

Cost Estimating

DOE G 413.3-21A

Project Management Programs

January 2023

DOE G 413.3-21A – cont'd

- Forward
- Purpose
- Key Guidance Characteristics
- Cost Estimating Inputs
- Cost Estimating Characteristics and Classifications
- Cost Estimating Methods
- Cost Estimating Development Process
- Cost Estimating Outputs
- Cost Estimating Expectations

DOE G 413.3-21A – cont'd

Project Management Document Hierarchy

Agency/DOE Policy/Guidance

Federal/National Level Policy/Guidance

OMB Circular A-11: Part 7

Capital Programming Guide: References EIA-748 for EVMS Requirements

FAR Part 34: Major System Acquisition

General Describes Acquisition Policy and Procedures to OMB Circular A-109 and OMB A-11

FAR Part 34.2: Earned Value Management System

Describes policies and procedures for EVMS in major acquisitions defined in OMB A-11, Part 7

FAR Part 52.234-4: Earned Value Management System

Establishes compliance the Earned Value requirements of EIA-748

SAE International EIA 748™

Earned Value Management System

DOE EM Program Management Protocol

DOE-PM-SOP- Current Version

PM EVMS ECRSOP Compliance Assessment Guide

DOE 413.3B Current Version

Program and Project Management for the Acquisition of Capital Assets

DOE 413.3-1

Managing Design and Construction Using Systems Engineering

DOE 413.3-5A

Performance Baseline

DOE 413.3-7A

Risk Management

DOE G 413.3.9A

Project Reviews for Capital Asset Projects

DOE 413.3-10.B

Integrated Project Management Using the EVMS

DOE 413.3-12

Project Definition Rating Index

DOE 413.3-15A

Project Execution Plans

DOE 413.3-18A

Integrated Project Team Guide for formation and implementation

DOE 413.3-20

Change Control Management

DOE 413.3-21A

Cost Estimating Guide

Field Office/TOC Contract/ Contractor Policy/Guidance

Tank Operations Contract - DE-AC27-08RV14800
Performance-Based Cost-Plus-Award Fee Contract

TFC-PLN-84
Tank Operations Contract Project Execution Management Plan

TFC-PLN-147
TOC Project Controls System Description

RPP-PLAN-62858
TOC Project Execution Plan for TSCR, Tank Farm Upgrades, and Waste Feed Delivery

Tank Operations Contract

Foreword

A strong cost estimating foundation is essential to achieving program and project success. Every Federal cost estimating practitioner is challenged to strive for high quality cost estimates by using the preferred best practices, methods and procedures contained in this Department of Energy (DOE) Cost Estimating Guide. Content in this guide supersedes DOE Guide 413.3-21, Chg1, Cost Estimating Guide, 10-22-2015.

The Guide is applicable to all phases of the Department's acquisition of capital asset life-cycle management activities and may be used by all DOE elements, programs and projects. When considering unique attributes, technology, and complexity, **DOE personnel are advised to carefully compare alternate methods or tailored approaches against this uniform, comprehensive cost estimating guidance.** Programs may specify more specific processes and procedures that augment or replace those in this guide (e.g. NNSA Life Extension Programs (LEPs) fall under the process/timeline in the Phase 6.X process).

Guides provide non-mandatory supplemental information and additional guidance regarding executing the Department's Policies, Orders, Notices, and regulatory standards. Guides may also provide acceptable methods for implementing these requirements. Guides are not substitutes for requirements, nor do they replace technical standards that are used to describe established practices and procedures for implementing requirements. Send citations of errors, omissions, ambiguities, and contradictions found in this guide to PMpolicy@hq.doe.gov.

Purpose

The primary purpose of the DOE Cost Estimating Guide is to supply DOE cost estimating practitioners with uniform guidance, methodologies, and best practices to ensure development of high-quality cost estimates.

Although applicable to all cost estimating, this guidance is tailored to be largely applicable to the cost estimation of construction projects and/or programs.

These cost estimates usually result in project independent cost estimates (ICEs) to validate a project performance baseline. They are similar but different from an independent government cost estimate (IGCE) normally used to support a contract action.

The guidance considers all phases of the Department's work in creating credible project cost estimates that can be used to predict, analyze, and evaluate a project and program's cost and schedule, and serve as a critical program control planning tool.

Once credible cost estimates have been presented to and approved by management, they can be used as a basis for measuring performance against an approved baseline using an Earned Value Management (EVM) System.

While this guide is largely applicable to the cost estimation of construction projects and/or programs, the recommended practices and methodologies are also valid when applied to IGCEs.

The IGCE can be used to support contract cost and price analysis, cost realism analysis for a negotiated contract action, or a contract source selection matter must be coordinated with the contracting officer and their supporting cost and price analyst to ensure that they are consistent with the prescribed methodologies, cost treatment, and guidance set forth in the Federal Acquisition Regulations, DOE Acquisition Regulations, and other agency policies and guidance.

This guide references the GAO Twelve Steps of a High-Quality Cost Estimating Process (GAO-09-3SP) for techniques that have been proven to improve cost estimates.

Formally documenting the cost estimate using the GAO 12-step process provides an additional measure of quality.

GAO best practices alone are not sufficient to ensure a high-quality cost estimate in all cases; thus this Guide outlines additional techniques and best practices that, when used in conjunction with the GAO 12-step process, should improve cost estimates.

The Guide conveys information that conforms to the accepted industry estimating standards and is intended to facilitate the development of local or site-specific cost estimating requirements.

KEY GUIDANCE CHARACTERISTICS

High quality cost estimates support the execution of projects and programs and help to ensure that management is given the information it needs to make informed decisions. The cost estimating principles and processes provided herein may be used to meet or adhere to Federal and DOE requirements while utilizing industry standards and best practices.

High-Quality Cost Estimates

The GAO Cost Estimating Guide, through documentation of industry best practices, cites four characteristics of high-quality cost estimates. They should be **credible**, **well-documented**, **accurate** and **comprehensive**.

Credible – Estimates are considered credible if they clearly identify limitations because of uncertainty or bias surrounding the data or assumptions. Major assumptions should be varied and other outcomes recomputed to determine how sensitive outcomes are to changes in the assumptions. A risk and uncertainty analysis should be performed to determine the level of cost estimate uncertainty or risk. A full scale Monte Carlo analysis may not be necessary based on type of estimate. Results of the estimate should be cross-checked and an Independent Cost Estimate (ICE) performed when deemed necessary based on the CD requirement and/or the risk of the work to determine whether alternative estimate views produce similar results. Estimates should also be evaluated against historical ACWP values for similar work that may have been done at DOE sites. Cost estimating involves collecting and analyzing available historical data and applying quantitative models techniques, tools and databases to predict a program's future cost.

Sensitivity analysis is used to identify key elements that drive cost by manipulating each potential driver in the cost estimate individually and analyzing the associated impact, to determine which activities have the potential for the greatest impact to the program amounting to a what-if analysis.

Along with a sensitivity analysis, a risk and uncertainty analysis adds to the credibility of the cost estimate, because it identifies the level of confidence associated with achieving the cost estimate. Risk and uncertainty analysis produces more realistic results, because it assesses the variability in the cost estimate from such effects as schedules slipping, missions changing, and proposed solutions not meeting users' needs. An uncertainty analysis gives decision makers perspective on the potential variability of the estimate should facts, circumstances, and assumptions change. By examining the effects of varying the estimate's elements, a degree of uncertainty about the estimate can be expressed with a range of potential costs that is qualified by a factor of confidence.

Another way to reinforce the credibility of the cost estimate is to see whether applying a different method produces similar results. In addition, industry rules of thumb can constitute a sanity check. The main purpose of cross-checking is to determine whether alternative methods produce similar results. If so, then confidence in the estimate increases, leading to greater credibility. If not, then the cost estimator should examine and explain the reason for the difference and determine whether it is acceptable.

Well-documented – Cost estimates need to be well documented, traceable to original sources, and easily repeatable or updated. Rigorous documentation also increases an estimate's credibility and helps support an organization's decision making.

The documentation should explicitly identify the primary methods, calculations, results, rationales or assumptions, and sources of the data used to generate each cost element. Cost estimate documentation should be detailed enough to provide an accurate assessment of the cost estimate's quality. For example, it should identify the data sources, justify all assumptions, and describe each estimating method (including any cost estimating relationships) for every Work Breakdown Structure (WBS) cost element. Further, schedule milestones and deliverables should be traceable and consistent with the cost estimate documentation.

Estimating methods used to develop each WBS cost element should be thoroughly documented so that their derivation can be traced to all sources, allowing for the estimate to be easily replicated and updated.

Accurate – Estimates should be based on an assessment of most likely costs, adjusted properly for inflation, and contain few, if any, minor mistakes. In addition, revise cost estimates to reflect schedule revisions initiated by contract modifications.

Validating that a cost estimate is accurate requires thoroughly understanding and investigating how the cost estimate was constructed. For example, all WBS cost estimate elements should be checked to verify that calculations are accurate and account for all costs, including indirect costs. Moreover, proper escalation factors should be used to inflate costs so that they are expressed consistently and accurately. Rechecking spreadsheet formulas and data input is imperative to validate cost model accuracy.

Besides these basic checks for accuracy, the estimating technique used for each cost element should be reviewed, to make sure it is appropriate for the degree of design or requirements definition that is complete.

Depending on the analytical method chosen, several questions should be answered to ensure cost estimate accuracy. The GAO Cost Estimating and Assessment Guide outlines typical questions that should be answered to assess accuracy associated with various estimating techniques.

Comprehensive – Cost Estimators or Analysts should make sure that the cost estimate is complete and accounts for all costs that are likely to occur. They should confirm its completeness, its consistency, and the realism of its information to ensure that all pertinent costs are included.

Comprehensive cost estimates completely define the program, reflect the project schedule, and are technically reasonable. The Cost Estimator should also identify the technical approach to complete the scope identified, considering that each approach may yield a different estimate covering the same scope. Estimates should be structured in sufficient detail to ensure that cost elements are neither omitted nor redundant. For example, if it is assumed that software will be reused, the estimate should account for all associated costs, such as interface design, modification, integration, testing, and documentation.

To determine whether an estimate is comprehensive, an objective review must be performed to certify that the estimate's criteria and requirements have been met. This step also infuses quality assurance practices into the cost estimate. In this effort, the reviewer checks that the estimate captures the complete technical scope of the work to be performed, using a logical WBS that accounts for all performance criteria and requirements. In addition, the reviewer must determine that all assumptions and exclusions the estimate is based on are clearly identified, explained, and reasonable.

From GAO-09-3SP, there are 12 key steps that are recommended to DOE practitioners to produce high quality cost estimates:

1. Define the estimate's **purpose**
2. Develop an estimating **plan**
3. Define the Project (or Program) **characteristics**
4. Determine the estimating **structure** [e.g., WBS]
5. Identify **ground rules and assumptions**
6. **Obtain data**
7. **Develop a point estimate and compare to an independent cost estimate**
8. Conduct **sensitivity analysis**
9. Conduct **risk and uncertainty analysis**
10. **Document the estimate**
11. Present the estimate for **management approval**
12. **Update** the estimate to reflect actual costs and changes

Cost Estimate Structure

One of the GAO characteristics and best practice steps – determining the estimating structure – includes the need to develop a “product-oriented” WBS that reflects the requirements and basis for identifying resources and tasks necessary to accomplish the project’s objectives.

DOE O 413.3B promotes the development of a well-defined and managed project performance baseline (defined by scope, schedule, cost, and key performance parameters).

This guidance highlights the importance of four closely interrelated processes to help define the project baseline: development of a WBS for scope definition, cost estimating, schedule development, and risk management.

- The Work Breakdown Structure process provides:
 - A complete decomposition of the project into the discrete products and activities needed to accomplish the desired project scope (the WBS dictionary should contain in a narrative format what each activity includes);
 - Compatibility with how the work will be done and how costs and schedules will be managed;
 - The visibility to all important project elements, especially those areas of higher risk, which warrant additional attention during execution;

DOE G 413.3-21A – cont'd

- The mapping of requirements, plans, testing, and deliverables;
- A clear ownership by managers and task leaders;
- Organization of data for performance measurement and historical databases; and,
- A living document that is the basic building block for the planning of all authorized work.

The Cost Estimate process provides:

- Documented assumptions and basis of estimate that provide further project definition;
- The activity quantities that make up the scope of work;
- The cost element data (labor and non-labor) needed to complete the products/deliverables;
- The estimated resource hours and non-labor values that make up the work;
- The component elements (labor, materials, equipment, etc.) required to complete activities and work packages; and,
- Additional WBS elements mined during the detailed take-off.
- Description of any applicable indirect costs (e.g. operation and maintenance, security, legacy pension requirements).

The Schedule process provides:

- The activity durations based on the “crew” production rates per quantity and other work influences, i.e. hold points, space restrictions, cure time;
- Logical relationships of all schedule activities;
- Critical path that represents the longest duration for the project and the sequence of work with the least margin for deviation or flexibility;
- The time phasing of activities that identify new activities or costs, i.e. winter work, escalation needs;
- The milestones and activity relationships that define possible impacts, i.e. overtime needed to complete activities.
- The durations of Level of Effort (LOE) activities needed for the cost estimate to accurately develop costs.
- The sequence of the procurement of long lead items needed for the cost estimate to accurately develop costs and expose any possible impacts to the overall project planning due to the procurements; and
- Additional WBS elements exposed during the development of the planning sequence and logic.

