workplace. Portions of effluent management systems and components that are required to control or limit the release of radioactive or hazardous materials to the environment or for safe operation of the system must be provided with redundancy where required by applicable federal, state, and local environmental regulations and permits. Effluent monitoring and control systems must be designed to allow periodic maintenance, inspection, and testing of components and to maintain occupational radiation doses ALARA during these operations. Appropriate nuclear criticality safety provisions must be applied to the design of airborne effluent systems. This includes design to preclude the holdup or collection of fissile material and other material capable of sustaining a chain reaction in portions of the system not geometrically favorable and design to ease of recovery of these materials in case of an accident as well as during normal operations.

The design of safety SSCs, as identified in the facility-specific safety analysis, must comply with the requirements of Section 5 of this Guide. Safety-class effluent monitoring and control SSCs are generally designed to operate in conjunction with physical barriers to form a confinement system to limit the release of radioactive or other hazardous material to the environment and to prevent or minimize the spread of contamination within the facility. Adequate instrumentation and controls must be provided to assess system performance and to allow the necessary control of system operation. Equipment in safety-class systems must be appropriately qualified or protected to ensure reliable operation during normal operating conditions, during anticipated operational occurrences, and during and following a design basis earthquake. Safety-class air filtration units, effluent transport systems, or effluent collection systems must be designed to remain functional throughout DBAs and to retain collected radioactive and hazardous materials after the accident.

4.5 Waste Management

This section applies to any DOE facility that under normal operating conditions produces containers of wastes having constituents that are regulated as radioactive, hazardous, or mixed waste. The design of waste management systems must be in accordance with the requirements of DOE O 435.1 and the Federal, State, and local requirements referenced therein.

Unless it can be demonstrated that the risk is acceptable, waste management and storage systems and associated support systems should be designed to remain functional following a DBA and should facilitate the maintenance of a safe shutdown condition. For high-level waste containment systems, at least one confinement barrier should be designed to withstand the effects of DBAs.

4.6 Fire Protection

4.6.1 General Application

Facility design must comply with the applicable fire protection requirements contained in DOE O 420.1, Section 4.2, Fire Protection; DOE O 440.1A, WORKER PROTECTION MANAGEMENT FOR DOE FEDERAL AND CONTRACTOR EMPLOYEES; and their companion document, DOE G 440.1-5, IMPLEMENTATION GUIDE FOR USE WITH DOE ORDERS 420.1 AND 440.1, FIRE SAFETY PROGRAM. Acceptable methods for fire protection design may be found in DOE-STD-1066-99, *Fire Protection Design Criteria*.

4.6.2 Fire Hazard Analysis

A fire hazard analysis must be prepared for each DOE facility in accordance with DOE O 420.1, Section 4.2, and should be initiated early in the design process and closely coordinated with the safety analysis effort as discussed in Section 2.1, Design Process and Safety Analysis Relationship, of this Guide.

4.7 Emergency Preparedness and Emergency Communications

4.7.1 Conditions that Initiate Requirements of this Section

This section applies to any DOE facility that must respond to internal or external emergency events to control acute exposures to radiation in excess of the annual exposure limits or to hazardous materials in excess of Permissible Exposure Limits, or to preclude multiple fatalities.

4.7.2 Primary Applicable Requirements

Provisions for emergency preparedness are contained in the requirements of DOE O 151.1, COMPREHENSIVE EMERGENCY MANAGEMENT SYSTEMS, which address installation of an Emergency Operations Center. Primary and backup means of communications with the Emergency Operations Center, provisions for evacuation and accountability; and adequate equipment and supplies for emergency response personnel to carry out their respective duties and responsibilities related to nonreactor nuclear facility must be provided in the facility design consistent with DOE O 151.1.

4.7.3 General Application

Emergency evacuation annunciation systems must conform with ANSI/ANS N2.3. General communication system installation requirements must be per NFPA 72, Section 3-12, which describes the minimum requirements for transmission of alarm conditions to building occupants, and Sections 6-3 and 6-4, which include minimum requirements for audibility above background noise and the use of visual signals, including minimum light intensities.

For facilities handling dispersible materials, meteorological data necessary to control consequences from an emergency event should be obtained from either the nearest U.S. Geological Survey or local (onsite) meteorological stations.

4.8 Explosives Criteria

The design and construction of all new DOE explosives facilities and modifications to existing explosives facilities must conform to the DOE explosives safety requirements established in the DOE EXPLOSIVES SAFETY MANUAL, DOE M 440.1-1. Facility structural design and construction must comply with the requirements of TM5-1300 (DoD), *Structures to Resist the Effects of Accidental Explosions,* and DOE/TIC-11268, *A Manual for the Prediction of Blast and Fragment Loading of Structures*. Blast resistant design for personnel and facility protection must be based on the TNT equivalency of the maximum quantity of explosives and propellants permitted. In accordance with TM5-1300, the TNT equivalency must be increased by 20 percent for design purposes.

The technical basis for establishing explosives quantity–distance separation for facility location, design, and operation (under normal and potential DBA conditions) must follow the stricter of the criteria provided in DoD 6055.9-STD, *Department of Defense Ammunition and Explosives Safety Standards*. DoD 6055.9 specifies the minimum distance for protection from hazardous fragments to facility boundaries, critical facility, and inhabited structures unless it can be shown that there will be no hazardous fragments or debris at lesser distances. The method of calculation presented in the DoD Explosive Safety Board (DoDESB) Technical Paper No. 13 may be used to establish a smaller fragment exclusion zone. It is not intended that these minimum fragment distances be applied to operating facilities or dedicated support functions within an operating line. The criteria presented in DOE M 440.1-1 must apply for these exposures.

For an unproven facility design, either a validated model or a full-scale test is required to ensure structural adequacy unless a high degree of confidence can be provided by calculations or other means. The contract administrator (head of field organization) with the advice of competent engineering review must concur in any determination regarding test requirements.

When an explosives facility is also a nonreactor nuclear facility, the requirements for nonreactor nuclear facilities must also apply.

5. SUPPLEMENTARY DESIGN CRITERIA FOR SAFETY STRUCTURES, SYSTEMS, AND COMPONENTS

This section provides supplementary guidance for the design and construction of safety SSCs to ensure reliable performance of their safety function under those conditions and events for which they are intended. Design methods and criteria commonly used to ensure required availability are discussed in Section 5.1, General Requirements, of this Guide. Discipline-specific consensus codes and standards (e.g., electrical, mechanical, and structural) are presented in Section 5.2, Specific Criteria, of this Guide. These design methods, design criteria, and consensus codes and standards are the minimum set of requirements that must be applied when designing safety SSCs.

5.1 General Requirements

Safety SSCs and their associated support systems must be designed, fabricated, erected, and tested to standards and quality requirements commensurate with their importance to safety. An acceptable level of assurance that the safety SSCs will perform their intended safety function can be achieved by meeting the requirements contained within the following sections.

5.1.1 Assurance of Safety Function

Safety SSCs must be designed to reliably perform their safety function under those conditions and events for which their safety function is intended. The following subsections must be applied to the design of safety SSCs to most effectively enhance system availability and provide for robust design. Further design guidance can be found in IAEA Standard No. 50-P-1 and ANSI/IEEE 603.

5.1.1.1 Conservative Design Features

Safety SSCs must be designed to withstand all design basis loadings with an appropriate margin of safety. The design should incorporate, commensurate with the importance of the safety function, multiple levels of protection against normal, anticipated, and accident conditions. For example, while built-in process controls may maintain pressure within a conservative limit, the design may also require provisions for relief valves, automatic shutdown capability, or other preventive features.

The design of safety-class SSCs must incorporate suitably conservative criteria contained in applicable DOE Orders and Standards addressing safety functions (e.g., natural phenomena design mitigation).

5.1.1.2 Design Against Single-Point Failure

The facility and its systems must be designed to perform all safety functions with the reliability indicated by the safety analysis. The single-point failure criterion, requirements, and design analysis identified in ANSI/IEEE 379 must be applied during the design process as the primary method of achieving this reliability.

5.1.1.3 Environmental Qualification

Environmental qualification must be used to ensure that safety-class SSCs can perform all safety functions, as determined by the safety analysis, with no failure mechanism that could lead to common cause failures under postulated service conditions. The requirements from ANSI/IEEE 323 for mild environmental qualification must be used unless the environment in which the SSC is located changes significantly as a result of the DBAs. In general, qualification for mild environments should consist of two elements:

- Ensuring that all equipment is selected for application to the specific service conditions based on sound engineering practices and manufacturers' recommendations.

- Ensuring that the system documentation includes controls that will preserve the relationship between equipment application and service conditions.

5.1.1.4 Safe Failure Modes

The facility design must provide reliable safe conditions and sufficient confinement of hazardous material during and after all DBAs. At both the facility and SSC level, the design must ensure that more probable modes of failure (e.g., fail to open versus fail to close) will increase the likelihood of a safe condition.

5.1.2 Support System and Interface Design

Safety SSCs often rely upon other SSCs to support their operation. Therefore, it is important to identify these support systems and the associated interfaces between safety and nonsafety SSCs. The following subsections address the design considerations for these related systems.

5.1.2.1 Support Systems

In some cases, safety SSCs rely upon supporting SSCs to perform their intended safety function. These support SSCs may be classified as safety-class or safety-significant SSCs. For example, a safety-class designation may be appropriate for an instrumentation and control (I&C) system that supports a tritium containment system if it can be demonstrated that failure of the I&C support system can lead to either failure or reduced availability of the safety-class containment barrier. In general, the following classification criteria apply.

- Support SSCs to safety-class SSCs must be classified as safety class if their failures can prevent a safety-class SSC from performing its safety functions.

- Support SSCs to safety-significant SSCs that mitigate or prevent accidents with the potential for significant onsite consequences should be classified as safety-significant if their failures prevent a safety-significant SSC from performing its safety functions.

- Support SSCs to safety-significant SSCs that mitigate or prevent accidents with the potential for significant localized consequences need not be classified as safety significant.

5.1.2.2 Interface Design

A nuclear safety design goal is to minimize interfaces between safety-class, safety-significant, and nonsafety SSCs. Ideally, safety SSCs should not have any interfaces; however, this is not always practical. Interfaces, such as pressure retention boundaries, integrity of fluid systems, electrical equipment, I&C, and mechanical and support systems, exist between safety SSCs and between safety SSCs and nonsafety SSCs. These interfaces must be evaluated to identify SSC failures that would prevent the safety SSCs from performing their intended safety function. For these SSC failures, isolation devices, interface barriers, or design class upgrades should be provided to ensure safety SSC protection and reliability. In many cases, systems may consist of a group of subsystems, where each subsystem supports the operation of the whole system. For example, an auxiliary power diesel generator system may consist of lubricating oil, fuel oil, diesel engine, jacket cooling, and room ventilation subsystems. System interface evaluations should clearly define these boundaries. In all instances, a case-by-case evaluation should be performed.

5.1.3 Quality Assurance

The QA requirements for the design, fabrication, construction, and modification of safety SSCs are developed using the facility safety analysis. At the earliest stages of the design, a hazard analysis, which identifies the functional requirements of safety SSCs, should be used as a basis for determining appropriate QA requirements.

As the design progresses, more detailed safety analyses will be performed to develop the basis for safety SSCs performance requirements. Once the safety SSCs and their performance requirements are identified, a set of detailed QA requirements can then be specified. As part of the safety analysis, a list of all safety-class SSCs must be prepared and maintained for the life of the project through decommissioning. This listing must identify the functions, performance requirements, and natural phenomena design requirements for each safety-class SSC and the associated QA requirements. These detailed component-specific requirements are typically contained in consensus codes and standards (e.g., ANSI/IEEE). A similar listing of all safety-significant SSCs should also be prepared.

In most cases, components used in DOE nonreactor nuclear facilities will be “off the shelf”; that is, they will not be subjected to the rigorous Nuclear Quality Assurance (NQA)-1-based requirements for “nuclear-grade” components. Therefore, safety SSC quality standards can either be design based or achieved through testing, vendor control, and inspection. However, the requirements of 10 CFR 830.120 still apply to safety SSCs.

5.2 Specific Criteria

The application of design criteria to safety SSCs entails the selection of appropriate and relevant criteria commensurate with the levels of safety. A purely prescriptive approach to the use of national codes and standards may fail to provide the appropriate level of safety. While national codes and standards will provide guidance and the basic design criteria for most systems, blanket application of such individual codes and standards or collections thereof is not necessary. It is necessary to tailor selections of codes and standards for each specific application based on the required safety function.

Note that the safety analysis conducted in accordance with DOE-STD-3009-94 that results in a particular safety classification is also the same analysis used to identify and define design criteria. Safety analyses identify the functions that must be performed and the conditions under which these functions must perform. These analyses will then result in both the functional safety classification and the identification of the appropriate and relevant criteria to ensure the prescribed safety functions can be performed.

Categorization and listing of design codes and standards as a portion of the design criteria process are performed to ensure that a correct and appropriate level of engineering design detail and attention are used for each safety classification. The intent is to specify the design codes and standards that will ensure that each safety SSC will perform its required safety function, including due consideration of the intangible areas of influence.

The national codes and standards listed in the following sections provide guidance on the minimum aggregation of codes, standards, and standard practices that should be considered in identifying the design criteria and other considerations for each specific SSC commensurate with its function. Additional design criteria may be applied as necessary to perform the safety function.

Specific design criteria for safety SSCs often relate to a confinement function. Generally, three confinement systems are used to achieve the complete confinement system objective. The terms confinement and confinement barriers used in the following sections are used in the context of the three types of confinement: primary, secondary, and tertiary (as defined in the glossary).

5.2.1 Structural

Structures classified as safety class or safety significant normally provide a passive confinement barrier and do not require redundancy in their design. The design of safety-significant and safety-class structures must ensure satisfaction of the functional requirements for the specific confinement system of which they are a part. In addition, safety-class confinement barriers must be designed to withstand likely secondary events as well as primary events with an appropriate margin of safety. Potential secondary events might be fire, explosion, or nuclear criticality caused by the primary event. Likely secondary events are those with a probability greater than 0.1, given the primary event. See Table 5.1 for the relevant codes and refer to Section 4.4 of DOE O 420.1 and Section 3.3 of this Guide for additional natural phenomena hazards design guidance information.

Table 5.1. Codes for Safety-Significant and Safety-Class Structures.

Structures	Safety Significant	Safety Class
Concrete	ACI-318	ANSI/ACI-349
Steel	AISC-M011	ANSI/AISC-N690

5.2.2 Mechanical

Mechanical equipment classified as safety significant or safety class provides both passive and active safety functions. The redundancy criteria as described in Section 5.1.1.2 of this Guide must be applied to the design of safety-class SSCs that provide an active safety function. The redundancy criteria should be considered in the design of safety-significant SSCs that provide an active safety function. Redundancy criteria are generally not applied to the design of safety SSCs that provide a passive safety function.

5.2.2.1 Ventilation

In general, the safety function of ventilation and offgas systems is to provide confinement integrity and to filter exhaust, thereby preventing or mitigating uncontrolled releases of radioactive and/or hazardous materials to the environment. Ventilation and offgas systems are included as a vital part of the primary and secondary confinement design. The need for redundancy and the degree of redundancy in these systems must be determined by the safety analysis process and maintenance concerns for both active and passive components. Designs must provide for periodic maintenance, inspection, and testing of components. Adequate shielding must be included in the design of filters, absorbers, scrubbers, and other air treatment components to ensure that occupational exposure limits are not exceeded during maintenance and inspection activities.

Safety-significant and safety-class ventilation system designs must include adequate instrumentation to monitor and assess performance with necessary alarms for annunciation of abnormal or unacceptable operation. Manual or automatic protective control features must be provided to prevent or mitigate an uncontrolled release of radioactive and/or hazardous material to the environment and to minimize the spread of contamination within the facility.

Vent streams potentially containing significant concentrations of radioactive and/or hazardous materials must be processed through an offgas cleanup system before being exhausted to the environment. Cleanup systems are to remove particulates and noxious chemicals and control the release of gaseous radionuclides. The design of safety-significant and safety-class offgas systems must be commensurate with the sources and characteristics of the radioactive and chemical components of the offgas air stream to prevent or mitigate the uncontrolled releases of radioactive and/or hazardous materials to the environment. See Table 5.2 for the relevant codes.

Table 5.2. Codes for Safety-Significant and Safety-Class Ventilation System Components.

Ventilation	Safety Significant	Safety Class
Ducts	SMACNA Manual	SMACNA Manual
Fans	ASHRAE Handbook	ASHRAE Handbook; ANSI/ANI-59.2
Filtration	ASHRAE-52.1; Mil-F-51068F; ANSI/ASME-N509 and N510; DOE NE STD-F3-45	ASHRAE-52.1; Mil-F-51068F; ANSI/ASME-N509 and N510; DOE NE STD-F3-45

5.2.2.2 Process Equipment

The usual safety function of process equipment is to provide primary confinement and prevent or mitigate radioactive and/or hazardous material releases to the environment. Process equipment that would be required to provide primary confinement includes the following: piping, tanks, pressure vessels, pumps, valves, and gloveboxes. These examples represent process system components that could be used to contain radioactive or toxic materials directly. Process equipment for some applications can provide secondary confinement. Examples include double-walled piping systems, double-walled tanks, and gloveboxes.

Safety-class and safety-significant process equipment providing passive confinement (piping, tanks, holding vessels, etc.) must be designed to suitably conservative criteria; redundancy in their design is not required. The redundancy criteria as described in Section 5.1.1.2 of this Guide must be applied to the design of safety-class SSCs that involve active confinement process equipment (pumps, valves, etc.). The redundancy criteria should be considered in the design of safety-significant SSCs that involve active confinement process equipment. See Table 5.3 for the relevant codes.

Table 5.3. Codes for Safety-Significant and Safety-Class Process Equipment.

Process Equipment	Safety Significant	Safety Class
Pressure vessels	ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2	ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2
Tanks (0-15 psig)	API-620; ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2	API-620; ASME Boiler and Pressure Vessel Code, Section VIII, Division 1 or 2
Tanks (containing flammable liquids)	ANSI/API-620; ANSI/API-650; NFPA 30	ANSI/API-620; ANSI/API-650; NFPA 30
Tanks (atmospheric pressure)	ANSI/API-650; AWWA-D100; ANSI/ASME-B96.1	ANSI/API-650; AWWA-D100; ANSI/ASME-B96.1
Pumps	ANSI/API; ANSI/ASME B73.1M, B73.2M; ASME Boiler and Pressure Vessel Code, Section VIII; AWWA; Hydraulic Institute Standards	ANSI/API; ANSI/ASME B73.1M, B73.2M; ASME Boiler and Pressure Vessel Code, Section VIII; AWWA; Hydraulic Institute Standards
Piping	ANSI/ASME B31.3	ANSI/ASME B31.3; ANSI-N278.1
Valves	ANSI/ASME B16.5, B31.3	ANSI/ASME B16.5, B31.3
Heat exchangers	ASHRAE Handbook; ASME Boiler and Pressure Vessel Code, Section VIII, Division 1; TEMA B, C, or R	ASHRAE Handbook; ASME Boiler and Pressure Vessel Code, Section VIII, Division 1; TEMA B, C, or R
Gloveboxes	ANSI/ASTM C852; ANS 11.16	ANSI/ASTM C852; ANS 11.16

5.2.2.3 Mechanical Handling Equipment

Safety-significant and safety-class handling equipment (cranes, manipulators, etc.) will only be classified as such if their failure would create a radiological material release exceeding the guidelines for either classification. The safety-significant classification, as a defense-in-depth provision, will be the more common classification for remote material handling equipment.

Failure modes for mechanical handling equipment used to move radioactive materials must address mid-operational failures, and designs must include recovery methods for such occurrences. Designs must accommodate periodic maintenance and inspection. See Table 5.4 for the relevant codes.

Table 5.4. Codes for Safety-Significant and Safety-Class Handling Equipment.

Handling Equipment	Safety Significant	Safety Class
Cranes	CMAA; ANSI/ASME NOG-1; ANSI/ASME B30.2; DOE-STD-1090-96	CMAA Nuclear Sections; ANSI/ASME NOG-1; ANSI/ASME B30.2; DOE-STD-1090-96
Other equipment	ANSI N 14.6; AISC M011	ANSI N14.6; AISC M011

5.2.3 Electrical

The safety function of an electrical power system is to provide power to systems and components that require electrical power in order to perform their safety functions. A safety-significant or safety-class electrical power system is defined as the system or component that provides actuation or motive force to safety equipment. These systems consist of onsite AC/DC power supply systems and associated distribution systems and components (e.g., conduits, wiring, cable trays, etc.).

Safety-class electrical power must be designed against single-point failure in accordance with the criteria in Section 5.1.1.2 of this Guide. Redundancy requirements for electrical systems pertain to normal and alternative power sources and should be analyzed on a case-by-case basis. For safety-significant systems, redundancy is not required if it can be shown that there is sufficient response time to provide an alternative source of electrical power.

Environmental capability of safety-class electrical equipment must be demonstrated by testing, analysis, and operating experience, or a combination of these methods in accordance with Section 5.1.3 of this Guide.

For the commercial nuclear industry, a multitude of ANSI/IEEE Standards define the requirements for the manufacture, installation, and testing of reactor Safety Class 1E electrical systems and components. The Safety Class 1E requirements may not be directly applicable to the safety-class category defined for nonreactor nuclear facilities. These standards, however, contain useful and significant information that should be considered. Table 5.5 lists a minimal set of national codes and standards that should be addressed for safety-significant and safety-class electrical systems, keeping in perspective the applicable use of ANSI/IEEE standards for Safety Class 1E components. Table 5.6 presents a list of ANSI/IEEE standards that can be used for guidance in specific applications. Before using these standards, their applicability to the design(s) being considered should be reviewed.

Table 5.5. Codes for Safety-Significant and Safety-Class Electrical Systems.

Electrical	Safety Significant	Safety Class
Hardware	NFPA 70; NFPA 110; NFPA 780; IES Lighting Handbook; ANSI C2; ANSI/IEEE C37; ANSI/IEEE -80, -141, -142, -242, -399, -493, -577	NFPA 70; NFPA 110; NFPA 780; IES Lighting Handbook; ANSI C2; ANSI/IEEE C37; ANSI/IEEE-80, -141, -142, -242, -308, -338, -379, -384, -399, -493, -577, -603

Table 5.6. ANSI/IEEE Standards to be Used as Guidance for Both Safety-Significant and Safety-Class Electrical Systems, as Appropriate.

Electrical	Safety Significant and Safety Class
Guidance standards for use as applicable for specific hardware	ANSI/IEE -323, -334, -336, -344, -381, -382, -383, -420, -450, -484, -535, -628, -649, -650, -833, -934, -944, -946

5.2.4 Instrumentation, Control, and Alarm Systems

The safety functions of instrumentation, control, and alarm systems are to provide information on out-of-tolerance conditions/abnormal conditions; ensure the capability for manual or automatic actuation of safety systems and components; ensure safety systems have the means to achieve and maintain a fail-safe shutdown condition on demand under normal or abnormal conditions; and/or actuate alarms to reduce public or site-personnel risk (e.g., effluent monitoring components and systems).

The design of safety-class and safety-significant instrumentation and control systems must incorporate sufficient independence, redundancy, diversity, and separation to ensure that all safety-related functions associated with such equipment can be performed under postulated accident conditions as identified in the safety analysis. Safety-significant components should be evaluated as to the need for redundancy on a case-by-case basis. Under all circumstances, safety-class instrumentation, controls, and alarms must be designed so that failure of nonsafety equipment will not prevent the former from performing their safety functions.

Safety-significant and safety-class instrumentation, control, and alarm-system designs must ensure accessibility for inspection, maintenance, calibration, repair, or replacement.

Safety-class instrumentation, control, and alarm systems must provide the operators sufficient time, information, and control capabilities to perform the following safety functions:

- Readily determine the status of critical facility parameters to ensure compliance with the limits specified in the Technical Safety Requirements.

- Initiate automatic or manual safety functions.

- Determine the status of safety systems required to ensure proper mitigation of the consequences of postulated accident conditions and/or to safely shut down the facility.

ANSI/IEEE standards contain design, installation, and testing requirements that should be considered for instrumentation, control, and alarm components without invoking all of the Safety Class 1E requirements. See Table 5.7 for the relevant codes.

Table 5.7. Codes for Safety-Significant and Safety-Class Instrumentation, Control, and Alarm Components.

Instruments, Controls, and Alarms	Safety Significant	Safety Class
Hardware	NFPA-70, -110; ANSI C2; ANSI/ANS-8.3, -N42.18, -N13.1; ANSI/ISA-Series; ANSI/IEEE-141, -142, -242, -493, -1050	NFPA-70, -110; ANSI C2; ANSI/ANS-8.3, -N42.18, -N13.1; ANSI-N320, -N323; ANSI/ISA-Series; ANSI/IEEE-141, -142, -242, -323, -336, -338, -344, -379, -384, -493, -1050

APPENDIX A

REFERENCES

Code of Federal Regulations

- 10 Code of Federal Regulations (CFR) 50.2, Definitions (1999).
- 10 CFR 830.120, Quality Assurance Requirements (1999).
- 10 CFR 834, Radiation Protection of Public and the Environment (Proposed Rule), Federal Register, 3-25-93.
- 10 CFR 835, Occupational Radiation Protection (1999).
- 29 CFR 1910, Occupational Safety and Health Standards: Subpart G, Occupational Health and Environmental Control; Subpart H, Hazardous Materials; and Subpart Z, Toxic and Hazardous Substances (1994).
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NOT MEASUREMENT SENSITIVE

DOE G 413.3-1
9-23-08

Managing Design and Construction Using Systems Engineering for Use with DOE O 413.3A

[This Guide describes suggested nonmandatory approaches for meeting requirements. Guides are not requirements documents and are not construed as requirements in any audit or appraisal for compliance with the parent Policy, Order, Notice, or Manual.]

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1.0 INTRODUCTION

1.1. Goal

The goal of this Guide is to provide the Department of Energy's federal project directors (FPDs) with the knowledge, methodologies, and tools needed to meet Order 413.3A's requirement that they plan, implement and complete their assigned project(s) using a Systems Engineering approach.[1] This requirement is particularly significant because Systems Engineering is the only specific engineering discipline imposed on the FPDs by the Department's directives; and because it provides the FPDs with a methodology that they can use to fulfill the following other responsibilities that DOE O 413.3A imposes on them to:

- demonstrate initiative in incorporating and managing an appropriate level of risk to ensure best value for the government";[2]
- "ensure that safety is fully integrated into design and construction for high-risk; high-hazard, and Hazard Category 1, 2, and 3 nuclear facilities";[3]
- ensure that design, construction, environmental, safety, security, health, and quality comply with the contract, public law, regulations, and Executive orders;[4]
- plan and implement a Quality Assurance Program for the project[5];
- initiate development and implementation of key project documentation;[6] and
- clearly define the roles and responsibilities of the Integrated Project Team relative to the contractor management team.[7]

The intent of this Guide is to provide the FPDs and the Integrated Project Teams (IPTs) with a better understanding of—

- how reports and tasks required by DOE O 413.3A can be brought together as a system,
- how the different DOE O 413.3A guides come together as a system,
- how other DOE rules and directives interface with the project development process, and
- how to use systems engineering lessons learned from past projects.

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[1] Paragraph 6g(2), page 38.
[2] Paragraph 6g, page 38.
[3] Paragraph 6g(13), page 39.
[4] Paragraph 6g(5), page 39.
[5] Paragraph 5k(10), page 31.
[6] Paragraph 6g(3), page 39.
[7] Paragraph 6g, page 38.

These tools, knowledge and insight can help to improve project performance by avoiding systems level integration deficiencies.

1.2. Applicability.

The Guide is applicable to any DOE capital asset acquisition project having a total project cost of $20 million or greater. It may also prove useful to program managers facing similar challenges.

1.3. What is Systems Engineering?

Attachment 3 of DOE O 413.3A, defines Systems Engineering as:

> "A proven, disciplined approach that supports management in clearly defining the mission or problem; managing system functions and requirements; identifying and managing risk; establishing bases for informed decision-making; and verifying products and services meet customer needs"

According to the Order, Systems Engineering is utilized:

- upon approval of mission need to analyze alternative concepts based on user requirements, risks, costs, and other constraints to arrive at a recommended alternative; [8]
- in the Project Definition Phase to integrate requirements analysis, risk identification and analysis, acquisition strategies, and concept exploration to evolve a cost-effective, preferred solution to meet a mission need;[9]
- in the Execution Phase to balance requirements, cost, schedule, and other factors to optimize the design, cost, and capabilities that satisfy the mission need;[10]
- to integrate the design and safety basis;[11] and
- to plan, implement, and complete a project.

1.4. Links with Other Directives

DOE O 420.1B also requires that all DOE federal and contractor elements responsible for design and construction of Hazard Category 1, 2, and 3 nuclear facilities have a Systems Engineering Program[12] that uses configuration management to:

[8] Paragraph 5c (2), page 5.
[9] Paragraph 5d(2), page 8.
[10] Paragraph 5c(3), page 5
[11] Paragraph 6o(3), page 43
[12] Chapter V for DOE. Attachment 2, Chapter V for contractors.

- develop and maintain consistency among system requirements and performance criteria, documentation, and physical configuration of the structures, systems, and components within the scope of the program;
- integrate the elements of system requirements and performance criteria, system assessments, change control, work control, and documentation control;
- compile and keep current system design basis documentation and supporting documents using formal change control and work control processes;
- identify and consolidate key design documents to support facility safety basis development and documentation;
- periodically assess:
  - the ability to perform design and safety functions,
  - physical configuration for conformity to system documentation, and
  - system and component performance as compared to established performance criteria; and
- test each system after modification to ensure its continued capability to fulfill system requirements.

DOE G 420.1-1, *Nonreactor Nuclear Safety Design Criteria and Explosives Safety Criteria Guide*, dated 3-28-00, adds the following systems engineering activities relating to nuclear safety:

- identifying and integrating facility nuclear safety requirements,
- coordinating multidisciplinary teamwork in implementing facility safety requirements,
- providing nuclear safety-related interface management,
- providing configuration management to include the establishment of baseline management, and
- coordinating technical reviews of the facility nuclear safety features.

The application of systems engineering to nuclear safety in facility design should be graded commensurate with the facility hazards and complexity. The goal is to ensure that systems engineering activities include consideration of the appropriate facility safety features.[13]

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[13] Paragraph 2.4, page 12.

1.5. Overlapping Systems Engineering and Safety Principles and Practices

Other safety and quality assurance requirements and recommendations in DOE O 413.3A and other DOE rules and directives often overlap with Systems Engineering principles and practices. For example:

- "Missions are translated into work, expectations are set, tasks are identified and prioritized, and resources are allocated." (DOE P 450.4, *Safety Management System*, page 2)

- "Incorporate applicable requirements and design bases in design work and design changes." [10 CFR 830.122, Section (f)(2) and DOE O 414.1C, *Quality Assurance*, paragraph 4f(2)]

- "Applicable standards and requirements are identified and agreed-upon, controls to prevent/mitigate hazards are identified, the safety envelope is established, and controls are implemented." (DOE P 450.4, *Safety Management System*, page 3)

- "Resources shall be effectively allocated to address safety, programmatic, and operational considerations. Protecting the public, the workers, and the environment shall be a priority whenever activities are planned and performed." (DOE P 450.4, *Safety Management System*, page 2)

- "Competence commensurate with Responsibility - Personnel shall possess the experience, knowledge, skills, and abilities necessary to discharge their responsibilities" [DOE P 450.4, *Safety Management System*, page 2) and DOE O 413.3A, paragraph 5k(6)(c)]

- "Identify and control design interfaces." [10 CFR 830.122, Section (f)(3) and DOE O 414.1C, *Quality Assurance*, paragraph 4f(1)]

- Ensure "effective communication among all project stakeholders." (DOE O 413.3A, paragraph 5a)

- "Risk Management is an essential element of every project. The DOE risk management approach must be analytical, forward looking, structured, informative, and continuous. Risk assessments are started as early in the project life cycle as possible and should identify critical technical, performance, schedule, and cost risks." [DOE O 413.3A, paragraph 5k(11)]

- "Verify/validate work before approval and implementation of the design." [DOE O 414.1C, *Quality Assurance*, paragraph 4f(5)]

- "Verify/validate the adequacy of design products using individuals or groups other than those who performed the work." [10 CFR 830.122, Section (f)(4) and DOE O 414.1C, *Quality Assurance*, paragraph 4f(4)]

Additional embedded materials and linkages are identified in Attachments 2, 3, 4 and 5.