The Risk Management process provides3:

- Identification of technical, schedule, and cost risks.
- Selection of appropriate risk handling strategies to either reduce impact of threats (negative risks) and enhance impact of opportunities (positive risks)
- Analysis of both threats and opportunities to determine fair and reasonable allowances for risk and estimate uncertainty to support the project/ program (Contingency & Management Reserve)

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Purpose of the Cost Estimate

- The purpose of a cost estimate is determined by its intended use (e.g., studies, budgeting, baseline proposals, etc.), and its intended use determines its scope and detail. Cost estimates should have general purposes such as:
- Establish cost and schedule ranges throughout the project development phases;
- Support the budget process by providing estimates of the annual funding and phased budget requirements required to efficiently execute work for a project or program;
- Support long-term portfolio cost projections;
- Provide data for value engineering/value analysis studies, independent reviews, and baseline changes.

For projects governed by DOE 413.3B, the purposes of cost estimates include:

- Provide a rough order of magnitude cost range at Critical Decision (CD)-0 (see Figures 3-1 and 3-2 for a pictorial description of the DOE Critical Decision Process);
- Help the DOE and its managers evaluate and select alternative solutions at CD-1;
- Create a Project Performance Baseline to obtain CD-2 approval and to measure progress following the CD-2 approval; or,

Overview of the Cost Estimating Process Model

Traditionally, cost estimates are produced by gathering input, developing the cost estimate and its documentation, and generating necessary output in an iterative fashion. The scope of work, schedule, risk management plan, and peer review interact to influence the cost estimating process and techniques used to develop the output.

COST ESTIMATING INPUTS

Cost estimate development is initiated by inputs to the process. These inputs are process elements that can be either one-time or iterative in nature as illustrated in the above process model. One-time inputs may include project/program requirements, the mission need statement, and the acquisition strategy or acquisition plan.

Iterative inputs may include the technical/scope development, the schedule development, and the risk management plan with associated risk identification and mitigation strategies. The peer review results in the process may also identify the need to revisit various process elements to improve the quality of the cost estimate. Cost estimates that are developed early in a project's life may not be derived from detailed engineering designs and specifications (may not be a point estimate but a high/low range project estimate), but they should be sufficiently developed to support budget requests for the remainder of the project definition phase.

Over the life of the project or program, the scope will become more definitive. As this level of definition increases cost estimates become more definitive with narrower cost ranges, and will eventually reflect the scope and schedule of work packages and planning packages defined for the project. Normally, this should reduce uncertainty, assumptions, and number of risks and/or their impact if realized.

Project/Program Requirements

Appendixes B and C provide summaries of the Federal and DOE requirements for cost estimates, respectively.

Each DOE program or project may have more specific, detailed requirements.

Examples include the

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA),
National Environmental Policy Act (NEPA);

safety and health;

site security requirements; and

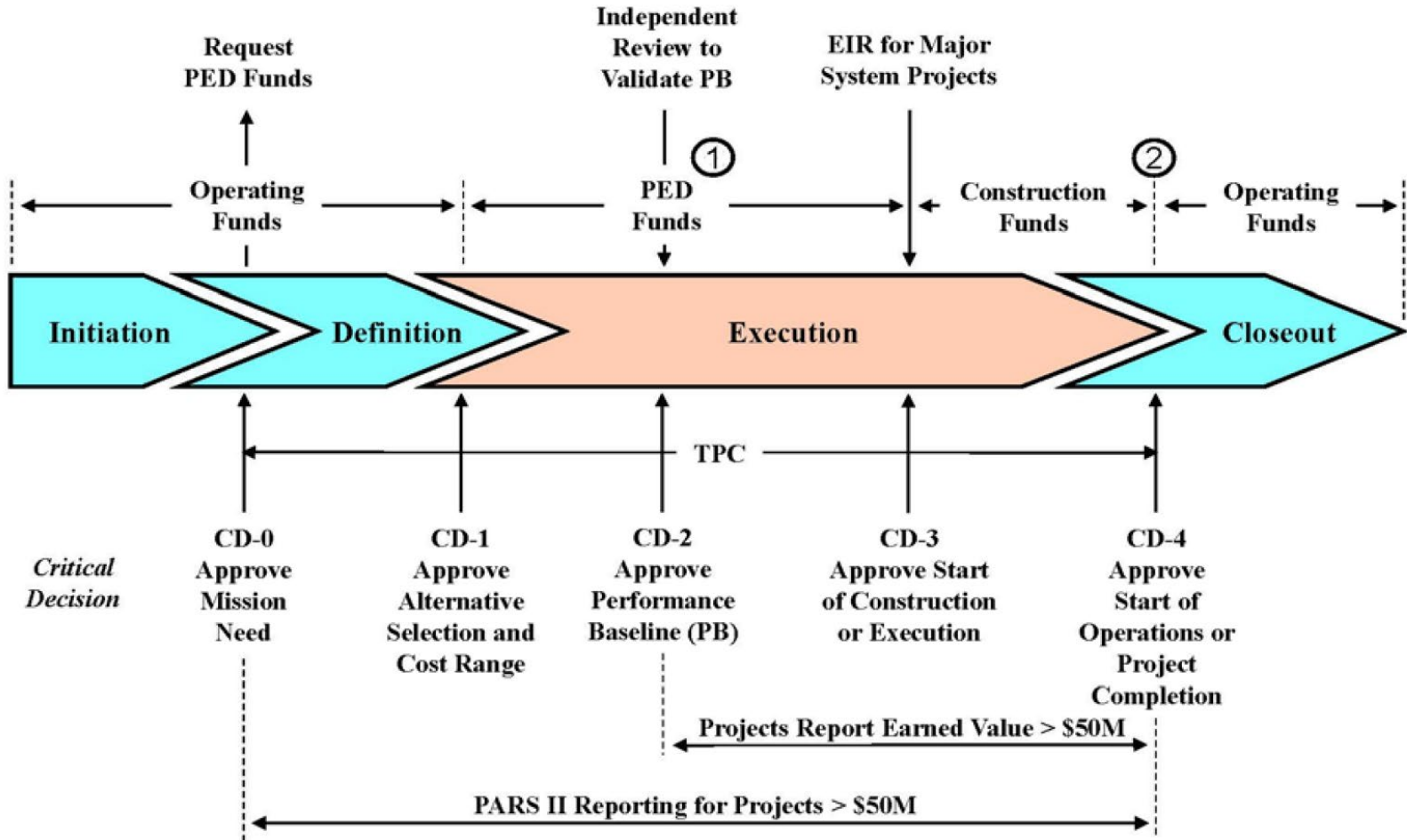
local requirements that may be specified in contracts, labor agreements, etc.

Many of these requirements are implemented through the DOE annual budget formulation and execution process, and may add cost to projects. The **primary requirement for developing cost estimates for capital asset projects is DOE O 413.3B.**

During the life cycle of a project (see figures below), various cost estimates and related documents are required to support the Critical Decision process, the project reviews process, and the annual budget formulation and execution process.

DOE G 413.3-21A – cont'd

Typical DOE Acquisition Management System for Line-Item Capital Asset



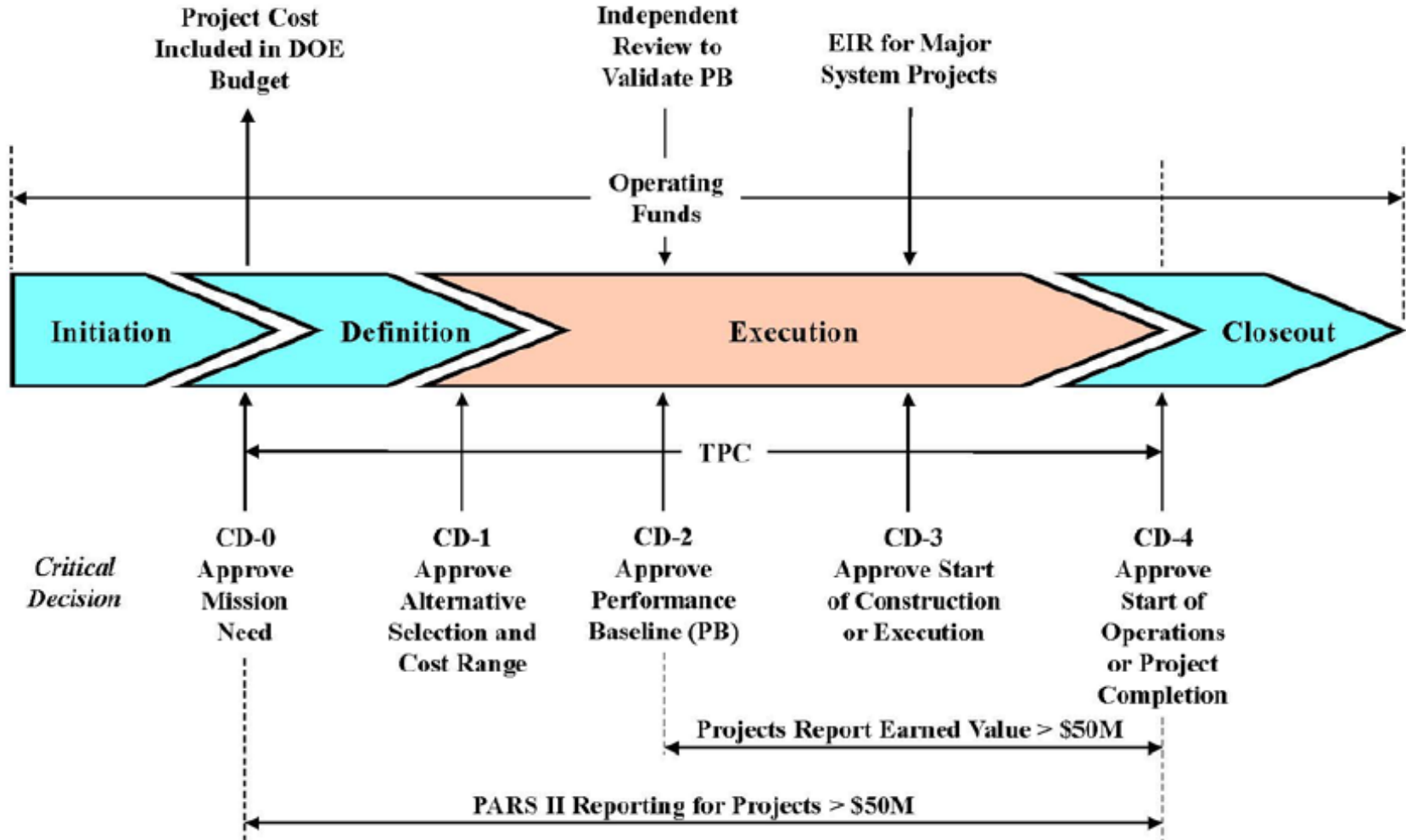
NOTES:

1. PED funds can be used after CD-3 for design.
2. Operating Funds may be used prior to CD-4 for transition, startup, and training costs.

CD = Critical Decision
 EIR = External Independent Review
 PARS = Project Assessment and Reporting System
 PB = Performance Baseline
 PED = Project Engineering and Design
 TPC = Total Project Cost

DOE G 413.3-21A – cont'd

Typical DOE Acquisition Management System for Other Capital Asset Projects (i.e., Major Items of Equipment and Operating Expense Projects)



Application of this Guide to DOE Estimating

Common cost estimating outputs are shown in the figure below. As this figure depicts, cost estimates must be developed, updated, and managed over the total life-cycle of any asset and are an important element for total life-cycle asset management within the DOE. Furthermore, project cost estimates are an integral element and key input into the management of programs over their life-cycle. Thus the concepts for cost estimate development described in this Guide can be applied to all instances when cost estimates are required to support both project and program management objectives.

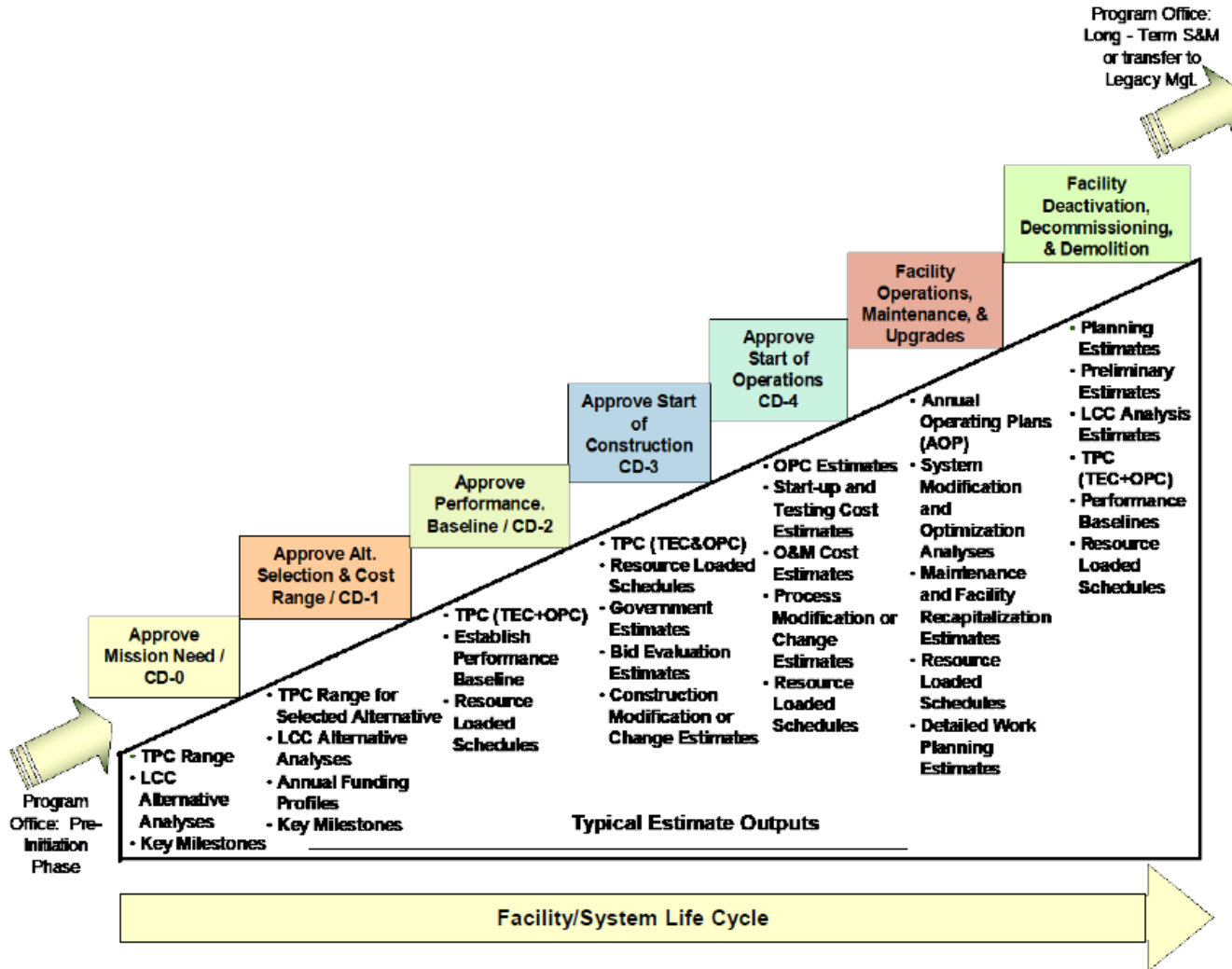
As described by the DOE O 413.3B, and other DOE directives, cost estimates and LCC analyses may be produced for a variety of purposes. As discussed below, these may include:

- The critical decision process within programs/projects (DOE O 430.1C and DOE O 413.3B);
- The DOE annual budget guidance document; and
- Other project/program management purposes (various Federal regulations, DOE Orders, and industry practices).