Some requirements do not specify a point in a project by which they should be met. This Guide addresses those points at which compliance should be attained.

1.6. Differences in Terminology

Functional requirements and performance requirements are defined differently and have significantly different contexts from domain to domain and in different Departmental directives. These differences will be pointed out, where possible, to avoid confusion.

1.7. How this Guide is Structured

The Guide's structure mirrors the project evolution process outlined in DOE O 413.3A and the above definitions of Systems Engineering to the extent possible. Specific actions that should be taken at each step in the project evolution are addressed in separate sections in the approximate sequence in which it would be performed; however, it should be recognized that many of the actions are iterative in nature and should be undertaken in parallel and would have to be undertaken in a different sequence if an architect-engineer is utilized to develop the alternative design concepts. Issues such as verifying that products and services meet customers’ needs that are integral to each step of the project evolution process are, by necessity, addressed in increments as they emerge.

Unlike the other 413-series Guides, this one begins from a higher level starting point to look at how all DOE directives (i.e., the various components that comprise DOE's management system) come together as a project evolves.

The FPD and the IPT roles and responsibilities for design and construction management are addressed with attention placed on the front-end of a project since the Department, as owner is responsible for defining the mission and the associated requirements; obtaining the human, financial, and technical capabilities needed to meets those requirements; and planning the project so as to deliver the greatest net value.

1.8. Sources of Information

The Guide presents acceptable methods for implementing the Systems Engineering requirements specified in DOE O 413.3A together with supplemental information about these methods including lessons learned. This information flows from other Government agencies’ procedures; professional societies' presentations and publications; national and international consensus standards; texts; doctorate dissertations; and, lessons learned from independent reviews and research studies of failed or troubled projects.

The quality and quantity of the research in the field has promoted an extensive evolution of Systems Engineering in the past decade. Principles and practices that are new include attention to interdependency and uncertainty management.

2.0 ASSEMBLE AND CHARTER THE INTEGRATED PROJECT TEAM

IPT assembly and chartering is one of the first actions taken on a project because the IPT performs the bulk of the activities in the project definition phase (i.e., the phase between Critical Decision 0 and Critical Decision 1). DOE O 413.3A specifies four separate requirements in regards to the assembly and chartering of the IPT. Specifically:

- FPDs clearly define IPT roles and responsibilities relative to the contractor management team[14]
- The Charter specifies IPT decision making authority.[15]
- The Charter provides the IPT’s operating guidance.[16]
- "Competence (shall be) commensurate with Responsibility - Personnel shall possess the experience, knowledge, skills and abilities necessary to discharge their responsibilities."[17]

The actions associated with these four requirements are frequently interdependent and should be considered and responded to in toto.

Responsibility for assembly of the IPT and the development of the Charter depends upon whether an FPD has been appointed. The program manager or the head of the field organizations establishes the IPT and prepares the initial Charter if a permanent FPD has not been approved. These same individuals formally concur with the Charter if a permanent FPD has been approved because the bulk of the project's staffing will be taken from their organizations. IPT assignments on larger projects typically require all, or nearly all, of the IPT member's time and can last for several years. Both IPT membership and the Charter must be approved by the Secretarial Acquisition Executive or the Acquisition Executive.[18] The Secretarial Acquisition Executive or the acquisition executive should evaluate whether the proposed staffing is adequate for the complexity and importance of the project before approving these documents.

On more complex projects, the Charter and the IPT staffing plan are likely to be modified and re-approved several times over the course of the project to accommodate membership needs and activities the IPT should perform. Updates and new requests for approval should be integrated with the Critical Decision approval process.

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[14] DOE O 413.3A, paragraph 6g, page 38.
[15] DOE O 413.3A, paragraph 6g(10), page 39.
[16] DOE O 413.3A, paragraph 6g(11), page 39.
[17] DOE O 413.3A, paragraph 5k(6)(c) and DOE P 450.4, page 2.
[18] DOE O 413.3A, Table 2, page 12.

3.0 PRE- CONCEPTUAL PLANNING

Pre-conceptual or up-front planning is initiated as either the final activity prior to Critical Decision 0 or the first activity immediately after[19] Critical Decision 0 approval and is the beginning of systems engineering. This multifaceted effort entails simultaneously defining the end product the project will deliver and how the design and construction activities will be undertaken and managed. Both efforts are tightly intertwined. The precise method of undertaking and managing the design and construction efforts depends upon the end product. And, conversely, the end product has to be compatible with what the designers, constructers, and management teams are actually capable of delivering successfully.

The FPD[20] and the IPT perform the bulk of pre-conceptual planning and ensure that the two efforts are aligned through a series of iterative steps starting with capturing the project requirements and ending with determining the appropriate project development strategies.

Each of these steps is defined below together with the specific action(s) that should be taken at the completion of the step.

3.1. Capture Project Requirements

Identifying project requirements is fundamental to systems engineering and is integral to or a prerequisite for nearly all of the tasks identified in DOE O 413.3A. It is impossible to develop a meaningful Risk Management Plan, Project Execution Plan, Acquisition Strategy, or the alternative design concepts needed for Critical Decision 1 approval without previously identifying the requirements associated with the project. Similarly, the probability of the architect and engineering firms' developing an acceptable design solution or the necessary depth of specifications and drawings are nil if they do not know the Department's requirements.

Project requirements are the primary means of communicating the Department's expectations to the organizational elements involved in the project. Accordingly, they should enfold all of the major aspects of the project, provide the depth of information each user needs to perform their particular role, and be available for the user at the right point in time.

3.1.1. Enfold All Major Aspects of the Project

Project requirements fall into two categories. The first is comprised of those attributes that the project is expected to demonstrate once it is completed (e.g., mission related requirements such as storage capacity and production rates, operational requirements such as mean-time-to-failure, and requirements that are adjunct to the mission but of major importance such as safety and security).

The second category is comprised of procedural requirements the deal solely with project delivery (e.g., calculation methods, reports and data to be developed and submitted at specific

[19] NNSA requires that a Program Requirements Document be included as part of the Critical Design 0 approval package.
[20] The program manager or the head of the field organization may be serving the FPD at this point in the project.

stages, approvals that must be received, codes and standards to meet, mandatory reviews, and specific design approaches.

Both categories can be fully defined only by:

- identifying all of the project stakeholders and their expectations, priorities and values;
- identifying the laws, rules, directives, and standards with which the project must comply; and
- working backward from the project mission and other end goals.

3.1.1.1. Project End Product

The Mission Need Statement is the starting point when capturing requirements related to the end product of the project in that it "translates an identified performance gap into functional requirements that cannot be met though other than material means."[21] The Mission Need Statement generally addresses only one or two aspects of mission related requirements and does not provide enough information to allow a valid comparison of alternative conceptual approaches. Additional information is needed on the operational and life cycle aspects of the mission including:

- quality;
- processing;
- operability;
- reliability/dependability;
- maintainability and reparability;
- availability;
- flexibility, agility, adaptability, upgradeability;
- survivability;
- durability;
- adaptability;
- decommissioning, deconability and disposition,
- sustainability;

[21] DOE O 413.3A, paragraph 5d(1), page 7.

- survivability; and

- testability.

These topics are most readily determined by seeking input from stakeholders that will use or be impacted by the project and undertaking a function analysis of the mission. Internal functions most frequently impacted by the project include management and operating contractors' safety, environmental, and health; security; maintenance; utility or plant; and transportation organizations. External organizations likely to be impacted by the project are generally the same as internal organizations and include both state and local governments.

The identification of such operational and life cycle requirements is particularly important when there is not an accepted industry-wide norm to utilize in the absence of definitive information. Much of the "requirement creep" on projects can be traced to a failure to capture operational and life cycle requirements.

3.1.1.2. Adjunct Goals and Recommendations

Adjunct areas of focus such as safety, environmental protection, security, contracting, value management, and energy efficiency have mandatory goals and requirements, and non-mandatory design and procedural preferences to be folded into both the final product and the project delivery process. Many objectives and requirements associated with adjunct areas are defined in government rules, policies and regulations; DOE directives and standards; and, contract terms and conditions. For example:

3.1.1.2.1. Quality Assurance

DOE G 414.1-2A, *Quality Assurance Management System*, sets forth the following recommendations pertaining to design:

- "A design process should be established that provides appropriate control of design inputs, outputs, verification, configuration and design changes, and technical and administrative interfaces."

- "The design of systems, structures, and components; software; and processes should be subject to design process controls and verification requirements appropriate to the level of risk the item presents to the public, the environment, and project success."

- "Designs should provide for appropriate acceptance, inspection, testing, and maintenance criteria to ensure continuing reliability and safety of the items."

- "The designer should consider the expected use and life expectancy of the items to allow appropriate disassembly and disposal requirements to be addressed."

- "Aspects critical to the performance, safety, or reliability of the designed items should be identified during the design phase."

3.1.1.2.2. Safeguards and Security

DOE G 413.3-3, *Safeguards and Security for Program and Project Management*, indicates that the following should be developed during the project definition stage:

- threat assessment,
- materials control and accountability,
- physical security,
- information security,
- personnel security,
- cyber security,
- barriers,
- access controls,
- explosives, and
- communication.

3.1.1.2.3. Fire Protection

DOE O 420.1B, *Facility Safety*, establishes fire protection design requirements pertaining to:

- water supplies,
- noncombustible construction materials,
- fire-rated construction and barriers, including penetration sealants,
- automatic fire extinguishing systems,
- redundant fire protection systems,
- the separation of redundant safety class systems,
- fire alarm and signaling systems,
- emergency egress and illumination,
- physical access and standpipes for fire department intervention,
- prevention of accidental release of contaminated products of combustion and fire fighting water, and

- fire protection and safety system interfaces.

DOE Standard (DOE-STD) 1189, *Integration of Safety into the Design Process*, states:

- A Fire Hazards Analysis (FHA) is required for all Hazard Category 1, 2, and 3 nuclear facilities or facilities that present unique or significant fire risks. A FHA requires a comprehensive evaluation of fire hazards, including postulation of fire accident scenarios and estimates of potential consequences (i.e., maximum credible fire loss).

- "In the conceptual design, a preliminary FHA provides fire protection strategy alternatives for control or mitigation of accident consequences. Fire protection strategies will dictate design requirement."

- "For designs that do not comply with appropriate NFPA Standards, Authority Having Jurisdiction (AHJ) review and acceptance of design outputs relevant to fire protection and life safety are required. Appropriate interfaces with the AHJ should be anticipated and planned."

DOE G 420.1-3, *Implementation Guide for DOE Fire Protection and Emergency Services Programs for Use with DOE O 420.1B, Facility Management*, defines acceptable methods to implement the fire protection requirements in DOE O 420.1B, including:

- fire protection designs,
- water supplies,
- automatic fire suppression,
- fire suppression system confinement or containment,
- fire protection system classifications, and
- the NEPA codes and standards likely to be applicable.

DOE-STD-1066-99, *Fire Protection Design Criteria*, provides guidance on:

- water supply and distribution systems,
- automatic sprinkler systems,
- fire alarm systems,
- structural fire protection,
- life safety,
- electrical equipment,

- general process hazard fire protection,
- special hazards,
- nuclear filter plenum fire protection, and
- glovebox fire protection.

DOE O 440.1B, *Worker Protection Program for DOE (including National Nuclear Security Administration) Federal Employees* provides requirements on:

- What constitutes an acceptable fire protection program.
- Life safety codes.

3.1.1.2.4. Sustainability

DOE O 430.2B, *Departmental Energy, Renewable Energy and Transportation Management,* requires that capital asset construction or major renovation projects:

- Attain U.S. Green Building Council Leadership in Energy and Environmental Design (LEED) Gold certification.
- Incorporate the Guiding Principles of Executive Order 13423.
- Incorporate renewable energy equipment into building design to the maximum extent feasible.

3.1.1.2.5. Value Engineering

DOE O 430.1B, *Real Property Asset Management*:

- Requires that the contractor use value engineering techniques in a tailored manner to reduce DOE's real property asset ownership costs (e.g., acquisition, operations, maintenance, and disposal) while maintaining the necessary level of performance and safety.
- Invokes the requirements contained in[22]
    - Office of Management and Budget Circular A-131, *Value Engineering.*
    - P.L. 104-106, Section 4306, *Value Engineering for Federal Agencies.*

[22] DOE P 413.3.2 similarly invokes Public Law (P.L.) 104-106 and OMB Circular A-131

- ASTM Practice 1699.00, *Standard Practice for Performing Value Analysis for Buildings and Building Systems.*

3.1.1.3. Project Delivery Procedures

Procedural requirements defining how the project is to be developed are found in the same source documents as the adjunct goals. It is generally not enough; however, to just state that the project should be developed in accordance with these source documents. A good share of the compliance problems that are surfaced during the various project reviews can be traced to a simple lack of awareness of procedural requirements. While reviews correct this lack of awareness, downstream corrections are always more costly than ensuring that the performing parties have a full understanding of the requirement before starting work. One of the keys to project success is the degree to which the procedural requirements can be clearly linked to the specific tasks to be performed in each project phase.

The establishment of such linkages is complicated by the fact that many of the procedural requirements contained in the source documents are situational in nature and only come into play if a particular condition is found to exist as the project unfolds. This is particularly significant from a project planning and management standpoint since both the information needed to determine if the triggering condition exists and the actual determination typically resides outside of the functional disciple/organizational element that is undertaking the impacted design. This creates an interdependence that can have a major impact on the manner in which the project is executed. Such interdependence is discussed in section 3.4.2.2.4.3.

3.2. Concurrent with Requirements Capture

A number of different activities should be performed concurrently with the requirements identification process just described. These activities are described below.

3.2.1. Determine the Depth to Which the Requirements Are Defined

Requirements at front-end of the project are typically defined to one of the following three increasing depths.

3.2.1.1. Performance Issues

Performance applies to end result but not the means, the processes or procedures by which it can be achieved. Performance requirements provide great latitude for innovation but only minimum bases for either the Department or contractors to estimate project scope, cost, and schedule. Even more important, they typically do not provide a measuring stick for determining progress or the acceptability of the end result.

3.2.1.2. Functional Issues

Functional requirements have varied definitions in DOE directives and are in most cases sub-elements that have the same two basic limitations as performance requirements in that they normally do not provide a measuring stick for progress assessment or a means of determining the acceptability of the final product.

3.2.1.3. Detailed or Procedural Issues

Detailed requirements or procedural requirements focus as much on how work is to be performed, as what is to be produced. They can appear in different forms including Departmental and consensus standards, design criteria, and state and local codes.

3.2.2. Determine if the Depth of Definition Is Adequate and Address Any Gaps

There are two opposing perspectives regarding the depth to which project requirements (end product and adjunct requirements) should be refined. The first is based on the premise that detailed requirements will overly constrain the private sector (the architect/engineering firms, the equipment suppliers, and the constructors) who should do the work and will result in higher project costs. The second perspective is based on the premise that detailed requirements are the only way of ensuring that the end product will perform as needed and are, therefore, essential.

The situation determines which of these two perspectives is correct . Detailed requirements are normally not warranted on projects that can be successfully delivered using proven designs and commercially available components or systems. They are warranted and are in some cases essential:

- on atypical projects that are pushing the state of art;
- when confronted with high risk environments/missions;
- when needed to ensure that individual designers will produce the correct end product. (Highly capable designers do not need detailed requirements. Designers that do not have extensive knowledge and experience, however, do need prescriptive requirements.); and
- when it is questionable whether the necessary level of fabrication, or construction experience is available in the market place.

These situations are common on Hazard Category 1, 2, or 3 nuclear facilities. Experienced with design breakage, construction rework, and technical disputes suggest a need for deeper levels of requirements. Some of the sub-areas that have proven particularly troublesome are listed in Attachment 1.

The FPD and the IPT should decide, at this point in pre-conceptual planning, what depth of refinement is appropriate in each of the listed sub-areas and address any gaps when evaluating conceptual alternatives, developing acquisition strategy, writing the project execution risk management plans, identifying tasks that should be completed prior to initiation of preliminary design, and scoping the project execution phase.

Design criteria constitute the deepest level of refinement normally justified at this stage of project development. Dedicated writing teams composed of true subject matter experts from the government, the management and operating contractor and the private sector are essential when developing design criteria level requirements. Architect/engineering firm personnel who will be executing the design should also be included on the writing team, if at all possible.

3.2.3. Identify and Address Any Missing Requirements

While the list of operational requirements that have been extracted from the mission stakeholders and the list of procedural requirements extracted from the adjunct stakeholders and the Department's directives may appear all inclusive, it is inevitable that some critical requirements were either overlooked or could not be ascertained. Operating requirements typically prove to be extremely difficult to define.

Both DOE and management and operating contractor organizations are built around specific missions and adjunct goals such as safety, security, environmental protection, procurement, etc. The spokespersons or champions for these areas are easily identifiable and can generally supply a fairly complete list of their procedural requirements. They are generally less able to define how requirements are likely to change before the project has been completed; i.e., the importance of maintaining flexibility. Even more important, it is normally difficult, if not impossible, to find an individual that understands all the site wide needs and uncertainties and can translate these into project level operating and flexibility requirements.

The FPD and the IPT need to determine the potential consequences the missing and/or unstable requirements may have on the project and factor their conclusions into the Risk Management Plan, the Project Execution Plan, the Acquisition Strategy, the evaluation of conceptual alternatives, and the list of activities that should be performed prior to the initiation of preliminary design.

3.2.4. Identify and Address Technology and/or Design Solution Limitations

New technologies, new material applications, and/or new design concepts may be necessary to satisfy an end product requirement on projects that are "pushing the bubble" or may be desired on more conventional projects to improve efficiency. Technology readiness level (TRL) analyses should be utilized when comparing requirements against available technical capabilities, material applications, and currently available design solutions. The TRL encompasses key factors such as scale-up and operating environment that are applicable to both of these constraints.

The acceptability of a TRL depends upon:

- how critical the system is to mission success or safety;
- the probability that the technology will prove successful;
- the availability of a proven backup technology or design concept that can be substituted if the new technology or design solution cannot be elevated to TRL 5 or higher by Critical Decisions 2; and

- the cost, schedule, and performance penalty that will be incurred if the backup solution should be utilized.

A TRL of less than 3 at the pre-conceptual stage of a project normally warrants management scrutiny.

The potential impact of a technology gap on a project is, in many ways, greater than on a program because project design is performed under an Architect-Engineer Services contract while the maturation and demonstration of the new technology would normally be performed by either the M&O or a totally separate contractor. This introduces yet another coordination complexity.

3.2.5. Identify and Address Market Related Limitations

Analytical tools, properly qualified engineering and construction forces, and materials will be needed to meet the requirements. The availability of these items should be taken into consideration when planning the project. Failing to recognize a lack of availability in any of these areas can result in reduced downstream competition with accompanying higher cost for the government, quality problems, and longer schedules.

This initial determination of available capabilities will serve as a forerunner for the more rigorous individual evaluations that the Federal Acquisition Regulations (FAR) require for architect/engineering services and should focus on the same areas as those evaluations. These include:

- "Specialized experience and technical competence in the type of work required …"
- "Past performance on contracts with Government agencies and private industry…"[23]

The FAR's position regarding discussions with potential suppliers has changed in recent years. The December 2007 edition now states:

> "Potential offerors should be given an opportunity to comment on agency requirements or to recommend application and tailoring of requirements documents and alternative approaches. Requiring agencies should apply specifications, standards, and related documents initially for guidance only, making final decisions on the application and tailoring of these documents as a product of the design and development process. Requiring agencies should not dictate detailed design solutions prematurely."[24]

This change provides an opportunity for an improved understanding of market constraints.

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[23] Federal Acquisition Regulations, Subpart 36.602-1.
[24] Federal Acquisition Regulations, Subpart 11.002.

3.2.6. Identify and Address Internal Staffing Limitations

DOE and the M&O contractors staffing limitations result from the aging of the work force and the decline of the nuclear power industry over the past three decades. These limitations are particularly severe in regards to certain individual requirements and are highlighted in numerous reports. Heavy workload demands and staff shortages make it difficult to assume that in-house M&O staffing will be available just because it may be present somewhere in the M&O contractor's organization. Possible methods of compensating for internal staffing limitations are addressed later in the Guide as part of a broader discussion.

3.3. Determine the Net Effect of Individual Requirements

The challenge of meeting a requirement can change dramatically when it is seen as part of a total set of requirements that must be satisfied. What may have been simple can become complex and the complexity of the development effort has a direct bearing on both the levels of skills that will be needed to successfully undertake the project and the type of tools and procedures that should be used. The greater the complexity, the higher the skill levels needed. While there is not a universally accepted method of dividing complexity into its various sub-elements or translating complexity into cost and schedule estimates, the following breakout provides enough of a yardstick to support parametric comparisons and should be used as a starting point.

3.3.1. Physical Complexity

Physical or detail complexity is a reflection of the number of components and number of networks that link them together. Projects involving many different goals, requirements, constraints, stakeholders, organizations, individuals, technologies, or components are probably physically complex. Physical complexity cannot, however, be determined simply by adding up numbers. The physical complexity of a facility composed of 1,000 different components may, for example, be greater from a designer perspective than the physical complexity of a facility composed of four identical assembly lines each composed of 500 components even though the latter contains twice the total number of components.

Numbers can be particularly misleading in the case of organizational elements. Most senior FPD are, for example, capable of successfully overseeing and communicating with seven directly reporting sub-organizations. The FPD's level of their success will, however, decline sharply if those organizations are vertically stacked as descending levels subcontractors. Both downward and upward communications will be reinterpreted at each organizational boundary it passes through and will soon take on a totally different content and meaning than originally intended.

Similarly, physical complexity can increase nearly exponentially once an individual's or an organization's limits are reached. The challenge of coordinating 30 different contractors is far more than twice as difficult as coordinating 15 different contractors; a fact that has contributed to many project problems.

3.3.2. Combinatorial Complexity

The degree to which the different goals, requirements, organizations, individuals, technologies, and components can be aligned can have an even greater bearing on staffing skill levels than the physical complexity of the project since misalignments make it more difficult to arrive at a mutually acceptable solution.

DOE has experienced particular difficulties when attempting to combine competing schedule and safety goals. DOE's formal process of extensive checks and balances focuses on ensuring the safety of nuclear projects. This process cannot be easily shortened or accelerated to meet schedule objectives.

Safety also appears as a combinatorial complexity element at lower levels of the project. The most common means of satisfying occupant life safety requirements for egress is, for example, to provide multiple fire exit doors directly out of the building. This design solution is fine for office or warehouse facilities, but directly conflicts with the security and contamination control necessary when a building contains nuclear materials. The likelihood of such negative linkages increases as the number of requirements increase. Some negative linkages can be resolved by using more sophisticated design approaches provided they are recognized and clearly identified as one of the challenges that designers address.

Combinational complexity can also be increased by the following:

3.3.2.1. Funding

Nearly every project is bound by some level of budgetary constraints. These constraints can add significant complexity and often even prove to be incompatible with the requirements. Failure to acknowledge the full impact of funding induced complexity inevitably leads to unrealistic plans and expectations.

3.3.2.2. The Site

Few DOE projects are self-supporting, "green-field" undertakings. Most fit within constrained physical spaces and utilize already existing site utilities and services. Also, there are typically very specific access and interface issues that should be taken into consideration at every phase of the project. This is particularly true in the case of projects in security areas and/or modifications of operational facilities that may contain hazardous materials.

3.3.2.3. Government Policies

Federal and state policies impose a number of constraints, and therefore complexity, that the private sector does not have to experience. These need to be understood by those charged with designing the project. Policies relating to small business utilization and Buy American Act are, for example, unique to Federal projects and should be made visible so that they can be taken into consideration during the planning process.

3.3.3. Dynamic Complexity

Dynamic complexity always involves some aspect of time. In appears in its simplest form as volatile or unstable conditions that change over the course of the project or even between Critical Decisions. Project requirements, funding, and personnel/staffing have shown a historic tendency to fluctuate over relatively short periods on past DOE projects and are recognized contributors to dynamic complexity. Projects that are experiencing this form of dynamic complexity are not yet ready to be baselined.

At the employee level, the amount of time needed to perform an activity is the most common form of dynamic complexity. Tasks that an individual can successfully perform given adequate time become dynamically complex for the same individual when they are to be performed in short periods of time.

The most common form of dynamic complexity at the group level is informational independence. Structural engineers cannot, for example, design a processing bay or cell roof unless process engineers tell them the distances they will have to span to accommodate the necessary processing lines. The process engineers cannot, in turn, size the processing lines until they know the throughput rates to be achieved, maintenance constraints, the operating environment, etc. Dynamic complexity, on complex projects, can increase to the point that conventional schedule tools lose their effectiveness.

A fourth, and significant different, facet of dynamic complexity is how easy or difficult it is for an individual employee or an organization to recognize and understand the cause and effect relationships that occur over the life span of a project. Effects that are widely separated in time and space from their causes are more dynamically complex that those that occur in close time proximity. Dynamically complex projects place greater cognitive demands on the senior members of the project team.

3.3.4. Evaluative Complexity

Evaluative complexity is a measure of how easy it is to determine if an objective is being met over the course of the project. The evaluative complexity of a particular requirement will normally be different at each Critical Decision point.

3.4. Risk Informed Planning to Set Strategic Direction

The FPD and the IPT should have an adequate understanding of the situation to undertake an integrated set of risk informed actions that will set the overall course of the project. These risk informed actions differ from those normally described in the Project Risk Management Plan in a very significant way. While the Risk Management Plans focus on how specific events would impact the already developed project plan if they were to occur; pre-conceptual risk management reverses this perspective, and focuses on how the project should be planned to avoid or minimize the various risks (i.e., constraints, challenges, or uncertainties) that are either known or are likely to surface (based on lessons learned from similar undertakings) as the project evolves. This reversed way of thinking is, in effect, the ultimate form of proactive management and provides a far broader range of opinions.

3.4.1. Determine if Necessary Skill Levels Are Obtainable

As can be seen from the earlier sections, project feasibility hinges on the experience, knowledge, skills, and ability and contractor personnel necessary to simultaneously meet project goals and handle delivery risks (constraints, challenges, and uncertainties). The FPD and the IPT should therefore:

- Identify the number personnel with specific experience, knowledge, skills, and abilities needed at each stage of the project.
- Link these needs with the individual requirements and risks to the extent possible.
- Determine the current and future availability of personnel and contractors.
- Package this information in the form of a Project Staffing Plan that can be incorporated into the Project Execution Plan, the Acquisition Strategy, and the Risk Management Plan.

If major gaps surface between project needs and the availability of qualified personnel the FPD and the IPT should:

- Adjust discretionary requirements downward.
- Adjust the delivery risks downward.
- Use collaborative organizational structures or other techniques to broaden the pool of available resources beyond that obtainable from a single operations office or contractor.
- Upgrade the obtainable experience, knowledge, skills, and abilities of the individuals or organizations.

Each of these alternatives is addressed below.

3.4.1.1. Adjust Discretionary Requirements Downward

Although adjusting the project's discretionary requirements downward to the capability level of the project is the surest, most cost effective means of correcting a capability gap, it is, often resisted by those advocating the discretionary requirements. Such resistance can often be resolved by verifying the requirement's link to the mission need or an adjunct goal and then performing a cost/benefit analysis. The results of these two efforts should be formally documented and made available to both the advocate and the Acquisition Executive.

3.4.1.2. Reduce Project Delivery Risks

A number of tools and techniques can be used to reduce project delivery risks as follows.

3.4.1.2.1. Benchmarking and Lessons Learned

An easy and reliable method of reducing uncertainties regarding the cost, schedule, and technical feasibility of the project at the pre-conceptual stage of development is benchmarking. Benchmarking involves determining the actual cost, schedule, and performance levels of similar projects (or systems) that have already been completed and then adjusting the data from those projects to compensate for any differences in scale, location, market conditions, etc. using parametric techniques.

Identifying a pool of similar projects to use as a benchmark offers a secondary benefit in that this pool of already completed projects can also serve as a source of lessons learned. The inability to find any similar projects to serve as benchmarks should be seen as a danger sign that we are attempting to push beyond the state of the practice and should expect the high level of difficulties and risks that come with a first-of-a-kind effort.

3.4.1.2.2. Collect/Generate Missing Knowledge

All projects begin with incomplete information and unverified assumptions. The benchmarking and lessons learned processes should provide some insight as to the relative importance of the missing information and unverified assumptions and allow the FPD and the IPT to determine which of the missing elements are the most critical to the conceptual effort and should, therefore, be addressed first.

The process of collecting and/or generating the missing or incomplete knowledge is, in essence, a mini project. A formal data base should be developed that identifies each uncertainty. The specific methods that will be used to obtain the knowledge should be laid out. Necessary quality levels should be defined and resources should be obtained. Schedules should be developed based on foreseen need dates and the level of importance of the missing information to the project development process. And, progress should be tracked and managed.

While the process of collecting missing information is straight forward, it is not always possible to fill in all the blanks, particularly in regards to the quality and reliability of the knowledge that can be obtained regarding elements such as political constraints and future funding available. These limitations can be partially addressed through the use of the project development strategies discussed in section 3.4.2.

3.4.1.2.3. Use a Collaborative Organizational Structure

Needed knowledge, skills, and experience levels can be obtained through the use of joint ventures or partnerships that bring together organizations with complementary skill mixes. Many of the Department's M&O contractors were formed using collaborative organizational concepts. Collaborative organizational structures have also been used to increase available funding and/or knowledge on some of Department's larger individual projects.

While collaborative organizational structures can reduce skill related risks they almost always add offsetting combinatorial complexity and have been the source of some high profile project failures. They should be approached with caution.

3.4.1.2.4. Upgrade Federal and/or M&O Skill Levels

It is possible, under some conditions, to fill skill gaps through individual and/or team training, which is most effective when tailored to specific project needs and delivered at the specific time of need.

3.4.2. Determine the Appropriate Project Development Strategies

A variety of project development strategies are available; but each is only appropriate for a particular set of circumstances. Selection of an appropriate strategy can decrease the risk of project failure, while selection of an inappropriate strategy can significantly increase the risk of failure. The general factors that determine which strategy is the most appropriate follow:

- the completeness and accuracy to which requirements can be defined;
- the compatibility of the requirements;
- the constraints;
- the complexity of the project;
  - what is known and what is unknown; and,
  - the knowledge, skills, and abilities of both the organizations and the individual project participants.

Further information is provided below.

3.4.2.1. Select the Appropriate Overarching Strategies

Two different overarching strategies are widely used outside of DOE. They are:

3.4.2.1.1. "Waterfall" Development

The "waterfall" strategy is a traditional approach that consists of defining the mission and adjunct requirements; producing the drawings and specifications that satisfy the requirements, and constructing a facility and/or process in compliance with the drawings and specifications. This strategy is straightforward and automatically selected by most project participants, however, it is optimal only when:

- The requirements can be clearly understood by all project participants, are unlikely to change during the development process, and accurately reflect the owner's or stakeholder's expectations.

- There are no significant uncertainties or risks associated with either the project delivery process or satisfying the requirements; i.e., there are no insurmountable staff, schedule, budgetary, or technology constraints.

- The project is being undertaken in a stable and predicable environment.
- The project is not overly complex.
- The Department is willing to limit its level of post Critical Decision 1 involvement to oversight.