Best practices for Life-Cycle Cost (LCC) include all anticipated costs associated with a project or program alternative throughout its life; i.e., from authorization through operations to the end of the facility/system life cycle. (figure below).

DOE G 413.3-21A – cont'd

Facility/System Estimate Outputs as Compared to Life-Cycle Major Milestones



DOE Critical Decisions for Project Management and the Supporting Cost

Estimates Critical Decision (CD)-0, Approve Mission Need — Generally, a Rough Order of Magnitude (ROM) cost estimate range is prepared to support CD-0. Assumptions developed by the project team generally will drive the project scope and bound both the project scope and costs.

There will likely be very little detail to support these cost estimates, so it is important that scope assumptions be well-documented. A project cost magnitude range should be established based on potential project alternatives and major areas of risk, with appropriate consideration of the accuracy range of any supporting estimates or analyses.

The proposed range should be sufficiently broad such that it fully bounds all possible project cost outcomes, understanding the very limited design basis that exists at the time and the more imprecise methodologies used at this stage of the project. This estimate assists in establishing the Acquisition Authority Level for CD-0.

In addition, an estimate of the costs to be incurred prior to CD-1, such as preparing an Analysis of Alternatives and Conceptual Design for the project, could also be required to support resource planning and near-term schedules.

CD-1, Approve Alternative Selection and Cost Range — Prior to the approval of CD-1, the project team should develop a definitive estimate of the near-term preliminary design cost, which is needed for the project engineering and design (PED) funding request (if needed for project execution). An estimate may also be used to support PED funding for use in preliminary design, final design and baseline development. The quality of the cost estimate at this stage, as well as other stages, depends on the uncertainties and risk.

As part of the CD-1 requirement, the project team should perform analyses of the most likely project alternatives. Thus, the second cost estimate needed at CD-1 is the LCC7 of the likely alternatives that are being considered. A risk adjusted LCC estimate should be prepared for each alternative under consideration to ensure the alternative with the best cost/benefit ratio (and generally the lowest life-cycle cost) to the government is considered. Full LCCs, including all direct and indirect costs for planning, procurement, operations and maintenance (operational analysis should be used to evaluate condition and any negative trends on cost projections for assets in use), and disposal costs must be considered for each alternative being evaluated (OMB A-11).

After selecting the alternative that best meets the mission, the project team develops the third estimate, the total project cost (TPC) range, a schedule range with key milestones and events, and annual funding profiles. The TPC range should consider identified project risks and estimate uncertainty and encompass the full range of potentially required resources necessary to successfully execute the planned work associated with the preferred/recommended alternative. The TPC range also assists in establishing the Critical Decision Authority Thresholds.

CD-2, Approve Performance Baseline—Cost estimates supporting CD-2 should utilize more definitive cost estimating techniques (see Section 5.0). For CD-2, since available information will be more developed, the range should be collapsed to a point estimate. A single cost estimate will represent the entire project, utilizing the current scope and associated design parameters. The estimate will include appropriate allowances for risk and estimate uncertainty, i.e., Management Reserve and Contingency (see Section 6.4.5). This estimate is the basis for the cost estimate of the project's Performance Baseline and the Performance Measurement Baseline used for earned value reporting as required for projects with a TPC greater than \$50 million.

CD-3, Approve Start of Construction—Cost estimates based on the Final Design may incorporate some actual bids received from contractors used to establish the project's requirements for construction or execution. Cost estimates for Other Project Costs and Operational phases of the asset being acquired are finalized. These updated estimates support authorization to commit resources necessary, within funds provided, to execute the project.

CD-4, Approve Start of Operations or Project Completion—establishes when the project is ready for turnover or transition to operations, if applicable. Determines the final Estimate at Completion (EAC) and provides final project cost and performance reports developed in accordance with the project's approved WBS. Cost and performance reports are necessary to document the TPC for the asset acquired, as well as assisting in the capture of historical cost information.

Annual Budget Process

Project or program budgets are sometimes adjusted to accommodate appropriations and allocations that are more or less than expected. Some situations may require development of alternative budget scenarios that can mitigate the risk of project funding uncertainty.

When actual funding differs from planned budgets, baselines and estimates for current-period work (work packages) should be adjusted accordingly. Timing changes of actual funding versus planned budgets may not change the technical scope for which an estimate has been developed.

However, those timing changes (extending work into the future from planned schedules) can cause changes to programmatic scope, project duration, and efficiencies, which affect overall project costs (such changes are subject to change control – scope, schedule and cost).

Contract Actions

During the normal course of project execution, contract actions occur. The Contracting Officer may request an Independent Government Cost Estimate (IGCE) to support the action. The guidance, methodologies, and best practices reflected in this guide are largely applicable to the cost estimation of projects (i.e., ICEs).

However, the development of an IGCE and other analyses that will be used to support contract cost and price analysis, cost realism analysis for a negotiated contract action, or a contract source selection matter must be coordinated with the contracting officer and their supporting cost and price analyst to ensure that they are consistent with the prescribed methodologies, cost treatment, and guidance set forth in the Federal Acquisition Regulation, DOE Acquisition Regulations, and other agency policies and guidance.

As a best practice and to derive efficiencies, it is possible and advisable to use the same cost estimating team to estimate the direct costs (labor, material, and subcontracts) and additional project cost elements (contingency and government other direct costs (ODCs)) required to complete an ICE in support of a project performance baseline but advisable to firewall information on other costs such as contract cost elements (e.g., indirect, fee, etc.) and incentives that directly impact contract negotiating strategies.

DOE G 413.3-21A – cont'd

The type of contract that will be used to execute the work impacts the basis of an estimate. Types of contracts range from firm-fixed price, where the contractor assumes the full cost and performance risk, to cost reimbursement, where the Government assumes the cost and performance risk and the available strategies for incentivizing successful performance include the potential for an award fee or a performance-based incentive fee. The contract type and incentive structure influences the balance of assumed government and contractor risks.

Other Project/Program Management Actions

Various other project or program management actions, such as development of LCC analyses, cost-benefit analyses, value engineering (VE) studies, earned value analyses, and change requests may require development of cost estimates.

LCC estimates may be required for many purposes. As a part of alternative selection, LCC analysis may point to the alternative with the lowest LCC but other analyses and considerations may need to be considered in the decision process. In cases where benefits can be quantified, LCC analyses can support more formal cost-benefit analysis for alternative evaluation and selection. Any time a change in the project is contemplated, or an alternative must be evaluated, LCC analysis should be considered. (Appendix F presents a simplified example of a LCC analysis).

Cost estimates are also required to support day-to-day project management decisions. In many cases, alternatives (e.g., changes in the work flow) are considered that do not affect the entire project, but do affect the day-to-day details of managing a project. A design detail change that does not exceed a cost or schedule threshold for management approval is an example.

Comparisons of estimates from diverse sources may require reconciliation. **Generally, the differences are due to the estimates not being based on consistent or current information.** Some examples of sources for differences include assumptions concerning weather, productivity, and commodity markets. The reconciliation should clearly state the differences and the rationale for the differences. The Government may have access to more detail on cost estimates for cost reimbursement projects.

COST ESTIMATING CHARACTERISTICS and CLASSIFICATIONS

Planning the Cost Estimates

The tables (below) describes the elements of planning required to produce credible cost estimates. GAO conducted an industry-wide survey to address the characteristics of a good estimate; participants represented a wide variety of industries– including aerospace, automotive, energy, consulting firms, the Navy, and the Marine Corps.

The survey verified that the characteristics listed in the table are valid and support estimate credibility. GAO also found that **despite the fact that these characteristics have been published and known for decades, many Federal agencies still lack the ability to develop cost estimates that can satisfy these basic characteristics.**

Basic Characteristics of Credible Cost Estimates

Planning Step	Description
Clear Identification of Task	<ul style="list-style-type: none"> • Estimator must be provided with the scope description, ground rules and assumptions, and technical and performance characteristics. • The estimate's constraints and conditions must be clearly identified to ensure the preparation of a well-documented estimate.
Broad Participation in Preparing Estimates	<ul style="list-style-type: none"> • The Integrated Project Team and the Integrated Acquisition Team should be involved in determining requirements based on the mission need, in development of the Project Execution Plan, and in defining parameters and other scope characteristics at each Critical Decision milestone. • Data should be independently verified for accuracy, completeness, and reliability.
Availability of Valid Data	<ul style="list-style-type: none"> • Use numerous sources of suitable, relevant, and available data. • Use relevant, historical data from similar work to project costs of the new work. The historical data should be directly related to the scope's performance characteristics.

Basic Characteristics of Credible Cost Estimates

<p>Standardized Structure for the Estimate</p>	<ul style="list-style-type: none"> • Use of a standard WBS that is as detailed as possible, continually refining it as the maturity of the scope develops and the work becomes more defined. • The WBS elements should ultimately drill down to the lowest level, the work package. • The WBS ensures that no portions of the estimate (and schedule) are omitted or duplicated. This makes it easier to make comparisons to similar work.
<p>Provision for Uncertainties and Risk</p>	<ul style="list-style-type: none"> • Identify the confidence level (e.g., 80 percent) needed to establish a successful planning process. Identify uncertainties and develop an allowance to mitigate cost effects of the uncertainties. • Include known costs and allow for historically likely but specifically unknown costs. (Reference: DOE G 413.3-7A, Risk Management Guide).
<p>Recognition of Escalation</p>	<ul style="list-style-type: none"> • Ensure that economic escalation is properly and realistically reflected in the cost estimate. Escalation is schedule driven, and scheduling assumptions need to be clearly noted. NOTE: Project teams may use specific rates relative to the site when available. In any case, the source of escalation information used should be

Basic Characteristics of Credible Cost Estimates

	identified and the applicability of the rates should be explained/justified.
Recognition of Excluded Costs	<ul style="list-style-type: none"> • Include all costs associated with the scope of work; if any cost has been excluded, disclose and include a rationale.
Independent Review of Estimates	<ul style="list-style-type: none"> • Conducting an independent review of an estimate is crucial to establishing confidence in the estimate. The independent reviewer should verify, modify, and correct an estimate to ensure realism, completeness, and consistency.
Revision of Estimates for Significant Changes	<ul style="list-style-type: none"> • Update estimates to reflect changes in the design requirements. Large changes that affect costs can significantly influence decisions.

DOE project review and assessment teams examine how well project cost estimates align with the GAO 12 Step Best Practices. Most DOE contractors have already incorporated a best management practice depicting how their project planning and cost estimating structure development relates to the GAO 12 Steps. Appendix I presents more detail for applying GAO guidelines to develop quality DOE cost estimates.

Cost Estimate Classifications

Most cost estimates have common characteristics, regardless of whether the technical scope is traditional (capital funded, construction, equipment purchases, etc.) or nontraditional (expense funded, research and development, operations, etc.). The most common characteristics are levels of definition, requirements (end usage/purpose), and techniques used.

These characteristic levels are generally grouped into cost estimate classifications. Cost estimate classifications may be used with any type of traditional or nontraditional project or work and may include consideration of (1) where a project stands in its life cycle, (2) level of definition (amount of information available), (3) techniques to be used in estimation (e.g., parametric vs. definitive), and/or (4) time constraints and other estimating variables.

Typically, as a project evolves, it becomes more definitive. Cost estimates depicting evolving projects or work also become more definitive over time. Determination of cost estimate classifications helps ensure that the cost estimate quality is appropriately considered. Classifications may also help determine the appropriate application of contingency, escalation, use of direct/indirect costs (as determined by cost estimate techniques), etc.

Widely accepted cost estimate classifications are found in AACE International Recommended Practice (RP) 17R-97 and RP 18R-97; see Appendix G). Appendix G includes a complete description of AACE International's classifications. The table below provides example primary and secondary characteristics and expected estimate uncertainty ranges, as a function of the estimate class.