3.4.2.1.2. Evolutional Development

The benefits of using evolutional development strategies became apparent in the 1990's following root cause analysis of cost, schedule, and performance problems in software development. Two different forms of evolutional development are now generally recognized as being preferable for higher complexity, higher risk projects. They are:

3.4.2.1.2.1. Spiral Development

A spiral development approach is appropriate when the desired project outcome can be stated but associated requirements cannot be defined. The development process is undertaken in a series of short exploratory cycles with each cycle designed to:

- provide clearer definition of the requirements,
- obtain better understanding of the associated risks,
- determine if the risks are resolvable, and
- clarify the path forward. Individual aspect of the projects can be explored concurrently rather than sequentially during the early stages of exploration.

The FPD and the IPT determine the specific objectives and scope of each cycle based on risk importance. They then evaluate the information obtained from the cycle and determine the cost/benefits of pursuing additional cycles. The option of recommending that the development effort be halted or totally redirected is available at the end of every cycle.

3.4.2.1.2.2. Incremental Development

An incremental development is selected when:

- The requirements associated with the outcome can be defined but do not appear immediately achievable because of technology, engineering, or funding constraints.
- Having an operational project that partially satisfies owner and stakeholder expectations is more desirable from a cost/benefit standpoint than not having or delaying the project until the necessary capabilities become available.

The project is specifically designed with adequate flexibility to allow future upgrades. Incremental development is inherently a risk avoidance or mitigation approach. It may be the only viable approach when faced with schedule pressures or significant staffing, budgetary, knowledge, or technology constraints.

3.4.2.2. Select Appropriate Sublevel Strategies

Sublevel strategies are available for use with either of the of the evolutionary development strategies or in advance of implementing a waterfall strategy. These are summarized below.

3.4.2.2.1. Strategies for Resolving Requirements Uncertainties and Unknowns

Most stakeholders cannot clearly state what their requirements are, or identify all of their requirements. The following five strategies or tools are available to help both situations.

3.4.2.2.1.1. Design Charettes

Architects have long utilized design charettes for several hundred years by as a means of understanding client needs and preferences. Clients and the architectural team hold face-to-face meetings during which the architects pursue specific lines of inquiry and generate on-the-spot sketches reflecting what they believe the client is requesting. These sketches are utilized to iteratively clarify the client's priorities.

3.4.2.2.1.2. Prototypes/Models

Prototypes and models are typically utilized to test new components or unproven design concepts but, can also be used as follow-on to design charettes to help occupants and maintenance forces discover unrecognized requirements and loosen overly restrictive requirements by providing a means to test drive alternative design solutions. The use of computer based models to assist communication has now become a standard practice in many design firms. Projects that provide prototypes and models for the users to evaluate early in the project development process experience lower levels of rework.

3.4.2.2.1.3. Agile Method

The agile method can be viewed as both a modern reinterpretation of design charettes or as a type of spiral development strategy. Small (eight person maximum) design teams are formed to work directly with the client or stakeholders to iteratively search out requirements and accompanying design solutions for a particular segment of the project. The length of each iteration varies somewhat with the specific form of the agile method being used (there are three popular forms; "scrum," the Rational Unified Process (RUP), and Extreme Programming) and may extend from a few days to six weeks. Planning is kept at a course-grain level and generally extends only two iterations into the future. Each iteration is expected to produce a testable end product that adds value regardless of whether additional iterations are, or are not, performed.

3.4.2.2.1.4. Broader Based Integrated Project Teams

The feasibility of atypical facility and equipment requirements should be verified by those that actually have to perform the construction or supply the equipment. This can be accomplished, in simple cases, through market surveys. On more complicated projects construction and component expertise should be added to the IPT. Consequence and Scenario Based Planning

3.4.2.2.1.5. Consequence and Scenario Based Planning

Many adjunct goals focus on the prevention of an undesired negative event or consequence. There are typically many different scenarios or pathways that can lead to these events or consequences. Each needs to be understood and then blocked though the development of specific requirements.

3.4.2.2.1.6. Sensitivity Analysis

Construction, procurement, and life cycle costs may be relatively insensitive to changes in a particular requirement or may undergo a linear, a non-linear, or a step function increase or decrease. The impact of changes should be evaluated and factored into the requirements definition process.

3.4.2.2.2. Strategies to Temporarily Compensate for Other Short Term Uncertainties

Schedule pressures such as consent degrees or time sensitive missions may necessitate that design and, in some unique cases construction, begin prior to the fully resolving the requirements and constraints. The strategies and procedures that should be utilized when this occurs are outlined next.

3.4.2.2.2.1. Set-Based Design

Set-based concurrent design postpones the need for commitment by using a set or range of requirements when beginning the design effort, rather than a single point requirement. The range or set of requirements is narrowed incrementally, with accompanying adjustments in the design effort, as uncertainties are eliminated and the requirements become firmer. Carrying multiple alternatives increases front-end costs, but also increases the project's ability to meet the imposed schedule.

3.4.2.2.2.2. Design Margins

Design margins are utilized during project development to temporary compensate for recognized uncertainties and unresolved differences of professional opinion regarding the correct method of calculation or analytical tools. Design margins differ from factors of safety in that:

- they are temporary and can be eliminated or reduced once the missing information is obtained or the differences of professional opinion are resolved and

- should be based upon **worst case**, rather than expected, outcomes.

The Secretary endorsed the importance of design margins in a March 2003 letter to the Defense Nuclear Facilities Safety Board stating that such margins should be carefully managed as a function of design uncertainty. The FPD and the IPT should ensure that formal design margins are established for each structure, system, or component and that these margins are appropriate to the situation.

3.4.2.2.2.3. <u>Fallback Alternatives</u>

Fallback alternatives should be identified and held in ready reserve whenever:

- a proposed design solution or component has a Technology Readiness Ranking of seven or below at this point in the project or

- market uncertainties exist that could result in a lack of competition or unavailability.

3.4.2.2.2.4. <u>Strategies to Compensate for Longer Term Uncertainties</u>

Two different strategies should be considered when the project is faced with longer term uncertainties.

3.4.2.2.2.4.1. Robust Design

Robustness is defined as the ability to endure unexpectedly adverse environments. As used in this case, it is an irreversible decision to proceed with construction on items such as building foundations or long lead procurements using the worst case situation as a design basis rather than delaying the project while differences in professional opinion or uncertainties are resolved. It is, in that regard, a permanent rather than a temporary strategy.

3.4.2.2.2.4.2. Real Options

The concept of a real option originated in the financial world and is defined as a right or ability, but not the obligation, to pursue a particular future course of action. Real options can generally be obtained only by an expenditure of funds. An example of a real option can be seen in a decision to buy right of way space for adding lanes when building a new highway. The additional lanes may never be constructed, but the option is available.

3.4.2.2.3. Strategies for Responding to Cost and Schedule Constraints

3.4.2.2.3.1. <u>Reuse</u>

The most successful sublevel strategy for meeting cost and schedule constraints is the use of existing designs or components that are readily available and have been proven in actual applications. Both the OMB and the U.S. Government Accountability Office

(GAO) endorse this strategy as a method of reducing risk and cost. IPT members should interview those currently using the design or components to verify their level of satisfaction and to gain the benefits of any lessons learned.

3.4.2.2.3.2. Modularity

Modular structures, systems and components are similar in concept to reuse and offer many of the same advantages. They can reduce both time and cost while concurrently reducing risk since the initial modules can be utilized for both verification testing and learning.

3.4.2.2.3.3. Design-Build Contracts

Design-Build contracts can reduce both cost and schedule. They are, however, applicable to only a narrow range of circumstances as is outline in paragraph 5g(3) of DOE O 413.3A. Design-build is not synonymous with fast tracking which initiates construction while design is still in progress.

3.4.2.2.3.4. Concurrent Engineering

Concurrent engineering (a.k.a. simultaneous engineering and early construction involvement) provides many of the cost and schedule advantages of design-build and applicable to a broader range of range of circumstances. It is widely used by in the commercial sector and can be accomplished by simply adding manufacturing or construction expertise to the design IPT. It provides a method for the designers to obtain the real world knowledge that is needed to avoid design solutions that appear good on paper but present downstream quality, cost, or schedule problems for the constructors and fabricators. Concurrent engineering has been confused with fast tracking in some oversight reports.

3.4.2.2.3.5. "Lean"

The Lean approach to design, manufacturing, and management is based on the highly successful Toyota production system. The Air Force and Department of Defense have been working with a consortium of manufactures and universities since 1993 to apply Lean concepts to government projects and programs. While the consortium has achieved very positive results, Lean is still not fully understood or applied by the bulk of the project management, design and construction community.

3.4.2.2.4. Strategies for Responding to Complexity

Complexity cannot be eliminated as either a challenge or a threat but can be reduced somewhat using the techniques discussed below.

3.4.2.2.4.1. Physical Complexity Responses

Government projects are inherently more physically complex than most similar private sector projects in that they involve a greater variety of goals, larger numbers of participants, and more interfacing internal and external organizations. IPTs and status reports provide a partial, but incomplete response. FPD's on larger projects should have full time staff members to coordinate information flow between the different units and ensure that the participants are working in synchronization. FPDs should also avoid solutions, such as intentionally procuring materials or services from large numbers of different individual suppliers, or large scale outsourcing that add physical complexity and increase the management and procurement workload.

Separate integrating and construction management contractors have been used by both the Department and other federal and state agencies as a response to physical complexity with mixed results. Those considering using either approach should invest the time necessary to fully understand the lessons that have been learned from these previous undertakings, particularly the higher profile failures.

3.4.2.2.4.2. Combinatorial Complexity Responses

Numerous "soft skill" approaches to the challenge of aligning different organizations with different goals have been advocated by business and project management publications over the past decade. The most successful of these continue to be IPTs and a achieving a clear understanding of group and task interdependencies. A proven method of showing group and task interdependences and helping to bring them into alignment is discussed below.

3.4.2.2.4.3. Dynamic Complexity Responses

A Dependence Structure Matrix (DSM) is a square matrix listing each activity, in the sequence in which it will be performed, on both the identically labeled vertical and horizontal axes (See Figure 1). Information flows between the activities are indicated by placing an "X" at the point the two activities intersect, using the sequencing nomenclature shown in the example below. An "X" below the diagonal line indicates a forward flow of information and is colored green; while an "X" above the diagonal line indicates than information flows backward from an activity that occurs later in time before the earlier event can be declared complete, and is colored red. Backward flows of information are particularly undesirable if the two interfacing actives are widely separated in time and other activities take place in between based on the earlier information since a larger quantity of work should be reiterated.

The planning approach should be changed, when the Dependency Structure Matrix indicates a backwards flow of information. The two tasks should be brought as close together as possible in sequence and managed as an interdependent or coupled pair if it is not possible to reverse their sequence. This type of situation appears on the Dependence Structure Matrix as a set of "X" at point of intersection both immediately below and above the diagonal line.

The quantity of information presented in the DSM can be increased by replacing the "X" with numbers that represent the quantity of information that flows between the linked activities or the level of interdependency. DSMs can also be developed using organizations, components, or project parameters as the two axis rather than activities.

The flow diagram corresponding to the example shown in Figure 1 is shown in Figure 2,

	Activity 1	Activity 2	Activity 3	Activity 4	Activity 5	Activity 6	Activity 7	Activity 8
Activity 1								
Activity 2	✓							✓
Activity 3		✓						
Activity 4		✓					✓	
Activity 5			✓	✓		✓		
Activity 6			✓	✓	✓			
Activity 7								
Activity 8								

Figure 1 - Sample Dependency Structure Matrix

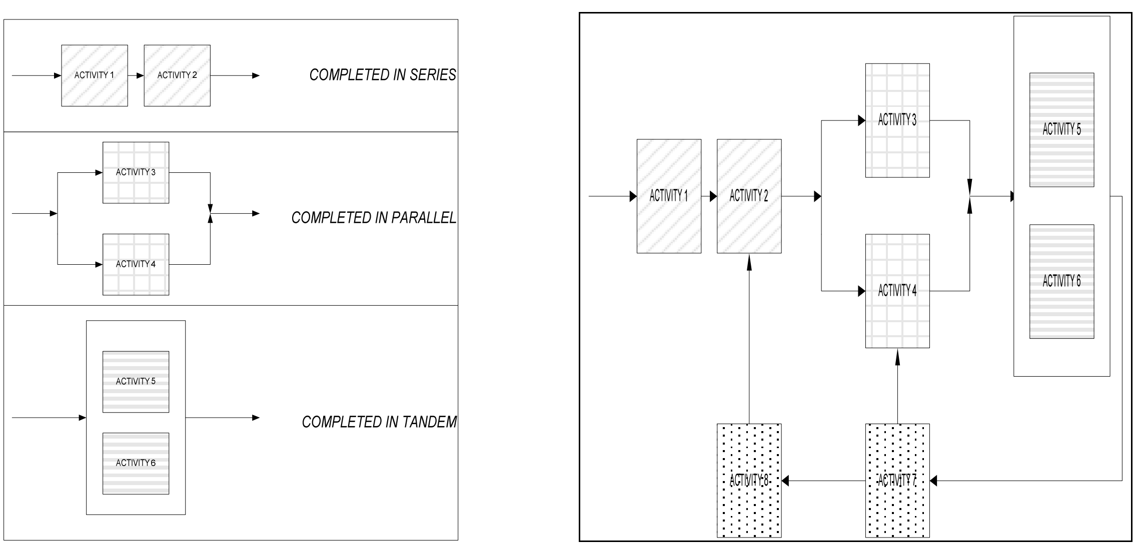

Figure 2 - Corresponding Flow Diagrams for the Figure 1 DSM

3.4.2.2.4.4. Evaluative Complexity Responses

A number of methods of responding to evaluative complexity are discussed in section 4.

3.5. Identify and Compare Alternative Design Concepts

DOE O 413.3A requires that alternative concepts be evaluated as part of the Project Definition Phase using Systems Engineering and other techniques and tools such as alternatives analysis and Value Engineering/Management.[25] Historically the process has confronted at least six major challenges.

- The identification, development, evaluation, and selection of alternate design concepts is often influenced more by the values of the organization performing the study and the types of design solutions that they are the most familiar with, than it is by the Department's and the stakeholder's requirements.
- Different stakeholders are likely to assign the requirements and constraints significantly different priority rankings, preventing the creation of a requirements priority list that is acceptable to all parties.
- Finding a collection of design solutions that provides the optimal answer for each individual requirement on a complex project will not produce a design solution that is optimal from a total project standpoint.
- Even the brightest of designers only has the cognitive capability to mentally integrate a small number (generally less than nine) of the requirements when pursuing a solution.
- The initial set of requirements is unlikely to accurately reflect the stakeholder's real needs or be fully achievable when matched against the constraints.
- Few people know how to handle the uncertainties that have been identified, and therefore circumvent the problem by making unwarranted assumptions such as the site's mission will not change in the future, soil explorations will not reveal any surprises, or there will be an adequate number of bidders/suppliers to provide full and open competition.

Most designers will pick one requirement around which the design will be optimized. They will then check to see if the resulting design solution appears to satisfy the other requirements. The following approach acknowledges this need to start with a single requirement, but provides a far more rigorous approach to ensure that all critical requirements are given equal consideration and that the six challenges listed above are met.

3.5.1. Identify the Dominant Requirements and Constraints

A small group (four or less) of dominant requirements and constraints should emerge from the above tasks and the program's, the FPD's and the IPT's experience on similar projects.

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[25] Value Management and this particular aspect of Systems Engineering are essentially synonymous in that both analyze the various elements of the project for the purpose of achieving the best value for the government. Value Engineering's objective is slightly different in that it has historically focused solely on achieving lowest cost. See DOE P 413.2, *Value Engineering*, and Public Law 104-106 Section 36 for additional information on Value Engineering.

This dominant group will automatically include safety if the project is a Hazards Category 1, 2, or 3 nuclear facility and is likely to include cost and staffing constraints. The requirements or constraints identified in this group should be used as the conceptual alternatives to be evaluated using a design for "X" approach.