These characteristics and ranges provide expected estimate accuracy ranges based on scope definition data from historical projects, **however they should not be used to calculate contingency.** Further information on risk analysis can be found in DOE G 413.3-7A, Risk Management Guide. DOE's cost estimate classifications generally follow these recommended practices, although historically the more common cost estimate classifications are order of magnitude, preliminary, and definitive, which approximately equate to the AACE International's Classes 5, 3 and 2, respectively. "Types of Estimates" table provides an example of the typical suggested types of cost estimates for each DOE Critical Decision as compared with the AACE International classification.

A project cost estimate may comprise separate estimates of differing classifications. Certain portions of the design or work scope may be well defined, and therefore warrant more detailed cost estimating techniques and approaches, while other areas are relatively immature and therefore appropriately estimated using parametric or other less definitive techniques.

Cost Estimate Classification for Process Industries

ESTIMATE CLASS	<i>Primary Characteristic</i>	<i>Secondary Characteristic</i>		
	MATURITY LEVEL OF PROJECT DEFINITION DELIVERABLES Expressed as % of complete definition	END USAGE Typical purpose of estimate	METHODOLOGY Typical estimating method	EXPECTED ACCURACY RANGE Typical variation in low and high ranges
Class 5	0% to 2%	Concept screening	Capacity factored, parametric models, judgment, or analogy	L: -20% to -50% H: +30% to +100%
Class 4	1% to 15%	Study or feasibility	Equipment factored or parametric models	L: -15% to -30% H: +20% to +50%
Class 3	10% to 40%	Budget authorization or control	Semi-detailed unit costs with assembly level line items	L: -10% to -20% H: +10% to +30%
Class 2	30% to 75%	Control or bid/tender	Detailed unit cost with forced detailed take-off	L: -5% to -15% H: +5% to +20%
Class 1	65% to 100%	Check estimate or bid/tender	Detailed unit cost with detailed take-off	L: -3% to -10% H: +3% to +15%

DOE G 413.3-21A – cont'd

Generic Anticipated Types of Estimates for DOE Critical Decisions

Critical Decision	Suggested Estimate	Recommended Minimum AACE International Estimate Classification
CD-0	Cost estimate range	Class 5
	Estimate of costs to be incurred prior to CD-1	Class 3
CD-1	TPC Range	Class 4
	Estimate of near term preliminary design cost	Class 3
CD-2	Single point estimate representing entire project:	
	– Low risk projects	Class 3
	– High risk projects	Class 2
CD-3	Cost estimate based on Final Design [or sufficiently mature to start construction]:	
	– Low risk projects	Class 2
	– High risk projects	Class 2
CD-4		N/A

As a general rule, particularly for projects that are in the early stages of development, a combination of estimate classifications must be used to develop the entire estimate.

In these situations, estimators should use a combination of detailed unit cost estimating, unit costs, and detailed take-off (Class 1) techniques for work that will be executed in the near future and is well defined; semi-detailed unit costs with assembly level items (Class 3) techniques for preliminary or budget authorization and control estimating work that is currently in the planning stages but less defined; and capacity factored parametric models, judgment, or analogy (Class 5) techniques for order of magnitude estimating of future work that has not been well defined.

As a project progresses through the Acquisition Management System (initiation, definition, execution, and transition/closeout phases) and the project development and planning matures, the life-cycle cost estimate becomes more definitive.

This may be referred to as “rolling-wave” planning, where detailed planning of future work is done in increments, or waves as the project progresses through phases.

Cost Estimate Ranges

The Department's Acquisition Management System includes Critical Decisions (CDs) that define exit points from one phase of project development and entry into the succeeding project phase. Prior to CD-2 approval, DOE O 413.3B requires the use of ranges to express project cost estimates. These ranges should depict TPCs in the early stage, even at CD-0. Ranges may be determined or based upon various project alternatives, project identified risks, and confidence levels.

LCC estimates that are developed early in a project's life may not be derived from detailed engineering, but must be sufficiently developed to support budget requests for the remainder of the project definition phase. In addition, ranges should include all anticipated resources, using appropriate estimating techniques that are necessary to acquire or meet the identified capability.

During the project definition phase, at the conclusion of the concept exploration process, the alternative selected as the best solution to a mission need is presented for approval. The solution presented includes the TPC range, a schedule range with key milestones and events, and annual funding profiles that are risk-adjusted and define all required resources necessary to successfully execute the planned work.

The estimate range (lower and upper bounds) as defined in DOE G 413.3-13, Acquisition Strategy Guide, is determined by independently assessing the lower and upper cost estimate range for each of the major WBS elements. In some situations, the range may be in part a function of scope variability, e.g., if a decision to add five or 10 glove-boxes is pending.

The range can also be established by the project team considering the cost and schedule estimate uncertainties as part of the risk analysis. A risk analysis is analytical in nature and, although simulation tools aid the analyst in assessing impact and consequences, no simulation tool can substitute for a thorough logical deterministic process. The risks are identified by the likelihood of occurrence and the probable impact.

The lower bound of the cost range may represent a scenario where the project team has determined a low likelihood of occurrence and low impact of the identified risks, and a higher likelihood for the realization of opportunities. The risks may be accepted; therefore it is not necessary to include resources to mitigate them.

The upper bound of the cost range may represent a scenario where the project team has determined a low likelihood of occurrence, but the impact of the identified risks would be significant. The risks will be managed and appropriate resources identified to mitigate each risk.

COST ESTIMATING METHODS

Many cost estimating methods/techniques are available to facilitate the cost estimating process. Depending on project scope, estimate purpose, project maturity, and availability of cost estimating resources, the estimator may use one, or a combination, of these techniques. As shown in the table above, as the level of project definition increases, the estimating methodology tends to progress from conceptual (stochastic/parametric) techniques to deterministic/definitive techniques. The following sub-sections include techniques that may be employed in developing cost estimates.

Detailed Estimating Method

Activity-based, detailed or unit cost estimates are typically the most definitive of the estimating techniques and use information down to the lowest level of detail available. They are also the most commonly understood and utilized estimating techniques.

The accuracy of activity-based detailed or unit cost techniques depends on the accuracy of available information, resources spent to develop the cost estimate and the validity of the bases of the estimate. A work statement and set of drawings or specifications may be used to identify activities that make up the project. Nontraditional estimates may use the WBS, team input and the work statement to identify the activities that make up the work.

Each activity is further decomposed into detailed items so that labor hours, material costs, equipment costs, and subcontract costs are itemized and quantified. Good estimating practice is to use a verb as the first word in an activity description. Use of verbs provides a definitive description and clear communication of the work that is to be accomplished. Subtotaled, the detailed items comprise the direct costs. Indirect costs, overhead costs, contingencies and escalation are then added as necessary. The estimate may be revised as known details are refined. The activity-based detailed or unit cost estimating techniques are used mostly for Class 1 and Class 2 estimates, and they should always be used for proposal or execution estimates.

Activity-based detailed cost estimates imply that activities, tasks, work packages, or planning packages are well-defined, quantifiable, and are to be monitored, so that performance can be reported accurately. Quantities should be objective, discrete, and measurable. These quantities provide the basis for an earned value measurement of the work within the activities and the WBS.

Advantages in using activity-based detailed or unit cost estimating methods include:

- A greater level of confidence;
- More detail that can be used for better monitoring, change control, etc.;
- Enhanced scope and individual activity definition;
- Detailed quantities to establish more accurate metrics; and,
- Better resource basis for the schedule.

Disadvantages include:

- More time needed to develop the estimate; More costly to develop than relationship estimating; and,
- Some elements can be omitted by accident.

Parametric Estimating Techniques

A parametric model is a useful tool for preparing early conceptual estimates when there is little technical data or engineering deliverables to provide a basis for using more detailed estimating methods.

A parametric estimate comprises cost estimating relationships and other cost estimating functions that provide logical and repeatable relationships between independent variables, such as design parameters or physical characteristics and cost, the dependent variable. Capacity factor and equipment factor are simple examples of parametric estimates; however, sophisticated parametric models typically involve several independent variables or cost drivers.

Parametric estimating is reliant on the collection and analysis of previous or historical project cost data in order to develop the cost estimating relationships.

Cost Estimating Relationships

Cost estimating relationships (CERs), also known as **cost models**, composites, or assemblies/ subassemblies, are developed from historical data for similar systems or subsystems. A CER is used to estimate a particular cost or price by using an established relationship with an independent variable.

For example, a CER of design hours per drawing may be applied to the estimated number of drawings to determine total design hours. Identifying an independent variable (driver) that demonstrates a measurable relationship with contract cost or price develops a CER. That CER may be mathematically simple in nature (e.g., a simple ratio), or it may involve a complex equation.

Parametric estimates are commonly used in conceptual and check estimates. A limitation to the use of CERs is that to be most effective, one must understand completely how the CER was developed and where and how indirect costs, overhead costs, contingency, and escalation are applicable.

The parametric estimating technique is most appropriate for Class 5, 4, and 3 cost estimates. The parametric technique is best used when the design basis has evolved little, but the overall parameters have been established.

There are several advantages to parametric cost estimating. Among them are:

- **Versatility**—If the data are available, parametric relationships can be derived at any level (system, subsystem component, etc.). As the design changes, CERs can be quickly modified and used to answer “what-if” questions about design alternatives.
- **Sensitivity**—Simply varying input parameters and recording the resulting changes in cost will produce a sensitivity analysis.
- **Statistical output**—Parametric relationships derived through statistical analysis will generally have both objective measures of validity (statistical significance of each estimated coefficient and of the model as a whole) and a calculated standard error that can be used in risk analysis. This information can be used to provide a confidence level for the estimate based on the CERs predictive capability.

There are also disadvantages to parametric estimating techniques, including:

- **Database requirements**—The underlying data must be consistent and reliable. In addition, it may be time-consuming to normalize the data or to ensure that the data were normalized correctly. Without understanding how data were normalized, the estimator is accepting the database on faith, thereby increasing the estimate's risk.
- **Currency**—CERs must represent the “state-of-the-art;” that is, they must be periodically updated to capture the most current cost, technical, and programmatic data.
- **Relevancy**—Using data outside the CER range may cause errors because the CER loses its predictive capability for data outside the development range.
- **Complexity**—Complicated CERs (e.g., non-linear CERs) may be difficult for others to readily understand the relationship between cost and its independent variables.

End Products Unit Method

The End Products Unit Method is used when enough historical data are available from similar work based on the capacity of that work. The method does not take into account any economies of scale, or location or timing of the work.

Consider an example of estimating the construction cost of a parking lot. From a previous project the total cost was found to be \$150,000 for 100 parking stalls, or \$1,500/stall. For a new parking lot of 225 parking stalls, the estimated cost would be \$1,500/parking stall x 225 parking stalls = \$337,500.

Physical Dimension Method

The Physical Dimension Method is used when enough historical data is available from similar work based on the area or volume of that work. This method uses the physical dimension relationship of existing work data to that of the physical dimensions of similar new work. The method does not take into account any economies of scale, or location or timing of the work

To consider the example in section 5.3, the total cost of the previous project was \$150,000 for a 3,000 square feet parking lot. The new parking lot is to be 7,000 square feet; therefore, ($\$150,000/3,000$ square feet = \$50/ square feet for the previous project so the estimated cost of the new project is \$50/ square feet x 7,000 square feet = \$350,000.

Capacity Factor Method

The Capacity Factor Method is used when enough historical data are available from similar work based on the capacity of that work. The method uses the capacity relationship of existing work data to that of the capacity of similar new work. It accounts for economies of scale, but not location or timing of the work.

For example, consider a known power plant that produces 250 MW(t)/hour and costs \$150,000,000 to construct. A new plant will produce 300 MW(t)/hour. From historical data, 0.75 is the appropriate capacity factor.

Using the equation $\text{Cost (new)} = \text{Cost (known)} \times (\text{Capacity (new)} / \text{Capacity (known)})^e$
Where: $e = \text{capacity factor derived from historical data}$
 $\text{Cost (new)} = \$150,000,000 \times (300/250)^{0.75}$
 $\text{Cost (new)} = \$172,000,000 \text{ (rounded)}$

Ratio or Factor Method

The Ratio or Factor Method is used when historical building and component data are available from similar work. Scaling relationships of existing component costs are used to predict the cost of similar new work. This method is also known as “equipment factor” estimating. The method does not account for any economies of scale, or location or timing of the work.

To illustrate, if a plant that cost \$1,000,000 to construct has major equipment that costs \$300,000, then a factor of 3.33 represents the plant cost to equipment cost “factor.” If a proposed new plant will have \$600,000 of major equipment, then the factor method would predict that the new plant is estimated to cost $\$600,000 \times 3.33 = \$2,000,000$.

Other Estimating Methods

Level of Effort Method

A form of parametric estimating is based on level of effort (LOE). Historically, LOE is used to determine future repetitive costs based on past cost data, as in, “we spent ~\$10M on operations last year, so we need ~\$10M next year.” Often LOE estimates have few parameters or performance objectives from which to measure or estimate, but are carried for several time periods at a similar rate (e.g., the costs of operations, such as X number of operators for Y amount of time). LOE estimates are normally based on hours, full-time equivalents (FTEs), or “lot.” Since they are perceived to have little objective basis, LOE estimates are often subject to scrutiny. The keys to LOE estimates are that they should generally be based on known scope (although quantities may be assumed) and have a basis, even if it is simply the opinion of an expert or a project team.

Variations on LOE techniques are numerous and should be considered carefully before deciding to employ a specific technique. For instance, using LOE for installing a piece of equipment may raise questions about why it does not include the circumstances surrounding the installation (contamination and security issues and related productivity adjustments). Also questionable in LOE estimates are indirect costs, overhead costs, profit/fee, and other assumptions.

Specific Analogy Method

Specific analogies use the known cost or schedule of an item as an estimate for a similar item in a new system. Adjustments are made to known costs to account for differences in relative complexities of performance, design, and operational characteristics.

A variation of this technique is the “review and update technique,” where an estimate is constructed by examining previous estimates of the same or similar projects for logic, scope completion, assumptions, and other estimating techniques, and then updated to reflect any pertinent differences. The specific analogy technique is most appropriate in the early stages of a project; that is, for Class 5 and 3 cost estimates.

There are several advantages to using the analogy method, including:

- It can be used before detailed program requirements are known;
- If the analogy is strong, the estimate will be defensible;
- An analogy can be developed quickly and at minimal cost; and,
- The tie to historical data is simple enough to be readily understood.

There are, however, also some disadvantages in using analogies, such as:

- An analogy relies on a single data point;
- It is often difficult to find the detailed cost, technical, and programmatic data required for analogies; and,
- There is a tendency to be too subjective about the technical parameter adjustment factors.

The last disadvantage can be better explained through an example. If a cost estimator assumes that a new component will be 20 percent more complex, but cannot explain why, this adjustment factor is unacceptable. The complexity must be related to the system's parameters, such as the new system will have 20 percent more data processing capacity or will weigh 20 percent more.

Expert Opinion Method

As stated in the GAO Cost Estimating and Assessment Guide, “expert opinion, also known as engineering judgment, is commonly applied to fill gaps in a relatively detailed WBS when one or more experts are the only qualified source of information, particularly in matters of specific scientific technology.” Expert opinion is an estimating technique whereby specialists are consulted until a consensus can be established regarding the cost of a program, project, sub-project, task, or activity. The expert opinion technique is most appropriate in the early stages of a project, or for Class 5, 4, and 3, cost estimates. These cost estimates document a list of the experts consulted, their relevant experience, and the basis for their opinions.

A formalized procedure, the Oracle Method, has been used to forecast cost based on expert opinion. Six or more experts are given a specific, usually quantifiable, question. Each expert sees the estimates produced by the others and modifies his or her previous estimate until a consensus is reached. If after four rounds there is no consensus, the original question may be broken into smaller parts for further rounds of discussion or a moderator may attempt to produce a final estimate.

This technique may be used for either portions of or entire estimates and activities for which there is no other sound basis. A limitation arises when a cost estimator's or project manager's status as an expert is questioned.

The advantages of using an expert opinion are:

- It can be used in the case where there are no historical data available;
- The approach takes minimal time and is easy to implement once the experts are assembled;
- An expert may provide a different perspective or identify facets not previously considered leading to a better understanding of the program; and,
- It can be useful as a cross-check for CERs that require data significantly beyond the data range.

The disadvantages associated with an expert opinion include:

It should be **used as a last resort due to its lack of objectivity;**

- There is always a risk that one expert will try to dominate the discussion and sway the group toward his/her opinion; and,
- This approach is not considered very accurate or valid as a primary estimating method.

Due to its subjectivity and lack of supporting documentation, expert opinion should be used primarily for confirming that the estimate does not contain elementary mistakes or invalid assumptions.

Trend Analysis Method

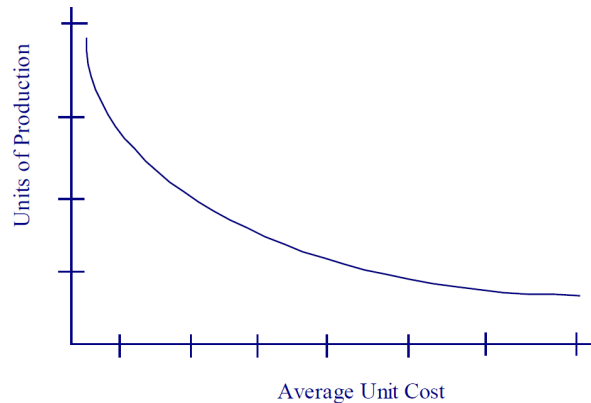
Trend analysis method is an estimating technique for current, in-progress work, and is also used to explain quantitatively how a project is progressing. It is especially useful when large quantities of commodities are a significant part of a project (e.g., mass excavations, mass concrete placement, structural steel fabrication/installation, etc.) A trend is established using an efficiency index derived by comparing originally planned costs (or schedules) against actual costs (or schedules) for work performed to date. For example, a project's actual costs to date, divided by the number of units produced provides a measure of current costs per unit. Variations in this measure from previous periodic trending information can be used to adjust the estimate for the remaining work, as well as to help project managers with decisions regarding resources (people, equipment, etc.) and make near term planning adjustments.

The trend analysis technique can be used at almost any stage of project development and can even be used to update cost estimates developed using other techniques. It should be remembered, however, that during a long project activity, productivity rates may vary, with less than optimal productivity occurring as project activity begins, improved productivity developing until an optimum sustained level can be achieved, and then less than optimal productivity encountered near the end of the project as problems are resolved and final activities are completed. Thus trend analysis estimates should consider the current stage and remaining stage of a project activity carefully before extrapolating current productivity or cost values.

Learning Curve Method

The learning curve is a way to understand the efficiency of producing or delivering large quantities. Studies have found that people engaged in repetitive tasks will improve their performance over time, i.e., for large quantities of time and units, labor costs will decrease, per unit.

The aircraft industry first recognized and named the learning curve and successfully used it in estimating. It can be used most effectively when new procedures are being fielded and where labor costs are a significant percentage of total unit cost. But it should always be understood that the learning curve applies only to direct labor input. Materials and overhead will not necessarily be affected by the learning curve. The figure below illustrates a hypothetical learning curve.



The Learning Curve Method

Typical learning curves start with high labor costs (hours) that decrease rapidly on early production units, and then flatten as production continues. This exponential relationship between labor productivity and cumulative production is expressed in terms of labor reduction resulting from production increases. For example, a 90-percent learning curve function requires only 90 percent of the labor hours per unit each time production doubles. When a total of 200 units are produced, labor costs for the second 100 units will be only nine tenths the costs of the first 100.

Increased productivity allows for lower labor costs later in a project, and should result in a lower overall project cost. Subsequent similar projects should have fewer labor hours for each unit of production also, which could result in both more contractor profit and lower government contract costs.

No standard reduction rate applies to all programs, and learning curve benefits will vary. When labor hour reductions of the first units are known, an accurate percentage reduction can be calculated and extended to subsequent units. If no data exists, it may be risky to assume that learning curve savings will be experienced.

The learning curve estimating technique can be considered for all traditional and nontraditional projects. The learning curve is most effective when applied to repetitive activities, and can also be used to update labor hours calculated in earlier estimates.

Methods of Estimating Other Life-Cycle Costs

Different methods may be used to estimate other project/program support costs, including design, engineering, inspections, environmental, safety and health (ES&H), etc. Some common methods are counting drawings and specifications, FTE, and percentage.

Count Drawings and Specifications Method

The estimator calculates the number of drawings and specifications representing a specific project. The more complex a project is, the more drawings and specifications it will require meaning that associated design costs will be higher.

Full-Time Equivalent Method

The number of individuals anticipated to perform specific functions of a project forms the basis. The man-hour quantity is calculated and multiplied by the cost per labor hour and the duration of the project function to arrive at the cost.

Percentage Method

The estimator calculates a certain percentage of the direct costs and assigns this amount to the other project functions (such as design, project management, etc.). Some possible benchmarks for DOE projects include:

- Total design percentages are usually 15 to 25 percent of estimated construction costs for DOE projects. Non-traditional, first of a kind projects may be higher, while simple construction such as buildings will be lower than this range (approximately 6 percent); the more safety and regulatory intervention is involved, the higher the percentage.
- Project management costs range from 5 to 15 percent of the other estimated project costs for most DOE projects, depending on the nature of the project and the scope of what is covered under project management. The work scope associated with this range should be defined very specifically and clearly.

COST ESTIMATING DEVELOPMENT PROCESS

Overview of the Cost Estimating Process

The overall Cost Estimating Process Model described here appeared earlier. The cost estimating development process discussed in this section follows the 12 steps model recommended by GAO and is part of the cycle of iterative activities for developing the cost estimate depicted in the earlier illustration. The figure below depicts the 12 step GAO model. The table below further identifies the implementing tasks related to the GAO-12 step cost estimating development process. Systematically conducting these tasks enhances the reliability and validity of cost estimates. **The process is iterative.**

The GAO 12 Steps Cost Estimating Development Process Model

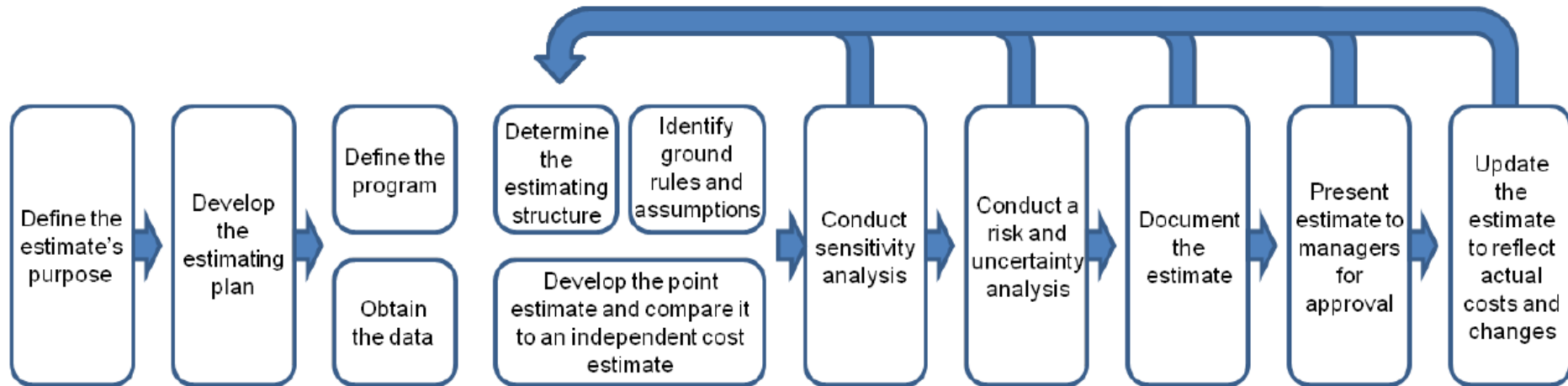
Initiation and Research
Your audience, what you are estimating, and why you are estimating it are of the utmost importance.

Assessment
Cost assessment steps are iterative and can be accomplished in varying order or concurrently.

Analysis
The confidence in the point or range of the estimate is crucial to the decision maker.

Presentation
Documentation and presentation make or break a cost estimating decision outcome.

Analysis, presentation, and updating the estimate steps can lead to repeating previous assessment steps



DOE G 413.3-21A – cont’d

DOE Crosswalk Depicting DOE G 413.3-21 and GAO Twelve Steps of a High-Quality Cost Estimating Process by Project Phase, Best Practices

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
Step 1: Define the Estimate's Purpose	<ol style="list-style-type: none"> 1. Determine estimate's purpose, required level of detail, and overall scope. 2. Determine who will receive the estimate. 	Guidance related to the purpose of the estimate is found in Sections 2.3, 3.2, 6.2, & 6.7.1.
Step 2: Develop an Estimating Plan	<ol style="list-style-type: none"> 1. Determine the cost estimating team and develop its master schedule. 2. Determine who will do the independent cost estimate 3. Outline the cost estimating approach 4. Develop the estimating timeline. 	Guidance related to planning the estimate development can be found in Section 4.1, Table 4-1, & Section 6.2.
Step 3: Define the Program Characteristics	<ol style="list-style-type: none"> 1. In a technical baseline description document, identify the program's purpose and its system and performance characteristics and all system configurations. 2. Describe technology implications. 3. Describe acquisition schedule and strategy. 4. Describe relationship to other existing systems, including predecessor or similar legacy systems. 5. Define support (manpower, training, etc.) and security needs and risk items. 6. Develop system quantities for development, test, and production. 7. Define deployment and maintenance plans. 	Guidance related to DOE Program characteristics and requirements for cost estimates are discussed in Section 3 & also in Section 6.3.2.
Step 4: Determine the Estimating Structure	<ol style="list-style-type: none"> 1. Define a WBS and describe each element in a WBS dictionary (a major automated information system may have only a cost element structure). 2. Choose the best estimating method for each WBS element. 3. Identify potential cross-checks for likely cost and schedule drivers. 4. Develop a cost estimating checklist. 	Guidance relative to estimate structure is found in Table 4-1, & discussed extensively in Section 5