3.5.2. Design for "X"

The design for "X" approach can be seen as an elaborate design charette where different solutions are quickly developed and presented to better determine priorities and trade-offs. It is ideally suited for evaluating conceptual alternatives in that it can be utilized when neither the relative priority of the dominant requirements nor their degree of interdependency can be readily determined. Different teams pursue independent design solutions in parallel, each starting with a different dominant requirement or constraint and developing a high level design solution that they believe optimizes the assigned requirement or constraint and satisfies the other requirements and constraints.

The depth to which a design for "X" study should be taken is project dependent and cannot be pre-prescribed. Normally, no more than a month should be needed on even the most complex of projects to achieve enough insight to:

- Select the design solution(s) to be used as a basis for full conceptual development, Critical Decision 1 approval, and Preliminary Design. (The selection may be one developed by a single team or a composite of those proposed by different teams.)
- Understand the tradeoffs that can, and cannot be made.
- Identify those requirements and constraints that are open to misinterpretation and need to be written to a deeper depth before preliminary design is initiated.
- Determine if the solutions are able to accommodate the uncertainties.

3.5.3. Check the Resulting Design Solutions

The design solutions proposed by each design for "X" team should be checked internally by the FPD and the IPT before deciding which design solution to propose for advancement. This check is a separate forerunner to the three independent Critical Decision 1 reviews specified in DOE O 413.3A in that it focuses nearly totally on requirements, constraints, and uncertainties.

3.5.4. Verify that the Design Solution Satisfy the Requirements

Each design for "X" team should provide evidence that their design solution adequately addresses each requirement. The degree of evidence that should be provided depends upon the importance of the requirement or constraint and the novelty of the design solution. Data showing that the proposed solution has satisfied similar requirements on past projects is desirable.

3.5.5. Look for Misaligned Linkages

Many requirements and constraints should be either positively or negatively linked from a design solution standpoint. A design solution that satisfies a demanding schedule requirement should, for example, also satisfy technical readiness requirements since proven technologies and approaches can normally be designed, procured, and constructed faster than first-of-a-kind technologies and approaches. A design solution that runs counter to normally expected linkages indicates a risk that needs to be fully evaluated prior to further pursuit. Such misalignment frequently involves schedule or cost goals that are incompatible with other objectives.

3.6. Incorporate Pre-conceptual Findings and Conclusions in the Project and Contract Documents

The information developed and the conclusions reached in sections 3.1 through 3.5 should be utilized as a "stepping off point" for the following documents which are begun next:

- Risk Management Plan
- Acquisition Strategy
- Project Execution Plan
- Architect-Engineers Statement of Work
- Architect-Engineer Services Selection Criteria
- Government Cost Estimate for Architect-Engineer Services
- Technology Maturation Plan
- Federal and M&O Contractor Staffing Plan
- Design Verification Roles and Responsibilities including a "Design Authority" Recommendation

The first three of these documents are covered in separate Guides and do not need to be addressed here. The latter six documents are not covered elsewhere and are addressed next.

3.6.1. Architect-Engineers Services Statement of Work

The process for acquiring architect-engineering services is prescribed in Subpart 36.6 of the Federal Acquisition Regulations. A contracting officer (CO) will be named to manage the acquisition process and to be the selection authority. The FPD and the IPT should provide the CO with a Statement of Work (SOW) that should:

- specify the Department's expected outcomes from the conceptual design, including the specific problems that should be solved;

- detail the tasks that the Architect-Engineer will perform;

- identify the associated tasks (such as determination of the site's geological conditions and local market limitations) that the Department or the M&O will perform;

- identify any specific tools and techniques that the Architect-Engineer should utilize;

- outline the information that the Department and/or the M&O will supply to the Architect-Engineer and when that information will be available;

- identify the performance standards for the conceptual effort, including quality, quantity, delivery schedules, packaging, etc.; and

- identify any design trade-off decisions that the Department wishes to retain as its authority. The latter should include the degree of design conservatism (i.e., design margins) to be maintained to offset the uncertainties and unknowns that are present at the early stages of the project.

The SOW, a critical document if the Department's "Waterfall" development strategy, is being used since it will become the sole official source of design direction to architect-engineer for the term of the contract. Post award changes to the SOW will have to be processed through the CO and be accompanied with a Government estimate of the cost impact as described in section 3.6.3. The creation of a SOW that adequately foresees all of the tasks that the architect-engineer will need to perform and identifies all of the design trade-off decisions that the Department wishes to retain control over can be highly challenging, if not impossible, on complex longer duration projects. There is also a significant timing problem on Hazard Category 1, 2, and 3 nuclear projects since the information in the Conceptual Design Safety Report, which is being developed concurrently, is needed in order to create the SOW.

The best approach in such cases may be one of the Evolutional Development Strategies discussed in section 3.4.2.1.2. The basic concept behind Incremental Development strategies can, for example, by simply providing a broader description of the Architect-Engineers total collection of tasks and then issuing more detailed tasking orders prior to the initiation of each project phase. This will result in some interruptions of the design effort, but will provide the FPD and the IPT with an increased ability to steer the Architect-Engineers activities.

The development of an adequate description of even the first two increments of the Architect-Engineers contract (conceptual and preliminary design) presents a significant challenge given the number of activities that are being conducted simultaneously during both increments and the high degree of interdependence between these activities.

DOE O 413.3A does not define either the specific content or the expected level of definition of either increment. It is up to the FPD and the IPT to make this determination based on the type of project being undertaken and the specific needs of the other project participants. For the conceptual design increment these needs are certain to include at least the following types of drawings which will be needed by those developing the Preliminary Hazards Analysis; the preliminary Security Vulnerability Assessment the Safety Design Strategy, Conceptual Safety

Design Report, and the Risk and Opportunities Assessments for Hazard Category 1, 2, and 3 nuclear facilities, the environmental impact documents; the project cost range; etc.

- Facility site location and utility connections
- Floor plans, elevations, and cross sections showing dimensions and the location of all major processing and building equipment.
- The structures, systems, and components selected to meet the requirements
- Building materials
- Structural loads, spans, and design approaches
- Process block flow diagrams
- Preliminary one-line diagrams for the:
  - Heating, ventilating, air conditioning systems
  - Electrical power system
  - Mechanical services systems
  - Instrumentation and control systems
- Process diagrams and configurations including the sizing of all major process systems and components

3.6.2. Architect-Engineer Services Selection Criteria

Architect-engineering service contracts for Government projects are awarded based demonstrated competence and qualifications. The FPD and the IPT should, accordingly, specify the capabilities and technical competence being sought in adequate detail to allow the CO and the evaluation board to ensure the candidates process the required knowledge, skills and abilities and to differentiate between the various candidates. This can be accomplished by cross linking capabilities and technical competence expectations to the firm's actual performance on similar Government and private sector projects. Quantitative measures such as the number and type of Request for Information, Engineering Change Notifications, Design Change Notifications, and Non-Conformance Reports provide valuable information on both the quality of the Architect-Engineer Firm's work and their understanding of the construction and manufacturing constraints that they should take into consideration when developing their design solutions.

If it is properly executed, the Selection Criteria can also serve as a vehicle for fulfilling the DOE P 450.4, *Safety Management System*, and DOE O 413.3A joint requirement that personnel possess the experience, knowledge, skills, and abilities necessary to discharge their responsibilities.

3.6.3. Government Cost Estimate for the Architect-Engineer Services

Subpart 36.605 of the Federal Acquisition Regulations specify that "an independent Government estimate of the cost of architect-engineer services shall be prepared and furnished to the contracting officer before commencing negotiations for each proposed contract or contract modification expected to exceed the simplified acquisition threshold" and that this "estimate shall be prepared on the basis of a detailed analysis of the required work as though the Government were submitting a proposal." The degree of accuracy that can be achieved in preparing such estimates depends on both the clarity of the SOW and the length of the contract.

3.6.4. Technology Maturation Plans

Technology Maturation Plans (TMP) detail the steps necessary for developing the technologies and/or design solutions that are currently less mature than desired, to a level that they can be safety inserted into the project. The TMP should identify:

- the specific tasks to be undertaken;
- the results to be achieved for a claimed advancement to a higher TRL to be statically valid
- the TRL expected to be reached at each of the Critical Decision points;
- the organization that will perform the maturation activities;
- the cost of these activities; and
- the off ramp that will be taken if results are less than required at each Critical Decision.

3.6.5. Federal and M&O Staffing Plan

The Acquisition Executive should have a detailed understanding of the Department's and the M&O contractor's staffing needs when making Critical Decision 1. This understanding can be provided through the submission of an updated IPT Charter and an accompanying project staffing plan that can be approved in conjunction with Critical Decision 1. The Staffing Plan should cover tasks such as preparation of a Preliminary Safety Validation Report and the Performance Baseline Validation Reviews that are performed by non-project personnel so that the Acquisition Executive, the site office manager, and other supporting organizations can foresee, and properly plan for the staffing loads they will have to accommodate.

3.6.6. Design Verification Roles and Responsibilities

The Department's directives contain multiple requirements and recommendations pertaining to project reviews, two of which are specifically aimed at ensuring that the design outputs satisfy project requirements. They are:

- "Beginning at CD-1 and continuing through the life of the project, as appropriate, Design Reviews are performed by individuals external to the project …to determine if a product (drawings, analysis, or specifications) is correct and will perform its intended functions and meet requirements. Design Reviews must be conducted for all projects and must involve a formalized, structured approach to ensure the reviews are comprehensive, objective, and documented."[26]

- "Design verification is a documented process for ensuring that the design and the resulting items will comply with the project requirements." "Design verification should be performed by technically knowledgeable persons separate from those who performed the design."[27]

Other DOE O 413.3A requirements that touch on the subject without specifically indicating that reviews should verify that the design satisfies the requirements are:

- The IPT "reviews and comments on project deliverables (e.g., drawings, specifications, procurement, and construction packages)."[28]

- "Contractors performing design for project must at a minimum conduct a Preliminary and Final Design Review, in accordance with the Project Execution Plan. For nuclear projects, the design review will include a focus on safety and security systems."[29]

DOE O 413.3A also specifies that the Acquisition Executive designates the Design Authority for the project at Critical Decision 1. The Design Authority (aka the Engineering Technical Authority) is the individual who formally signs off on the design drawings, calculations, and specifications. The Design Authority is typically not a DOE employee or official. This role and responsibility for assuring the technical adequacy of the design is normally delegated to the M&O contractor.

DOE-STD 1073, *Configuration Management*, provides the following additional information on the roles and responsibilities of the Design Authority on Hazard Category 1, 2, and 3 and nuclear facilities.

- "Contractors should establish the design authority for each SSC (structure, systems, and components). [30]

- The above "responsibilities are applicable whether the process is conducted fully in-house, partially contracted to outside organizations, or fully contracted to outside organizations." [31]

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[26] DOE O 413.3A, paragraph 5h(2)(c), page 22.
[27] DOE G 414.1-2A, section 4.6.5
[28] Paragraph 6m(9), page 42
[29] Attachment 2, Item 13
[30] Paragraph 3.5, page 3-9
[31] Appendix B, page B-3

- The design authority should define the category (mission critical, environmental protection, costly, critical software, master equipment list, adjacent) that the SSCs fall under.[32]

- "The contractor must assign a database owner for the equipment database, with established roles and responsibilities … the design authority is a likely choice. As such, the design authority would be the focal point for resolving discrepancies and updating the database."[33]

- "When facilities or systems are turned over from one organization to another, the design authority may also change. This may occur over a period of time. Procedures should be developed to govern this turnover. However, at any given time, there should be a single, defined authority for each SSC." [34]

- "Changes that affect the design basis require a design analysis by the design authority."[35]

- "The design authority should prepare a change control package consistent with the design process and controls for the proposed change."

- "The design authority must approve partially implemented changes prior to operation." [36]

The FPD and the IPT should provide the Acquisition Executive with a project design Roles and Responsibilities Proposal, which should include both the Department's and the M&O contractor's specific validation responsibilities including those assigned to the Design Authority. The depth and frequency of validation should be risk based with priority placed on the validation of high risk and importance requirement. It is recommended that these high priority requirements be checked at each formal review point.

It will be extremely difficult for those performing design verification roles to determine how, or if, preliminary designs that the architect/engineering firms develop and submit satisfy the Department's requirements unless an accompanying "roadmap" is also provided. The FPD should ensure that the need for such a "roadmap" is specifically identified in the SOW together with the methodology to be used in creating this "roadmap."

System Design Descriptions have proven to be highly effective in communicating or "mapping" the linkage between the design solutions and the Department's requirements on even the largest and most complex of projects and should be used as the benchmark against which other possible methods are evaluated. Information on System Design Descriptions can be found in DOE Standard 3024-98, *Content of System Design Descriptions* and Section 3.7 of DOE-STD-Standard 1073, *Configuration Management.*

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[32] Paragraph 3.2, page 3-5
[33] Paragraph 3.8, page 3-13
[34] Paragraph 3.5, page 3-9.
[35] Paragraph 5.3.1.1, page 5-8
[36] Paragraph 5.2.2, page 5-5

4.0 SUPPORT CRITICAL DECISION 1

DOE O 413.3A requires that the IPT review all Critical Decision packages and recommend whether they should be approved or disapproved.[37] Fulfillment of this recommendation involves far more than just checking the conceptual design report. It should also be based on: 1) whether the Critical Decision requirements specified in Table 2 of DOE O 413.3A have been properly completed; and, 2) a self evaluation of whether an adequate level of planning and risk mitigation/avoidance has been undertaken for the upcoming phase of the project. Each is addressed below for the Critical Decision 1.

4.1. DOE O 413.3A Critical Decision 1 Requirements

Most of the actions specified in Table 2 of the Order are performed by or involve different DOE, M&O contractor organizational elements. These include:

- Development of the Conceptual Design Report.
- Development of the Acquisition Strategy.
- Preparation of the Preliminary Project Execution Plan.
- Preparation of the Project Data Sheet.
- Preparation of a Preliminary Security Vulnerability Assessment Report.
- Preparation of a Preliminary Hazard Analysis Report for facilities that are below Hazard Category 3 threshold as defined in 10 CFR 830, Subpart B.
- DOE field level approval of the Preliminary Hazard Analysis Report.
- Preparation of a Safety Design Strategy, Preliminary Hazard Analysis, Risk and Opportunities Assessment, and Conceptual Safety Design Report for Hazard Category 1, 2, and 3 nuclear facilities.
- Preparation of a Preliminary Safety Validation Report based on DOE's review of the Conceptual Safety Design Report.
- Compliance with the One-for-One Replacement legislation mandated in House Report 109-86.
- Determination that the (site's already existing) Quality Assurance Program is acceptable, continues to apply, and fully addresses all of the applicable Quality Assurance Criteria defined in 10 CFR 830 Subpart A and DOE O 414.1C.

[37] Paragraph 6m, page 42.

- The Technical Independent Project Review that is required for high-risk, high-hazard, and Hazard Category 1, 2, and 3 nuclear projects.
- Preparation of the environmental documents.
- Preparation and processing of the Project Engineering and Design budget request.

Further, each action commences at a different point in time and most are dependent upon the receipt of information from one or more of the other organizations. The project is responsible for keeping each organizational element and activity in synchronization with the others. This can be a full time job for multiple individuals on even relatively modest projects since the individual actions are historically highly dynamic in nature and each change or perturbation tends to impact the other organizational elements. Such interdependencies between the different activities are often difficult to foresee. Negative findings and recommendations from the Technical Independent Project Review may, for example, result in the need to undertake previously unplanned work that in turn pushes the total cost of the conceptual effort over the $3 million conceptual design notification threshold imposed by Title 50 United States Code for projects authorized by the annual National Defense Authorization Act and necessitates a preparation and transmittal of a Congressional Notification.

4.2. Adequate Planning and Risk Reduction for the Next Project Phase

The adequacy of the project's advanced planning and risk reduction, activities such as those just discussed in section 4.1 for Critical Decision 1, is one of a number of the readiness-to-proceed questions that the IPT should ask themselves before appearing before the Acquisition Executive. Others include the quality of the cost and schedule estimates for the upcoming phase; the availability of funds for these activities; and, the status of the Architect-Engineer's contract and work force. The underlying issue is again the project's ability to keep all of these diverse activities in synchronization.