DOE G 413.3-21A – cont'd

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
<p>Step 5: Identify Ground Rules and Assumptions</p>	<ol style="list-style-type: none"> 1. Clearly define what the estimate includes and excludes. 2. Identify global and program-specific assumptions, such as the estimate's base year, including time-phasing and life cycle. 3. Identify program schedule information by phase and program acquisition strategy. 4. Identify any schedule or budget constraints, inflation assumptions, and travel costs. 5. Specify equipment the government is to furnish as well as the use of existing facilities or new modification or development. 6. Identify prime contractor and major subcontractors. 7. Determine technology refresh cycles, technology assumptions, and new technology to be developed. 8. Define commonality with legacy systems and assumed heritage savings. 9. Describe effects of new ways of doing business. 	<p>The concepts related to ground rules and assumptions are discussed in Table 4-1, and again in Section 6, with specific guidance in Section 6.7.1.</p>
<p>Step 6: Obtain Data</p>	<ol style="list-style-type: none"> 1. Create a data collection plan with emphasis on collecting current and relevant technical, programmatic, cost, and risk data. 2. Investigate possible data sources. 3. Collect data and normalize them for cost accounting, inflation, learning and quantity adjustments. 4. Analyze the data for cost drivers, trends, and outliers and compare results against rules of thumb and standard factors derived from historical data. 5. Interview data sources and document all pertinent information, including an assessment of data reliability and accuracy. 6. Store data for future estimates 	<p>Estimate data sources and associated guidance can be found in Section 2.2, Section 3, and is the focus of Section 6.3</p>
<p>Step 7: Develop a Point Estimate and Compare it to an Independent Cost Estimate</p>	<ol style="list-style-type: none"> 1. Develop the cost model, estimating each WBS element, using the best methodology from the data collected, and including all estimating assumptions. 2. Express costs in constant year dollars. 3. Time-phase the results by spreading costs in the years they are expected to occur, based on the program schedule. 4. Sum the WBS elements to develop the overall point estimate. Validate the estimate by looking for errors like double counting and omitted costs. 5. Compare estimate against the independent cost estimate and examine where and why there are differences. 6. Perform cross-checks on cost drivers to see if results are similar. 7. Update the model as more data become available or as changes occur and compare results against previous estimates. 	<p>The techniques available for estimate development are described in Section 5 and the estimate development process itself is discussed extensively in Section 6.4. Other tasks identified here are discussed in Sections 6.5 and 6.6.</p> <p>Independent Cost Estimates are discussed in Section 8.3 with guidance provided in Appendix I.</p>

DOE G 413.3-21A – cont'd

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
<p>Step 8: Conduct Sensitivity Analysis (method and rigor of the analysis will vary depending on the estimate level)</p>	<ol style="list-style-type: none"> 1. Test the sensitivity of cost elements to changes in estimating input values and key assumptions. 2. Identify effects on the overall estimate of changing the program schedule or quantities. 3. Determine which assumptions are key cost drivers and which cost elements are affected most by changes. 	<p>The concept of Sensitivity Analysis discussed in Section 6.4.5 is a subset of contingency analysis. Requirements for analyses can also be found in Guidance document Section 6.1, Table 6-1 and Section 6.7.1.</p>
<p>Step 9: Conduct Risk and Uncertainty Analysis (method and rigor of the analysis will vary depending on the estimate level)</p>	<ol style="list-style-type: none"> 1. Determine and discuss with technical experts the level of cost, schedule, and technical risk associated with each WBS element. 2. Analyze each risk for its severity and probability. 3. Develop minimum, most likely, and maximum ranges for each risk element. 4. Determine type of risk distributions and reason for their use. 5. Ensure that risks are correlated. 6. Use an acceptable statistical analysis method (e.g., Monte Carlo simulation) to develop a confidence interval around the point estimate. 7. Identify the confidence level of the point estimate. 8. Identify the amount of contingency funding and add this to the point estimate to determine the risk-adjusted cost estimate. 9. Recommend that the project or program office develop a risk management plan to track and mitigate risks. 	<p>A full explanation of DOE's guidance relative to risk and uncertainty analysis and contingency allowances can be found in Section 6.4.5 and more in-depth treatment can be found in DOE G 413.3-7A, Risk Management Guide.</p>

DOE G 413.3-21A – cont'd

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
<p>Step 10: Document the Estimate <i>(method and rigor of the analysis will vary depending on the estimate level)</i></p>	<ol style="list-style-type: none"> 1. Document all steps used to develop the estimate so that a cost analyst unfamiliar with the program can recreate it quickly and produce the same result. 2. Document the purpose of the estimate, the team that prepared it, and who approved the estimate and on what date. 3. Describe the program, its schedule, and the technical baseline used to create the estimate. 4. Present the program's time-phased life-cycle cost. 5. Discuss all ground rules and assumptions. 6. Include auditable and traceable data sources for each cost element and document for all data sources how the data were normalized. 7. Describe in detail the estimating methodology and rationale used to derive each WBS element's cost (prefer more detail over less). 8. Describe the results of the risk, uncertainty, and sensitivity analyses and whether any contingency funds were identified. 9. Document how the estimate compares to the funding profile. 10. Track how this estimate compares to any previous estimates. 	<p>Estimate documentation is discussed in Section 3.2, and extensively in Section 6.7.</p>
<p>Step 11: Present Estimate to Management for Approval</p>	<ol style="list-style-type: none"> 1. Develop a briefing that presents the documented life-cycle cost estimate. 2. Include an explanation of the technical and programmatic baseline and any uncertainties. 3. Compare the estimate to an independent cost estimate (ICE) and explain any differences. 4. Compare the estimate (life-cycle cost estimate (LCCE)) or independent cost estimate to the budget with enough detail to easily defend it by showing how it is accurate, complete, and high in quality. 5. Focus in a logical manner on the largest cost elements and cost drivers. 6. Make the content clear and complete so that those who are unfamiliar with it can easily comprehend the competence that underlies the estimate results. 7. Make backup slides available for more probing questions. 8. Act on and document feedback from management. 9. Request acceptance of the estimate. 	<p>Guidance related to the presentation of estimate results can be found in Section 3.2.4, Section 6.7.1, and specifically in Section 7.2.</p>

DOE G 413.3-21A – cont'd

GAO Best Practice	GAO Cost Estimating Activities	Where Conformance to GAO Practice is Demonstrated in DOE G 413.3-21
<p>Step 12: Update the Estimate to Reflect Actual Costs and Changes (Projects should update estimates once incurring actual costs.)</p>	<ol style="list-style-type: none"> 1. Update the estimate to reflect changes in technical or program assumptions or keep it current as the program passes through new phases or milestones. 2. Replace estimates with EVM EAC and Independent estimate at completion (EAC) from the integrated EVM system. 3. Report progress on meeting cost and schedule estimates. 4. Perform a post mortem and document lessons learned for elements whose actual costs or schedules differ from the estimate. 5. Document all changes to the program and how they affect the cost estimate. 	<p>Estimate maintenance is discussed in Sections 6.8 and 7.3, and more extensively in DOE O 413.3B (requirements) and other associated guidance documents.</p>

Estimate Planning

Estimate planning (see The GAO 12 Steps Cost Estimating Development Process Model above) should include:

- Establishing when the estimate is required;
- Determining who will prepare the estimate;
- Producing a plan/schedule for estimate completion;
- Selecting and notifying individuals whose input is required;
- Collecting scoping documents;
- Selecting estimating technique;
- Conducting an estimate kickoff meeting; and,
- Visiting the work site.

Develop Estimate Purpose Statement—The purpose of the estimate should be stated in precise, unambiguous terms. The purpose statement should indicate why the estimate is being prepared and how the estimate is to be used. This should include a description of any relevant regulatory or DOE drivers.

Prepare Technical Scope Summary—The technical scope summary should provide a detailed description of the work included in the estimate. Additionally, the technical scope should identify the activities included in the cost estimate as well as relevant activities excluded from the cost estimate and the rationale for their exclusion.

Determine Approaches to be used to develop the Estimate—Develop the estimate using techniques and methodologies such as the ones described. For example, when developing a detailed estimate, the following approach could be followed (among others):

- **Activity-Based Estimates**—Describes detailed estimating methodologies used for preparing activity-based cost estimates. To be activity based, an estimate activity should have discrete quantifiable units of work associated with it. Examples of work items that are activity-based include:
 - Place 16 CY of concrete
 - Produce 12 monthly reports
 - Perform 100 surveillances
 - Prepare a lesson plan for a course in safe lifting

Level-of-Effort (LOE)—Certain activities cannot be associated with quantifiable units of work. Instead, these activities should be expressed as a defined level of expenditure over time. **Estimates that include LOE activities should be closely scrutinized, and the use of LOE estimates minimized.** Examples of LOE activities include:

- Secretarial support
- Site safety program
- Clerical support

Cost Estimate Inputs

Sources of Data Input

Since all cost estimating methods are data-driven, it is critical that the estimator know the best data sources. Whenever possible, estimators should use primary data sources. Primary data are obtained from the original source, are considered the best in quality, and are ultimately the most useful. They are usually traceable to an audited document. Secondary data are derived, rather than obtained directly from a primary data source. Since they were derived (and thus changed) from the original data, they may be of lower overall quality and usefulness. In many cases, data may have been “sanitized” for a variety of reasons that may further complicate its use as full details and explanations may not be available. Cost estimators must understand if and how data were changed before determining if they will be useful or how that data can be adjusted for use. Furthermore, it is always better to use actual costs, rather than estimates as data sources since actual costs represent the most accurate data available.

While secondary data are not the first choice, they may be all that are available. Therefore, the cost estimator must seek to understand how the data were normalized, what the data represent, how old the data are, and whether the data are incomplete. If these questions can be answered, the secondary data should be useful for estimating and would certainly be helpful for crosschecking the estimate for reasonableness.

Some specific sources of data are the following:

Estimating Manuals—The construction industry produces numerous costing manuals to assist in the pricing of work. RSMMeans and Richardson are two readily available manuals.

Data Bases—Commercial and in-house data bases provide the estimator with the ability to retrieve data to be used for estimating. Commercial data bases are readily available. **In-house data bases more accurately reflect the parameters that influence local costs.**

Vendor Quotes—Vendor quotes provide for a greater confidence of real time accuracy. Use caution when using vendor quotes. Often the vendors provide quotes with either incomplete or preliminary information. Other times only one vendor is polled, possibly skewing the information. In other situations, market conditions may drastically change from the time vendor quotes were obtained.

Level of Effort Data—As discussed, LOE activities are of a general or supportive nature usually without a deliverable end product. Such activities do not readily lend themselves to measurement of discrete accomplishment. LOE is generally characterized by a uniform rate of activity over a specific period of time. Value is earned at the rate that the effort is being expended. LOE activities should be kept at a minimum for Class 1 and 2 estimates.

Expert Opinions (Subject Matter Experts)—As described, expert opinions can provide valuable cost information in the early stages of a project, for Class 5, 4, and 3 cost estimates. **The data base should include a list of the experts consulted, their relevant experience, and the basis for their opinions.** If a formalized procedure was used, such as the Oracle Method, it should be properly documented.

Benchmarking—Benchmarking is a way to establish heuristics, or rules-of-thumb. Benchmarks may be useful when other means of establishing reasonable estimates are unavailable. An example of a benchmark is the statistic indicating that design should be 6 percent of construction cost for non-complex facilities. If construction costs can be calculated (even approximately) using a parametric technique, design should be approximately 6 percent. Typical benchmarks include such rules as:

- Large equipment installation costs should be X percent of the cost of the equipment
- Process piping costs should be Y percent of the process equipment costs
- DOE facility work should cost approximately Z percent of current, local, commercial work

Team/Individual Judgment Data—Team/Individual judgment data are used when the maturity of the scope has not been fully developed and/or the ability to compare the work to historical or published data is difficult. This involves the reliance of information on individuals or team members who have experience in the work that is to be estimated. This process may involve interviewing the person(s) and applying their judgment to assist in the development of the cost estimate. Because of its subjectivity and usually the lack of supporting documentation, team/individual judgment should be used sparingly.

Trend Analysis Data—As described, trend analysis can provide data for comparing the original planned baseline costs (or schedules) and the per unit value against actual costs (or schedules) and the per unit value for work performed to date. Trend analysis data can be used at almost any stage of work and can even be used as a basis for cost estimates developed using other techniques.

The Learning Curve Data—As described, learning curve data are useful for understanding the efficiency of producing or delivering large quantities. Numerous sources are available from trade associations and governmental organizations.

Considerations for Cost Estimate Development

When given the task of developing an estimate, an estimator must first gather general project information, including:

- Project background;
- Where the project stands in its life cycle;
- General description of the technical scope;
- Pertinent contract or sub-contract information;
- Estimate purpose, classification, how the estimate will be used, and techniques anticipated; and,
- Approximate time frame for the work to be performed.

Some specific inputs to the cost estimating process include:

- Mission Need Statement;
- Critical Decision approval documents;
- Acquisition Strategy;
- Project Execution Plan;
- WBS;
- Code of Accounts (COA -also known as account code);

- Key Milestone Activities and Proposed Dates;
- Functional Design Criteria;
- Functional Performance Requirements;
- Conceptual Design Report;
- Preliminary Design;
- Definitive Design;
- Risk Analysis and Register;
- Historical Information and Other Sources of Information, including previous cost estimates;
- Results of Alternative and Requirements Analyses;
- Applicable Resources and Labor Rates;
- Applicable Indirect Rates;
- Assumptions
 - **Estimate ground rules and constraints;** e.g., 4 day work-weeks, 10 days of weather shutdowns per year, site access limitations, acquisition strategies and associated contractor markups, and all other assumed conditions under which the estimator believes project work will be performed;
 - Assumptions made by the estimator to fill gaps and inconsistencies in the technical scope, sources of materials;
- Estimate Allowances;
- Exclusions (a clearly stated list of excluded items such as furnishings, equipment, finishes, landscaping, etc.);

DOE G 413.3-21A – cont'd

- Government Supplied Equipment; and,
- Construction and Operations Input.

From this information, whether provided by others or developed by the estimator as an assumption, appropriate estimating techniques may be determined.