Larger projects have historically experienced high levels of rework with accompanying cost and schedule impacts because design and construction elements have been allowed to proceed in advance of full requirements definition and/or without adequate information on site conditions, operating environments, market capabilities, etc. The data base of actions being taken to eliminate uncertainties and knowledge gaps that was discussed in section 3.4.2.2 should be used together with the larger list of project development strategies provided in section 3.4.2 to prevent premature commitments of resources and help keep all of the project's activities in synchronization.

One of the more critical readiness-to-proceed questions that should be a resolved prior to advancing to Critical Decision 1 is what will constitute Preliminary Design completion? Order 413.3A does not define the level of calculation basis that should be achieved, which design elements should reach the component depth of detail, the accuracy to which equipment and structure components should be sized, the number or type of assumptions that are still allowable, etc. These questions are seen as project specific and left up to the FPD and the IPT to decide. They should be fully addressed in the SOW for preliminary design Architect-Engineering services and submitted to the Acquisition Executive for his or her approval.

4.3. Implement Requirements Change Control

The requirements that were captured as part of the pre-conceptual planning effort should be submitted to the Acquisition Executive for acceptance or rejection as part of Critical Decision 1. If approved, they should be placed under the non-Performance Baseline side of the project's formal change control system and utilized as the criteria for verifying/validating the acceptability of all future design solutions.[38]

5.0 TRANSITION TO AN OVERSIGHT AND COORDINATION ROLE UPON CRITICAL DECISION 1

DOE O 413.3A is based on the concept that the FPD and the IPT will transition to predominately an oversight and coordination role upon approval of Critical Decision 1. These two intertwined roles are discussed below.

5.1. Integrate the Preliminary Design Activities

The preliminary design activities specified in DOE O 413.3A and Standard DOE-STD 1189 are normally performed by more than twenty separate organizational elements. Each organizational element requires input from other organizations and, in turn, provides output information that the other organizations require. Interactions between the various organizational elements need to be highly iterative and should be planned and implemented using the strategies and tools specified in section 3.4.2 of this Guide.

This planning and integration should be performed by the FPD and the IPT since a number of the organizations involved are at the Headquarters level of the DOE organization.

5.2. Project Oversight

The extent of this transition to an oversight role and the length of time over which it takes place should be risk based. Noncomplex projects with fully defined requirements and few uncertainties require only a minimum transition period and relatively sparse interactions between the Architect-Engineer's designers and the other project participants. Conversely, the transition should occur at a slow pace with high levels of interactions maintained for the duration of preliminary design on:

- Complex projects
- Projects on which the requirements are still evolving.
- Projects where there are still significant uncertainties.
- Hazard Category 1, 2, and 3 nuclear projects.
- Projects of greater than normal management and/or public interest.

[38] See DOE O 413.3A, paragraph 5.i.(3), page 24 for the two categories of change control.

Those situations that require high levels of interaction with the Architect-Engineer should be handled with care to ensure that individual level discussions are not interpreted as contractual direction by the Architect-Engineer's staff and that all project participants fully understand that contractual direction only come through the CO. Similarly, these interactions need to be structured in such a way that they do not violate the Order 413.3A's requirement that the Federal Project Director "serve as the single point of contact between Federal and contractor staff for all matters relating to a project and its performance."[39] These constraints have been successfully handled on past projects by: 1) having the FPD serve as the Contracting Officer's Representative[40]; 2) holding regularly scheduled meetings between the Architect-Engineer's design team and the FPD/IPT; and, 3) inserting an on-site IPT field representative or representatives (working under a tightly written delegation of authority memorandum) in the Architect-Engineer's offices. The drafting of "Agreement and Commitment" memos (that only become effective upon the CO's signature) at the end of each periodic meeting has also proven to be a useful method of achieving the level of interactions necessary to prevent undesirable schedule delays and design breakage without violating contractual protocol.

The degree of interaction between the FPD/IPT, the M&O, and the Architect-Engineer Services Contractor should, under either case, be adequate to satisfy DOE O 413.3A requirements that:

- The FPD "evaluates and verifies reported progress; makes projections of progress and identifies trends."[41]

- The FPD "is responsible for (the) timely, reliable, and accurate integration of the contractor performance data into the project's scheduling, accounting and performance measuring systems."[42]

- The IPT "perform periodic reviews and assessments of project performance and status against established performance parameters, baselines, milestones and deliverables."[43]

- The head of the field organization, and the Acquisition Executive: "Develop project performance measures, and monitor and evaluate project performance throughout the project's life cycle."[44]

- The Acquisition Executive conduct monthly and quarterly project performance reviews.[45] plus, DOE O 414.1C's (*Quality Assurance*), requirements that:

    - Services that do not meet established requirements be identified and controlled.[46]

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[39] Paragraph 6g(8), page 39.
[40] Paragraph 6g(9), page 39.
[41] Paragraph 6g(7), page 39.
[42] Paragraph 6g(6), page 39.
[43] Paragraph 6m(6), page 42.
[44] Paragraph 6e(7), page 37.
[45] Paragraph 6f(7), page 38.
[46] Paragraph 4b(3)(b), page 4.

- Design interfaces be identified and controlled.[47]

5.2.1. Select Preliminary Design Performance Metrics

Earned value performance metrics are not formally required until Critical Decision 2 and DOE O 413.3A does not specify how preliminary design progress should be measured; therefore, the FPD will be forced to determine, in conjunction with the Acquisition Executive, an appropriate set of project specific performance metrics for this period of the project. This set of metrics should be weighted towards ensuring that the following mutually dependent sub-elements of the preliminary design phase are in synchronization.

5.2.1.1. Architect-Engineering Services

The Architect-Engineering Services tasks and products of greatest risk and importance should be tracked from the perspective of: 1) the Architect-Engineers schedule of deliverables as stated in the SOW; and, 2) the informational needs of the other tasks that must also be completed prior to Critical Decision 2. These tasks are addressed below.

5.2.1.2. Baseline Development and Review

The performance baseline development process, which is described in a separate DOE O 413.3A Guide, should be tracked with an eye towards the follow-on Performance Baseline Validation Review that DOE O 413.3A requires be completed before Critical Decision 2.

5.2.1.3. NEPA Documentation

The status of National Environmental Policy Act Compliance documentation, public meetings, and decisions should be tracked with emphases on its alignment or misalignment with the Architect-Engineering's activities and the overall preliminary design schedule.

5.2.1.4. DOE Standard 1189

If the project is a Hazard Category 1, 2, or 3 nuclear facility, progress on the following activities that are required by Standard 1189 should be tracked:

- Demonstration of how the preliminary design will satisfy the nuclear safety design criteria in DOE O 420.1B.
- Updating of the Safety-in-Design Risk and Opportunity Assessment.
- Development of the Preliminary Safety Design Report.
- Development of the systems or process level hazard analysis.
- Updating of the Fire Hazards Analysis.

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[47] Paragraph 4b(6)(c), page 5.

5.2.1.5. Independent Cost Estimate

DOE O 413.3A requires that either an Independent Cost Estimate or an Independent Cost Review be conducted prior to Critical Decision 2. The preparation for and performance of these activities should be tracked since an Independent Cost Review may be on the critical path and an Independent Cost Estimate is certain to be on the critical path.

5.2.1.6. Design Rework

The cost and time for design rework should be tracked against original allowances. Complex projects have historically been marked by high level rework or iteration that is not accounted for in either the cost estimates or schedules. Design approaches, drawings, specifications, reports, and documents are repeatedly abandoned or modified because of unidentified requirements, changes, incompatibilities with other areas of the project, and feedback from reviews. A significant amount of the cost and schedule growth that has occurred on the design portion of the Department's projects can be traced back to such iteration.

5.2.1.7. Elimination of Uncertainties/Unknowns

A formal data base that identifies each uncertainty, unknown, and unverified assumption was created as part of the pre-conceptual engineering project activities as described in section 3.4.1.2.2. The elimination of these uncertainties, unknowns, and unverified assumptions should now be tracked, together with the any needed increases in TRL, as part of the oversight process. The tracking process should again focus on ensuring that the information that is required by dependent sub-elements of the project is available on time.

5.2.2. Integrate Quality Assurance and Project Management Oversight

The degree of commonality between quality assurance and systems engineering is repeatedly mentioned throughout this Guide. The FPD and the IPT, should take advantage of this commonality by integrating oversight activities at the start of preliminary design. This should provide improved oversight and concurrently reduce the amount of time the architect-engineer and the other project participants expend providing information to the oversight functions.

5.2.3. Determine the Timing and Depth of Periodic IPT Reviews

It is possible, on shorter duration projects, for the FPD and the IPT to rely on the Performance Baseline Validation Independent Review and the project initiated Design Reviews to surface design errors. This approach is not workable on longer duration projects since preliminary design can take well over a year to complete and the cost and schedule impacts of waiting until the preliminary design work is finished to identify errors could be severe. It is more cost effective on such projects for the IPT to conduct mid point reviews that are timed to:

- the Architect-Engineer's internal design decision points,
- the possible cost and schedule impacts of design rework, and
- the importance of the design element.

5.2.4. Intercede While Emerging Problems Are Still Correctable

Oversight involves taking corrective actions as well as observing. The FPD and the IPT should, for example, direct the Architect-Engineer to increase the design margins on a particular structure, system, or component if they determine that such increases are needed to ensure that that the proposed design solutions adequately compensate for still unresolved uncertainties and unknowns or newly recognized uncertainties and unknowns. It is important, from a cost and schedule impact standpoint that such direction be given as soon as the FPD and the IPT become aware of the problem since delays can result in additional rework and design breakage.

Most directions for corrective actions will need to be transmitted to the CO or the Acquisition Executive for implementation since the majority of the Preliminary Design phase tasks are performed by organizational elements that are outside of the FPD's direct line of authority. The transmittals should be linked with the mandatory monthly and quarterly project performance reviews when time allows since these reviews provide a natural setting for in depth discussions of the problem and the need for action. Issue and risk identification and correction should be a standard element of these reviews. Two of the most frequently overlooked, but important project metrics are: 1) how quickly problems and negative risks trends are identified; and, 2) how quickly these same problems and negative risk trends are then corrected.

6.0 OVERSEE AND COORDINATE THE FINAL DESIGN ACTIVITIES

The magnitude of the FPD's and the IPT's coordination activities declines significantly during the final design phase of the project as can be seen from the reduced number of prerequisite tasks listed in Table 2 of DOE O 413.3A. The different organizational elements should now be in a position to work relatively independently of each others. This, together with the approval of the project performance baselines at Critical Decision 2, changes the thrust of the FPD's and the IPT's oversight and reporting effort to earned value variance identification and analysis. Risk management should, however, continue to be a major focus since earned value metrics may not pick up emerging market situations and other changes in the external environment.

Reductions in the FPD's and the IPT's coordination work load will be partially offset by increase in three other areas:

- change control,
- product acceptance/verification, and
- construction and procurement support.

6.1. Control Baseline and Requirements Changes

The Project Performance Baselines approved at Critical Decision 2 are placed under the formal control system described in the Project Execution Plan and DOE O 413.3A.[48] The FPD and the IPT should develop and implement a supplemental set of project level controls that operate below the thresholds specified in DOE O 413.3A and serve as early warning indicators of negative trends that necessitate corrective action.

Any additional requirements emerging during this phase of the project should be processed individually by the FPD and the IPT and immediately submitted to the Acquisition Executive for approval together with an analysis of the new requirement's impact and a recommendation as to how it should be back fitted into the on-going project.

6.2. Product Acceptance/Verification

The product acceptance/verification tasks assigned to the FPD and the IPT in the Proposal that was submitted to the Acquisition Executive prior to Critical Decision 1 (see paragraph 3.6.6 of this Guide) should be performed incrementally as the design products are completed to avoid the workload spike that would occur if they were treated in mass at the end of Final Design. Such incremental verifications should not introduce additional risk if the project tasks are properly synchronized.

6.3. Provide Construction and Procurement Support

As was the case with design, the CO rather than the FPD is responsible for the selection and award of the construction contract(s) and any Government furnished equipment. The CO may elect to self perform these efforts or may formally devolve them to the M&O contractor. Both the governing rules and the supporting activities performed by the FPD and the IPT remain the same regardless.

6.3.1. Provide Information to Help the CO Determine the Appropriate Form of Contract

The type of contractual relationship selected for equipment and construction is dependent upon:

- the level of risk and uncertainty inherent in the work to be performed and
- market conditions.

6.3.1.1. Integrate Risk Considerations into the Contract Form Selection Process

The Department's Acquisition Guide specifies that the contract type should be commensurate to the level of risk reflected in the Statement of Work. If too much risk is assigned to the contractor few, if any, bids or proposals may be received and those that are received will typically include significant additional allowances to cover the contractor's risk.

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[48] Paragraph 5i, pages 23 and 24.

Some of the risk factors that the DOE or the M&O contracting officer will take into consideration when selecting the form of contract to be utilized are:

- The type and complexity of the requirements. Requirements that are complex or unique to the Government increase the level of risks and suggest the use of cost reimbursement type contracts that shift the risk from the contractor to the Department.

- The urgency of the requirement results in the Department assuming a greater proportion of the risk or offer incentives to ensure timely contract performance if there is schedule urgency.

- The longer the performance period of the contract, the greater the possibility for unforeseen events.

- Contractors will be reluctant to shoulder the cost risk associated with technical challenges that they have not previously faced.

- Small firms may not have the financial means to take on risks.

The FPD and the IPT need to provide the contracting officer with the information necessary to make the above determinations and understand the interdependencies between quality and quantity of information that they can provide, the type of contract selected, and the ensuing relationship between the Department and the contractor. The types of contracts most frequently utilized for construction and government furnished equipment are discussed below together with the circumstances under which each is appropriate.

6.3.1.1.1. Firm-Fixed Price Contracts

Firm-fixed price contracts are generally utilized for construction. They require that the supplier deliver a defined product at a specified price at a specified time. Firm-fixed price contracts can accommodate uncertainties only if they can be fully identified and incorporated into the work scope at the time of award at a price that is acceptable to both parties. They place 100 percent of the responsibility and risk on the contractor. The Department's influence into how the product is developed is limited to the specific terms and conditions of the contract. Further information can be found in FAR Subpart 16.202.

6.3.1.1.2. Firm-Fixed Price Incentive Contracts

Firm-fixed price incentive contracts may be appropriate when there is uncertainty as to the cost of the product. They require agreement on: a possible range of cost; a reasonable target cost and target profit; a price ceiling; and, a share formula for establishing the final price. The share formula may be varied to fit the specific situation, commensurate with the degree of confidence both parties have in the range of possible cost and in the possible cost variations above or below target cost. The contractor is liable for all costs above the specified cost ceiling.

Firm-fixed price incentive contracts are not suited for situations involving technical uncertainty. Further information can be found in Subpart 16.403-1 of the FAR.

6.3.1.1.3. Cost-Plus Incentive Fee Contracts

Cost-plus incentive fee contracts are appropriate when performance objectives are known and there is high confidence that these objectives can be achieved; but there are technical and cost uncertainties. A target cost; a target fee; minimum and maximum fee limits; a fee adjustment formula; and, delivery, performance or cost incentives are negotiated at the time of contract award. Overall weight factors should be set for the different incentive factors.

Further information can be found in Subparts 16.304 and 16.405-1 of the FAR.

6.3.1.2. Cost-Plus Fixed Fee Contracts

Cost-plus fixed fee contracts are appropriate when there is high technical and cost uncertainty. There are two separate forms of cost-plus fixed fee contracts, a Completion Form and a Term Form. An identified product is specified under the "Completion Form" of a cost-plus fixed fee contracts, whereas the contractor is only obligated to deliver a specified number of hours for a specified time period under the Term Form of contract. The Completion Form is preferred over the Term Form.

Cost-plus fixed fee contracts provide minimum incentive for the contractor to control cost. Departmental oversight is the only assurance that efficient methods and effective cost controls are utilized. They normally should not be used once there is a high degree of probability that the product can be successfully developed and the Department has established reasonably firm performance objectives and schedules. Further information can be found in Subpart 16.306 of the FAR.