Cost Estimate Production

The principle step in the estimating process is producing the cost estimate and its corresponding schedule and basis of estimate. It is important that scope development, documentation, and control be coordinated with the cost estimate production as key iterative processes. Cost estimate production includes several steps that should be based on requirements, purpose, use, classification, and technique, including:

- Identify the scope of work;
- Identify the project, subprojects, milestones, activities, and tasks;
- Document all bases of the estimate, assumptions, allowances, risks, etc. during the estimating process;
- Perform quantity takeoffs and field walk-downs;
- Develop the detail items or models that make up the activities;
- Assign measurable quantities to the detail items or models;
- Obtain budgetary or vendor information, conduct market research, or establish other pertinent sources of information;
- Establish productivity rates or perform task analyses;
- Calculate all applicable costs, including direct costs, indirect costs, contingency, and escalation (utilizing the schedule to calculate years for escalation);
- Produce all applicable detail and summary reports;
- Establish a funding profile utilizing the WBS and time phasing from the schedule;
- Determine what risks (and to what extent) should be mitigated with activities (or assumptions) in the cost estimate; and, Consider other inputs, including schedule information, risk management plan, and peer reviews, as appropriate.

Schedule Development

A project plan and schedule should be developed as the main basis for any cost estimate. By going through the process of schedule development, the activities needed to execute a project are clearly identified and appropriately sequenced. This, then, forms a basis for estimating the resources and costs needed to accomplish the project plan. That process in turn provides a basis for estimating activity durations used to construct the schedule. As this process indicates, the development of schedule and cost estimates is a highly iterative and inter-related process. However, it is difficult to generate a credible and realistic cost estimate without at least a basic understanding of the project plan and the activities that comprise the project schedule.

After both the schedule and cost estimates have been developed, the project schedule is also used to determine a cost estimate over time in order to calculate escalation, identify available resources, and establish budget requirements. This process can result in further iteration, both to refine the schedule (to accommodate resource and budget constraints) and to finalize the estimate (to adjust escalation allowances and other time-based costs, e.g., management staffing).

A project's schedule should not only reflect activities in a cost estimate, but it should also indicate project milestones, deliverables, and relationships between activities.

Direct Cost Development

Direct Costs include any costs that can be attributed solely to a particular project or activity, including labor, materials, subcontracts, equipment, salaries, and travel. Emphasis is placed on the term activity, which typically in standard practice equates to a lowest WBS element, account code, work package, or planning package.

Commonly recognized direct costs include:

- Design, planning, and development;
- Project management;
- Construction management;
- Construction activities to include mobilization and de-mobilization, site work, concrete work, masonry work;
- Operations labor, materials, equipment, subcontract costs, premium pay, and similar productivity adjustments, such as those for contamination or security restrictions;
- Maintenance labor, materials, equipment, subcontract costs, premium pay, and similar productivity adjustments, such as those for contamination or security restrictions;
- Routine and preventive maintenance activities include minor facility repairs or upgrades, minor paving or landscaping;
- De-contamination, de-commissioning, dismantling, and demolition;
- Security escorts and restrictions;
- Special (capital) and standard (capital or non-capital) equipment;
- Freight, packaging, and transportation;
- Health physics support, radiological controls support, protective clothing/PPE, and industrial safety/health; and,
- Sales and use taxes.

Resources and Crews and Quantities

Cost estimators should be familiar with any site or project-specific labor agreements, and if applicable, reflect these labor agreements in the cost estimate.

Resources include the labor, material, equipment, services, and any other cost items required to perform a scope of work. One or more resource can be assigned to an activity. A list of the resources and their associated unit prices needs to be defined before applying resources to activities:

- Rates for labor should include wages, taxes, insurance, fringe benefits, overtime, and shift differential as applicable;
- Unit prices for material should include the material price, sales tax, and shipping costs as applicable; and,
- The hourly rate in cases involving equipment purchased by the Government should include only operation and maintenance costs **but not the capital cost of ownership since the site may have some pre-arranged pool and the equipment rate should correspond with current pool service rates.**

Crews are groupings of the various labor classifications along with the tools and equipment (not installed equipment) required to accomplish activities. A production rate/output for each crew is identified. A crew used to place concrete slabs might include a foreman, laborers, cement finisher, concrete vibrators, forms, and air compressor. In addition, the crew's production rate/output should be established (e.g., 110 cubic yards per day).

- Estimators should examine the production rate/output for each crew and make adjustments for local conditions if necessary. Working with crews, rather than the individual cost elements, allows the estimator to estimate work activities more quickly.

Quantities are the units of measure and number of units associated with each activity. Each activity needs to have an identifiable unit of measure and a quantity associated with that activity (e.g., 200 tons, 75 linear feet, etc.) For LOE activities, the quantity may be “one” and the unit of measure “lot.”

Assigning Resources to Activities

Detailed Work Scope. Once activities have been defined, units of measure identified, and quantities determined, resources are assigned to each activity. Unit rates are used to assign resources to estimate activities. The resources assigned should correspond with the resources that will be used to complete the work. Such distinctions are especially important when detailed schedules are required, but less important for ROM or conceptual estimates. Unit rates can be expressed as dollars per unit, labor hours per unit, or a percentage of an associated cost.

Direct Labor. Unit rates expressed as labor hours per unit require that the type of labor (carpenter, engineer, secretary, etc.) be identified by associating a labor type or a crew with each unit rate. A crew is defined by the various labor types that make up the crew. Each labor type has a corresponding wage rate to allow calculation of cost in dollars. If there is a contract already in place, rates should be provided by the cognizant auditor. The wage rates for each labor type includes the base rate, taxes and insurance, fringe benefits, travel or subsistence, and adjustment for overtime, if required.

Percentages. Some activities may use percentages to assign resources. The appropriateness of using percentages for such items as project management and construction management will depend on the level of maturity in the work scope definition. **Examples of cost items where percentages are often used include:**

- Plan of the day (POD) meetings;
- Small tools;
- Consumable materials;
- Labor insurance;
- Project management; or,
- Construction management.

Regardless of the method used to assign resources to an activity, the following is true for each activity; all costs are identified, labor hours, when applicable, are identified, and labor type for all labor hours is identified.

Summary Work Scope. When details of the work scope are not known, the work scope may be estimated by using the analogy technique or the parametric technique. These techniques may use unit rates expressed as dollars per unit, labor hours per unit, or percentages.

Costs Included in Unit Rate. All costs should be “fully burdened.” A description of what is included in the burdened rate should be included because the definition of “fully burdened” frequently varies.

Unit Rate Adjustments. The development and/or use of estimating factors to adjust unit rates require the skills of an experienced cost estimator. Such adjustments allow use of a database with known productivity or costs, which are then adjusted to reflect the project specific activities and the conditions under which the work is to be performed. Situations that might affect productivity include type of work, weather conditions, level of confinement, security posture. Examples of estimating factors (or unit rate adjustments):

- Add 25 percent to labor for work in radiation zones
- Reduce labor for shop work by 20 percent
- Add 20 percent to labor for work requiring use of a respirator

Estimating factors are available from published sources or estimators can develop them. For example, the U.S. Army Corps of Engineers, “Productivity Study for Hazardous, Toxic and Radioactive Waste (HTRW) Remedial Action Projects,” dated October 1994, provides suggested labor productivity adjustment factors considering levels of worker protection and temperature.

Allowances

In planning projects, it is normal to include allowances for activities for which there is little or no design basis, especially in the earliest stages. These are not considered contingency costs. Allowances should be included at the discretion of the Federal Project Director, project manager, and IPT to cover anticipated costs associated with a known technical requirement or activity. **Any allowances included in cost estimates should include a basis for these costs within the supporting Basis of Estimate (BOE) document.**

For instance, in a Class 5 cost estimate (order of magnitude), it would be appropriate to see a line item (cost account or activity) such as “utility relocation, 1 lot, \$1M material and \$1M labor,” indicating that some utilities needed to be relocated as part of this project. **Documentation supporting these costs should include approximate quantities, basis for those quantities, and source of the projected costs (e.g., consensus of the project team) proportional to the significance of the activity.** Allowances also may be included in a project to cover costs associated with productivity adjustments, anticipated subcontract changes, anticipated design changes, and similar elements of known scope and costs.

Allowances for Special Conditions

Consideration must be given to all factors that affect a project or program. Some of these factors are:

- Availability of skilled and experienced manpower and its productivity;
- The need for overtime work;
- The anticipated weather conditions during the period of performance;
- Work in congested areas;
- Working under the authorization basis;
- Work in radiation areas;
- Security requirements imposed on the work area;
- Use of respirators and special clothing;
- Training; and,
- Site access.

Special conditions may be estimated by applying a factor. For example, 10 percent applied to labor hours for loss of productivity due to work in a congested area. Other items may be calculated by performing a detailed takeoff. An example would be an activity that could only be performed over a two-day period. Overtime would be required to complete the activity and the number of hours and rates could be calculated.

An estimator should be vigilant that there is no duplication of costs—for example, if the control account manager who provided the cost data to the estimator already included unit rate adjustments such as productivity factors, additional allowances for productivity should not be included or the cost estimate may be inflated. All allowances applied or used to develop the cost estimate should be documented in the BOE

Design Costs

To estimate design costs, the estimator should understand what activities are included. Typical design-related activities include:

- Surveys (surveying), topographic services, core borings, soil analyses, etc., to support design
- Preliminary and final design calculations and analyses
- Design studies required to support safety analysis if not included in the Conceptual Design Report
- Building Energy Modeling
- Preparation of as-built drawings
- Travel to support design
- Acceptance procedures
- Outline specifications

- Reproduction during design
- Design Reviews (not third party)
- Construction cost estimates
- Design kickoff meeting
- Certified engineering reports
- Computer-Aided Drafting and computer services
- Constructability reviews
- Bid package preparation
- A/E internal design coordination
- Safety reviews by A/E
- Bid evaluation/opening/ award
- Design cost and schedule analyses and control
- Value engineering
- Inspection planning
- Design progress reporting
- Identification of long lead procurements

- Inspection services
- Regulatory/code overview by A/E
- Design change control
- Review shop drawings
- Procurement and construction specifications
- Modification of existing safety analysis report
- Preliminary and final plans and drawings

Design costs are normally directly related to the magnitude and complexity of a project. The following factors should be considered when assessing design costs for the design-related activities due to the magnitude and complexity of a particular project.

- Comprehensive functional requirements
- Off-site architecture/engineering
- Quality level
- Overtime
- Design planning
- Adequacy of plans and specifications
- Design layout
- Off-site fabrications
- Drafting and CADD methodologies

Travel and per diem

Project reviews

Guidelines

Design reviews

Performance specification

Safety analysis requirements

Cost estimating Activities

Reporting requirements

Inspection Requirements

Government furnished equipment

Schedule Analysis

Complexity

Labor density

For EM projects, the regulatory process requires rigorous examination of design alternatives before the start of cleanup design, especially for remedial investigation/feasibility studies under CERCLA to support a record of decision (ROD) or for corrective measure studies under RCRA to support issuance of a permit. Cleanup design executes a design based on the method identified in the ROD or permit, which often narrows the scope of preliminary design and reduces the cost and schedule requirements.

On EM projects, the estimator should assess the extent to which design development is required or allowed in cleanup design. In some cases, the ROD or permit will be specific, such as for a disposal facility where all features such as liner systems and configuration, are fixed. When treatment options such as incineration are recommended, considerable design effort may be required.

Requirements for construction engineering, including observation, design of temporary facilities, quality control, testing, and documentation, will often be higher than for conventional construction because of requirements to comply with rigid regulations governing health and safety, quality assurance and other project requirements.

Construction Management Costs

A construction management (CM) firm, whether in the form of a subcontractor or as a function of an M&O contractor, is responsible for construction activities, including coordination between prime contractors and subcontractors. This responsibility includes subcontracting, purchasing, scheduling, and often a limited amount of actual construction. The cost estimate for this function must include all CM costs for site management and force account labor wages, payroll taxes, overheads, and procurements for which the CM is responsible.

Project Management Costs

The estimates for project and program management must consider project duration from start of preliminary design through completion of the construction for the project. Other factors to consider are the complexity of the project, the specific design group, the organization for which the project is to be performed, and the extent of procured items. The encompassed functions include:

- Management and integration;
- Program/project management;
- Administrative services;
- Peer review;
- Records management;
- Training;

DOE G 413.3-21A – cont'd

- Information resources management;
- Project controls;
- Quality assurance;
- Licensing;
- Communications; and,
- Travel by management staff.

Management functions associated with environmental restoration projects parallel construction project management.

Construction Coordination Costs

Construction coordination comprises field engineering services, sometimes called “Title III Engineering” services or “Engineering Support during Construction”. Field engineers should be involved in the review of the design documents, as well as in the coordination of field construction and resolution of design conflicts encountered during the construction phase. Other responsibilities may include furnishing and maintaining governing lines and benchmarks to provide horizontal and vertical controls to which construction may be referred; checking and approving or requiring revision to all vendor shop drawings to assure conformity with the approved design, working drawings and specifications; inspecting the execution of construction to assure conformance with approved drawings and specifications, and with established requirements for workmanship, materials and equipment; and providing field or laboratory tests of construction workmanship, materials and equipment as may be required.

Research and Development (R&D) Costs

Traditionally, cost estimating involves the use of historical cost data to correlate and validate existing estimating methodologies. Historical cost data lend some accuracy and credibility to a cost estimate. When a cost estimate is required for new, innovative, state-of-the-art, first, or one of-a-kind projects, historical data are not always available.

For these projects, knowledge of the processes involved should help the cost estimator to prepare an accurate and credible cost estimate. In the absence of accurate cost information, process knowledge can focus the estimator toward parts of the project that are significant contributors to overall project cost.

Personnel Costs—Personnel costs are usually the largest R&D expense. R&D personnel are often well-educated and may have a correspondingly higher pay scale than personnel for conventional projects. Personnel resources include those needed to construct R&D facilities; purchase supplies, materials, and equipment; operate equipment, prototypes, pilot plants or laboratories; develop software; information technology operations; and other labor functions needed to complete R&D efforts.