6.3.1.2.1. Cost-Plus Award Fee Contracts

Cost-plus award fee contracts are appropriate when the level of effort and the feasibility of the undertaking have been established; but milestones, targets, or goals to measure the contractor's performance cannot be expressed in objective terms. All allowable costs are reimbursed by the Department. The contractor's fee is established subjectively using an award fee evaluation criteria that include identified performance ranges. Cost-plus award fee contracts are not considered to be appropriate once requirements are defined.

Further information can be found in Section 16.305 and 16.405-2 of the FAR.

6.3.1.3. Integrate Market Conditions into the Contract Selection Process

Manufacturers and constructors are generally unwilling to invest the funds necessary to prepare a fixed price bid for a federal project if equivalent private sector work is available. This has led to a general lack of competition at many DOE sites with only one to two bids being submitted in response to many solicitations and those bids that are received being significantly higher than the government estimate. The FPD and the IPT should utilize the information they have obtained though their market surveys to identify those situations when the most cost effective solution would be to use one of the cost-plus forms of contracting. These situations will also generally be those that involve significant financial risk for the bidders.

6.3.1.4. Provide an Independent Government Estimate

Subpart 36.203 of the Federal Acquisition Regulations specify "an independent Government estimate of construction costs shall be prepared and furnished to the contracting officer at the earliest practicable time for each proposed contract and for each contract modification anticipated to exceed the simplified acquisition threshold." "The estimate shall be prepared in as much detail as though the Government were competing for award."

An independent estimate that is developed in strict accordance with this last sentence provides the FPD with both a basis for judging the reasonableness of the bids and an opportunity to discover previously unnoticed omissions, errors, and risk risers. The likelihood of such valuable discoveries taking place can be increased by using a truly independent estimator whose only source of information is the same bid package that the contractors and vendors will receive and requiring that he submit the same "Requests for Information" (RFI) when confronted with an unclear specification or drawing.

Some degree of iteration is an unavoidable part of combining different frames of reference and should be accepted. The FPD's and IPT's focus should, therefore, focus on controlling the cost and schedule impacts of iterations, rather than attempting to eliminate the iterations. This can be done using a simple Systems Engineering tool called Dependence Structure Matrix models that show the existence of dependencies between different activities in a format that is clearer and easier to read than flow diagrams and provides information that cannot be conveyed in most Critical Path Networks.

6.3.1.5. Determine if Construction and Procurement Should Be Split into Multiple Contracts

Construction and procurement can be combined into a single or multiple contracts. Single contracts place all coordination responsibilities on one contractor and are far easier for the Department or the M&O to administer. They can, however, also become so large on major projects that only a few companies have the resources necessary to either bid or successfully perform the work. Single large contracts can similarly require major step increases in project funding levels that can tax the Department's budgetary ceilings. Acquisition Executives and FPDs have, occasionally attempted to alleviate these problems by breaking construction into multiple packages and self procuring major equipment items. This approach transfers contractor and procurement integration responsibilities back to the M&O or the project and can quickly overwhelm these staffs.

As an alternative, a Construction Manager or Integrator can be utilized to place and manage these individual contracts. This can be done as either a contracted service or as a fixed price At Risk Construction Management Contract. Both approaches have significant advantages and disadvantages and should only be pursued after careful, project specific evaluations by the FPD and the IPT.

7.0 OVERSEE CONSTRUCTION

The FPD and IPT focus shifts to ensuring that the prime construction contractors, component manufactures, and subcontractors comply with the requirements of DOE O 413.3A and DOE O 414.1C, *Quality Assurance*, with Critical Decision 3 approval. Their activities now entail:

- assisting the CO evaluate and select bidders based on the bidders past performance on similar undertakings,
- ensuring that the requirements flow down to the subcontractors,
- establishing procedures to detect and prevent quality problems,
- reviewing and approving the contractors Quality Assurance Plan, and
- verifying and accepting end product.

In performing these duties the FPD and the IPT should track the following items and recommend corrective actions where appropriate:

7.1. Requests for Information

Requests for Information by the bidders are an indication that the bid packages (drawings or specifications) are incomplete, unclear, or conflicting. The FPD and the IPT should reassess the bid packages in light of requests for information and formally modify the drawings and specifications accordingly.

7.2. Engineering Change Notices (ECNs)

The FPD and IPT should maintain a log of all Engineering Change Notices and determine the cost, schedule, and quality impact of each change together with the reason for the change. This information should be utilized in the preparation and submission of lessons learned. A systematic method for posting ECNs against the affected documents needs to be established, including criteria for when affected documents need to be revised to incorporate outstanding ECNs.

7.3. Field Change Notices (FCNs)

Field Change Notices are initiated by the construction contractor, and, or the startup testing organization in response to installation or fabrication problems. They constitute a potential violation of configuration management and should be approved by the Authority Having Jurisdiction or Design Authority. A systematic method for posting FCNs against the affected documents needs to be established, including criteria for when affected documents need to be revised to incorporate outstanding FCNs.

7.4. Nonconformance Reports (NCRs)

Nonconformance reports are initiated by the projects construction inspectors and constitute a requirement that the contractor take corrective active to correct a noncompliance. Each noncompliance should be formally tracked to ensure that it is corrected. Each NCR should undergo a root cause analysis to ensure the underlying problem is not repeated. Each NCR should undergo an extent of condition evaluation to determine whether the condition is a one time event or requires a more generic action to prevent recurrence, in which case consideration needs to be given to either revising the underlying requirement document (e.g., specification or drawing), or issuing an ECN or FCN. A systematic method for posting NCRs against the affected documents needs to be established, including criteria for when affected documents need to be revised to incorporate the NCRs. Of special concern are NCRs that allow a one time deviation for the affected documents.

7.5. Contractor and Vender Claims

Contractor and vendor claims should be assessed for validity and compensation recommended as appropriate. All pending claims should be identified as potential sources of contingency draw down and summarized in the project's status reports. Valid claims should be considered for possible inclusion in the Department's lessons learned files.

7.6. As-Built Documents

The decision needs to be made prior to the start of construction activities as to which documents will be required to reflect the as-built condition once the construction and testing activities have been completed**.**

ATTACHMENTS

REQUIREMENT AREAS THAT HAVE REPEATEDLY PROVEN TO NEED A GREATER DEPTH OF DETAIL OR REFINEMENT

- Safety-class and safety-significant fire protection system requirements relating to:
  - Adequacy of water supplies.
  - Fireproofing of structural steel.
  - Degradation of HEPA filters.
  - Combustible loadings.
  - Fire detection and suppression system activation mechanisms.
- Required analysis of possible hydrogen and flammable gas generation and accumulation.
- Seismic design requirements relating to:
  - Ground motion.
  - Geotechnical investigations.
  - Soil settlement
- Structural engineering requirements relating to:
  - Soil-structure interaction analyses.
  - Load paths for seismic and settlement induced forces.
  - Finite element analysis.
  - Structural computer codes.
- Confinement strategy requirements relating to:
  - Analysis of the adequacy of the confinement barriers.
  - Magnitude of the radiological source term.
  - Models.
- Criticality standard requirements.
- Chemical processing safety requirements.
- Definition, selection, and implementation of quality assurance requirements.

- Requirements relating to the potential for solids settlement in pipes and ducts.
- Requirements relating to the application of lessons learned.
- Requirements relating to assumptions:
    - Basis.
    - Degree of conservatism.
    - Timely verification/confirmation.
- Requirements relating to acceptable calculation tools and techniques.

PROJECT EXECUTION INTERFACES WITH DOE P 450.4

DOE O 413.3A requires that projects be planned, design, and executed using Integrated Safety Management policies and procedures. Integrated Safety Management policies and procedures are specified in other Directives and Rules including DOE P 450.4, *Safety Management System Policy*. Some of the most pertinent interfaces between DOE P 450.4 and this Guide can be seen in the following extracts from DOE P 450.4:

- "Direct involvement of workers during the development and implementation of safety management systems is essential for their success."
- "Personnel shall possess the experience, knowledge, skills, and abilities that are necessary to discharge their responsibilities."
- "Before work is performed … an agreed-upon set of safety standards and requirements shall be established which, if properly implemented, will provide adequate assurance that the public, the workers, and the environment are protected from adverse consequences."
- "Missions are translated into work, expectations are set, tasks are identified and prioritized, and resources are allocated."
- "Applicable standards and requirements are identified and agreed-upon…"
- "…opportunities for improving the definition and planning of work are identified and implemented…"
- "Responsibilities must be clearly defined in documents appropriate to the activity."

PROJECT EXECUTION INTERFACES WITH DOE G 450.4-1B

DOE O 413.3A requires that projects be planned, designed, and executed using Integrated Safety Management policies and procedures. Integrated Safety Management policies and procedures are specified in other Directives and Rules including DOE G 450.4-1B, Volume 1; *Integrated Safety Management System Guide*. Some of the more pertinent interfaces between DOE G 450.4-1B and this Guide can be seen in the following extracts from DOE G 450.4-1B, Volume 1:

- "Integration is especially important for programs and activities with conflicting or competing goals or requirements (e.g., fire protection and criticality safety, or personnel safety and safeguards and security)." (page 6)

- "Other programs, such as those for configuration management and conduct of operations are more appropriately specified at the facility or project level." (page 6)

- "Identify Facility Standards and Requirements." (Figure1, page 8)

- "Identify Activity Standards and Requirements." (Figure 1, page 8)

- "A first step is to translate missions into work requirements in conjunction with the prioritization of budget and resources." (page 10)

- "Individuals responsible for engineering the processes (e.g., weapons assembly and disassembly, nuclear material fabrication and stabilization, criticality experiments, waste storage, hazardous waste cleanup, routine maintenance, pollution prevention, and waste minimization) should work with multidisciplinary teams who have direct responsibility for analyzing hazards, identifying control measures derived from that analysis, and ensuring those measures are effective." (page 11)

- "…managers responsible for individual systems should know where each of their processes interfaces with a process owned by another organization. Responsible managers should then communicate routinely with interfacing managers to assess the efficiency and effectiveness of the process and communicate immediately whenever changes occur that have an impact on one or more interfaces." (page 11)

- "Meaningful management commitment to worker safety requires … ensuring compliance with all applicable requirements and regulations." (pages 11 and 12)

- "Further, for processes involving multiple types of hazards, consideration should be given to the use of worker/management teams with a variety of expertise to ensure that each type of hazard receives informed considerations." (page 14)

- "The exact nature of the activity changes as the safety processes are integrated:

  - first, with the conceptual design, preliminary design, and final design activities;

  - second, with the engineering design and development activities;

- third, with the more traditional integrated safety management activities associated with the physical plant during the construction and operational phases; and

- finally, with the activities to be performed during facility disposition." (page 15)

▪ "Work planning begins the integration of all systems pertinent and necessary to a process, operation, or task." (page 26)

▪ "It is extremely important for DOE and its contractors to formally establish and clearly define the work to be performed, the priority assigned, and the expectations for completion." (page 28)

▪ "Each organizational level (i.e., DOE Headquarters, DOE field element, contractor) should, therefore, establish a method for ensuring a proper balance among competing priorities of the organization (e.g., budget, schedule, safety, quality) …Typically, a senior management review committee or council within DOE or the contractor organization may be established to resolve conflicts, establish priorities, and ensure a balance in resource allocation." (page 31)

▪ "The knowledge, skills, and abilities of the work force should be considered when selecting the form of controls." (page 41)

▪ "The DEAR ES&H clause (48CFR 970.5223-1(b) (6)) and DOE P 450.4 require the integration of environment, safety, and health functions and activities including pollution prevention and waste minimization into work planning and execution. Integration should be evident throughout all organizational functions at all organizational levels from the site to the individual activity." … "Typical site wide processes, procedures, and/or programs that need to be integrated include engineering support, fire protection, emergency preparedness, maintenance, environmental protection, waste management, industrial hygiene, occupational safety, chemical safety, radiological protection, and training." (page 72)

PROJECT EXECUTION INTERFACES WITH DOE G 450.3-3

DOE O 413.3A requires that projects be planned, designed, and executed using Integrated Safety Management policies and procedures. Integrated Safety Management policies and procedures are specified in other Directives and Rules including DOE G 450.3-3; *Tailoring for Integrated Safety Management Applications.* Some of the more pertinent interfaces between DOE G 450.3-3 and this Guide can be seen in the following extracts from DOE G 450.3-3.

- "Designing work entails making decisions about a continuous variety of options and tradeoffs. It is the balance of these options and tradeoffs that determine if a work design will be successful. Many of these tradeoffs are integrally related to tailoring the other elements. They include developing and resolving the work scope, establishing a technical approach, adjusting resources, adapting personnel (experience and expertise), adjusting schedule, and performing tasks sequentially or in parallel to minimize hazards or to optimize the critical work path." (page 8)

- "Too often, formality and documentation are associated, or equated, with budget or cost, even when the work and the hazards are of a routine nature. A better gauge of the need for formal documentation is the complexity of the work…" (page 8)

- "There is a faded management adage that "systems break down at the interfaces." So, too do the benefits of hazards analyses, if no attention is paid to how workers' jobs can affect one another to cause accidents; how juxtapose (either directly connected or nearby) activities or processes can influence one another; how multiple activities or projects within a single facility can adversely affect or be affected by the shared support systems provide by that facility…." (page 10)

PROJECT EXECUTION INTERFACES WITH DOE O 440.1B AND DOE G 440.1-2

Construction safety is not specifically addressed in DOE O 413.3A. It is, however, an inherent part of integrated safety management and the FPD and the IPT need to be cognizant of the following interfaces with DOE O 440.1B, *Worker Protection for DOE (including National Nuclear Security Administration) Federal Employees* and DOE G 440.1-2, *Construction Safety Management Guide for Use with DOE O 440.1*.

- "Construction Project Mangers determine the necessity for requiring dedicated construction contractor safety and health personnel on project workplaces." [DOE O 440.1B, Attachment 1, paragraph1(b)(1)]
- "Construction Project Managers ensure that construction project acquisition documents provide information or reference to existing documentation that describes known hazards to which project workers ma be exposed." [DOE O 440.1B, Attachment 1, paragraph1 (b)(2)]
- "Construction Project Managers ensure that a pre-work safety meeting is conducted with the construction contractor to review project safety and health requirements." [DOE O 440.1B, Attachment 1, paragraph1(b)(3)]
- "Construction Project Managers ensure that the project safety and health plan is approved prior to any on-site project work and that required hazard analyses are completed and approved prior to start of work on affected construction operations." [DOE O 440.1B, Attachment 1, paragraph1(b)(4)]
- "Construction Project Managers ensure that project safety and health plans and hazard analyses are revised, as necessary, to address identified deficiencies in project safety and health performance or changes in project operations, contractors, or personnel. [DOE O 440.1B, Attachment 1, paragraph1(b)(5)]
- Construction Project Managers, through personal on-site involvement and/or formal delegation to support staff … , perform frequent and regular documented on-site reviews of construction contractor safety and health program effectiveness. [DOE O 440.1B, Attachment 1, paragraph1(b)(6)]
- "Construction Project Managers ensure documentation exists for all formal contract actions taken to enforce construction contractor compliance with project safety and health requirements." [DOE O 440.1B, Attachment 1, paragraph1(b)(7)]
- "… to the greatest extent possible, integrate the management of safety and health, both in terms of project personnel and management methodologies, with the management of the other primary elements of construction project performance: quality, cost and schedule."(DOE G 440.1-2, section 1, page 1)

- "… it is the intent of the Order to integrate the safety and health requirements of the Order, to the greatest extent practicable, with the required activities of the project management team otherwise necessary to ensure compliance with the cost, quality, and schedule requirements of the project." (DOE G 440.1-2, section 3, page 2)

- "It is intended that the safety and health requirements of the Order be clearly communicated to the construction contactor through the development and incorporation of appropriate contract language in the project acquisition documents and not simply by reference." (DOE G 440.1-2, section 4.4, page 6)

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The following list includes general sources of information on Systems Engineering plus topic specific documents from outside of the Project Management field that might not otherwise come to the users' attention. Neither DOE directives, nor those documents identified via footnotes in the body of the Guide, are included:

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