Equipment Costs—Equipment costs for R&D projects can be divided into hardware (for prototypes and pilot plants as well as other activities) and software costs (including computer models discussed below). Hardware includes machinery, computers, and other technical equipment. Equipment costs increase with increasing project complexity and a lengthy testing and verification phase may be required. Vendor quotes can sometimes be obtained to support early-stage cost estimates, but expert opinion is often the only recourse to obtain Class 5 cost estimates for equipment with no precedent.

Prototypes and Pilot Plants—In some instances, it will be cost effective to develop a prototype or a pilot plant for an R&D project. A cost estimate for a prototype or a pilot plant will have to account for the following major items:

- Procurement and/or construction of the equipment or plant
- Operation of the equipment, including necessary utilities
- Development of test criteria for plant studies
- Analysis of test results
- Computer simulation of plant processes
- Supplies and materials used for testing

The cost estimate may also need to include costs for project management and other personnel during the pilot plant study or prototype testing.

Scaled and Computer Models—Scaled or computer-generated 3D models may need to be created for some projects. For example, if the project goal is to construct a new incinerator for mixed waste, site-specific air-dispersion modeling may be required to demonstrate that emissions from the incinerator will not have an adverse impact on public health or the environment. Groundwater modeling may be required for some remediation sites (e.g., groundwater contamination has been found at a site, and several technologies are being proposed). Modeling can be used to select the best technology or determine the optimum locations for equipment. DOE regulations on energy efficiency performance standards require the use of whole building energy simulation models in accordance with 10 CFR 433. Some models can be quite complex and require specialized technical expertise.

R&D Disposition – Finally, it is important to consider the cost of disposing of all equipment, chemicals, products, materials, facilities, etc., used during the R&D phase. **The assumption that another project will pay for the “cleanup” of an experiment, bench-scale demonstration or even a pilot scale facility has often resulted in low initial government life-cycle estimates.** The initial government life-cycle estimate should consider the R&D disposition estimate attributable to the project or share of the R&D disposition estimate when attributable to multiple projects.

Regulatory Costs

ES&H regulatory compliance is required for all projects thus, an estimate should contain sufficient provisions for ES&H compliance costs. **Regulatory costs should include the cost of coordination and negotiation with regulators, documentation costs, site characterization analysis, stakeholder meetings and other related activities.**

For Government projects, the facility must satisfy all Federal, state, and local requirements (i.e., building permits, energy conservation and the Leadership in Energy and Environmental Design (LEED) requirements, waste disposal, wastewater effluent disposal, and air emission limitations) imposed by the other agencies. Regulations are even more stringent for facilities that process or store radioactive materials. Construction sites must follow Occupational Safety and Health Administration (OSHA) rules.

Familiarity with applicable regulations is required so that a plan may be developed for the project to comply with those regulations.

Environmental Compliance Costs

The number and requirements of environmental regulations have increased dramatically in the past 30 years. When preparing cost estimates for environmental compliance activities, the following should be considered:

- Type of project;
- Project location;
- Waste generation;
- Effluent characteristics;
- Air emissions;
- Noise requirements; and,
- Project start-up or completion date.

Location significantly influences project costs when a wetlands area will be disturbed, or the project is located in an area with extensive environmental regulations. Increased environmental compliance costs should be factored into projects in such locations.

Knowledgeable design staff and personnel familiar with environmental regulations that will affect the project should be consulted when composing an estimate. Knowledge of wastes or air emissions generated during the project will facilitate the identification of environmental compliance design requirements and subsequent costs. For example, wastewater treatment may be required prior to effluent discharge into a stream or publicly owned treatment works. Air pollution control devices may be required for process equipment. Permitting costs could include:

- Labor for data gathering;
- Equipment for testing;
- Analytical tests;
- Data analysis and writing or completing documents;
- Time for interface with project personnel and outside consultants;
- Time for interaction and negotiation with regulator and stakeholders;
- Application and/or permit fees;
- Annual permitting costs;
- Upgrades to existing equipment; and,
- New pollution control equipment

Once a plan for regulatory compliance has been established, the regulatory costs can be estimated. This will establish a baseline for the regulatory costs such that changes that affect the baseline can be tracked and estimated throughout the project's life.

DOE G 413.3-21A – cont'd

For some projects, a permit is required before work can commence. For example, construction projects that will disturb more than five acres are required to obtain a storm water permit before commencing construction. Project scheduling can be affected if operating permits are not received in a timely manner. Facilities may be shut down for violations of operating permits or failure to comply with existing regulations. The time required for regulatory review of the permit application also must be factored into the cost estimate.

Health and Safety Compliance Costs

Employee health and safety regulations have also increased. As allowable limits for worker exposure decrease, design cost estimates must account for specific engineering controls to minimize employee exposures to toxic or hazardous substances in the workplace, especially for facilities with radioactive materials. Planning for environmental controls is essential because retrofit costs can exceed original installment costs. State-of-the-art, high-technology facilities may require initial employee exposure monitoring if unknown factors are encountered. Protective equipment must also be supplied and maintained for the employee.

Past experience with increased regulatory rigor within DOE has shown that the costs associated with employee workspace controls, including industrial hygiene monitoring, is the most significant cost factor in a rigorous health and safety program. The trend will probably continue. Health and safety compliance issues may involve strict health and safety requirements, including routine medical surveillance, preparation of health and safety plans, and employee training.

Employees may not be able to work 8 hours per day if daily personnel and equipment decontamination is mandatory.

Other Regulatory Costs

In addition to the costs described above, there are quality assurance (QA) costs, security costs, other ES&H requirements, project controls compliance costs, building energy modeling costs to meet energy performance standards, and other standards or legal requirements that drives costs the project must consider.

Indirect Costs

Indirect costs support common or joint objectives that do not link to a particular activity or project. Indirect costs are “any costs not directly identified with a single final cost objective but identified with two or more final cost objectives.”

Consequently, IPTs should identify opportunities to allocate indirect costs to an activity or asset based on direct cost elements, such as labor hours, material cost, or both. No definitive criteria for determining the appropriate cost type, direct or indirect, exists.

Some examples of indirect costs include:

- Facilities, operating equipment, small tools, and general maintenance;
- Temporary facilities (e.g., water, compressed air, and power);
- Motor pool, camp, and aircraft operations;
- Warehousing, transfer, and relocation;
- Safety, medical, fire protection, and first aid;
- Security;
- Administration, accounting, procurement, and legal;
- Personnel expenses, office supplies, and time reporting;
- Site-wide permits and licenses;
- Contributions to welfare plans and signup/termination pay; or,
- Contract fee/profit, bond costs (performance and material payment).

NOTE: Do not double count costs. For example, if acquisitions personnel are costed with the pilot plant activity ensure that this person is not also included as part of Indirect Costs.

Indirect Rates

The development of indirect rates is usually the responsibility of both the financial accounting organization and the cost estimator. **Indirect rates should be developed in accordance with Cost Accounting Standards.** The financial accounting organization determines rates for organizational overheads and general and administrative (G&A) cost, while the cost estimator usually estimates rates for project management, construction management, and subcontract costs. **If there is a contract in place, the indirect rates are provided by the Contracting Officer (CO), obtained from the cognizant audit entity).** The estimator, however, should clearly understand how to allocate all indirect rates in the estimate to avoid duplication or omission, as well as document what each indirect rate includes.

Indirect rates estimated for subcontract work such as design services, construction, and remedial actions should be estimated and documented at a level of detail appropriate to the type of cost estimate being prepared. There is no uniform standard for establishing indirect rates; a typical method for applying indirect rates calculates indirect costs as a percentage of a category of work. For example, quality control inspection could be estimated as 6 per cent of direct craft labor, consumable materials at 6 percent of direct craft labor, and administrative support for engineering at 38 percent of direct engineering, etc.

The basis for applying individual indirect rates will vary greatly depending on the specific costs included in the rate. Allowances for small tools or consumable materials would typically use the direct labor cost of the appropriate construction craft, operations or maintenance activities as its base. General and administrative cost is usually estimated using the sum of all direct and indirect costs for the specific items of work as its base. Indirect rates should be documented in detail so that what is included (and excluded) in each rate is clear. A separate line item in the estimate should exist for each rate used.

Escalation

Escalation costs change continuously following changes in: such as technology, availability of resources, and value of money (e.g., inflation).

Historical cost indices and forecast escalation indices have been developed to document and forecast changing costs. The use of an established escalation index is required to consistently forecast future project costs. To ensure proper use of an index, Estimators must understand its basis and method of development.

Escalation is the provision in a cost estimate for increases in the cost of equipment, material, labor affected by continuing price changes over time. Escalation may be: forecasted, to estimate the future cost of a project based on current year costs; or historical, to convert a known historical cost to the present.

Although the forecasted and historical escalation rates may be used in succession, most cost estimating is done in current dollars and then escalated to the time when the project will be executed. This section discusses the use and calculation of escalation and historical cost indices. An example of the calculation and use of escalation can be found in Appendix E.

Forecasted Escalation Rates

Forecasted escalation rates may be obtained from commercial forecasting services, such as Global Insight, which supplies its most current predictions using an econometric model of the United States economy. The forecast escalation index is the ratio of the future value to the current value expressed as a decimal.

Forecasted escalation rates are simply the percentage change from one year to the next, typically prepared for various groups, utilizing different sources of data. Because larger projects extend over several years, it is necessary to have a method for predicting budgets that must be made available in the future. This is where forecasted escalation rates are used. The current year cost estimate is divided into components and then multiplied by the appropriate escalation rate to produce an estimate of the future cost of the component. The future costs of these components are then summed to give the total cost of the project.

To properly apply escalation, the following data are required:

1. Reference date the estimate was prepared and base date of costs;
2. Escalation index, or cumulative rates, to be used (including issue date and index); and,
3. Schedule, with start and completion dates of scheduled activities.

Escalation could be applied for the period from the date the estimate was prepared to the midpoint of the performance schedule or the activity being escalated. There are many other more detailed methods of calculating escalation, but **care should be taken not to make this calculation too complex.** Remember, someone external to the project may need to review this calculation. Regardless of the method used, the process should be well-documented.

“Which comes first, contingency or escalation?” If a project includes a contingency that is based on risks, and those risks have associated costs, this may imply use of the same base-year dollars. And generally, performance periods can be associated with those risks within components, so, escalation may be applied to contingency. However, if contingency is not easily discernable by WBS element (or cost elements) or cannot be associated with a time period, it may not be appropriate to escalate contingency. Also, the accuracy of an escalation forecast can also be considered a risk, with appropriate cost impacts that are then included in contingency allowances. The cost estimate should ultimately represent total escalated costs, or “then-year dollars.”

Historical Escalation

Generally, historical escalation is generally easily evaluated. For example, the cost of concrete increased between 1981 and 2002. The ratio of the two costs expressed as a percentage is the historical escalation rate, or expressed as a decimal number is the historical cost index. Several commercial historical cost indices are available.

To properly apply a historical cost index to make price more current, the following data are required:

- An applicable historical cost index; and,
- The prior cost or price, with a reference date, such as an actual price for a known project or a component. This cost or price may include direct material and/or labor cost, and it should be known to what extent indirect costs (sales taxes, freight, labor burden, etc.), overheads, and profit were included.

Escalation Calculations

Most costs are estimated in “current dollars” and then escalated to the time when the work is expected to be performed. The escalation rates are used for developing project performance baselines. Rates should be evaluated for global, regional, and local conditions; should have a maximum period of 1 year; and should be clearly documented including the basis. The following are some suggested sources of major indices and escalation (recognized by industry best practices):

- U.S. Department of Labor, Bureau of Labor Statistics, Inflation & Prices, <http://www.bls.gov/bls/inflation.htm>;
- U.S. Department of Labor, Bureau of Labor Statistics, Contract Escalation, <http://www.bls.gov/bls/escalation.htm>;
- Engineering News Record, Economics, <http://enr.construction.com/economics/>;
- RSMeans, Cost Books, <https://rsmeans.com/CostBooks.aspx>;
- The Richardson Construction Estimating Standards, <http://www.costdataonline.com/>;
- IHS Global Insight, <http://www.ihsglobalinsight.com>; and
- Office of Management and Budget Circular A-94, Guidelines and Discount Rates for Benefit Cost Analysis of Federal Programs, <https://www.whitehouse.gov/sites/whitehouse.gov/files/omb/circulars/A94/a094.pdf>

DOE G 413.3-21A – cont'd

- **DOE schedule contingency** is the risk-based, quantitatively derived portion of the overall project schedule duration that is estimated to allow for the time-related risk impacts and other time-related project uncertainties. It is recommended that project schedule contingency should be estimated to provide a CL range of 70-90 percent.
- **Contractor MR Budget** is the risk-based quantitatively derived portion of the contract budget base (CBB) that is set aside for management purposes to handle risks that are within the contractor's contractual obligations. Once the CBB has been established, it is allocated to MR and the Performance Measurement Baseline (PMB). The MR is not intended to justify a post contract increase to the CBB. MR is maintained separately from the PMB and is utilized through the contractor's change control process. MR is not used to resolve past variances (positive or negative) resulting from poor contractor performance or to address issues that are beyond the scope of the contract requirements. Use of MR should follow EVMS rules as per EIA-748 (current).
- **Contractor schedule margin** is the risk-based quantitatively derived portion of the overall contract schedule duration estimated to allow the contractor time to manage the time-related impacts of contractor execution risks and other contractor duration uncertainties within the contract period. Contractor schedule margin does not add time or schedule duration to the contracted end date.

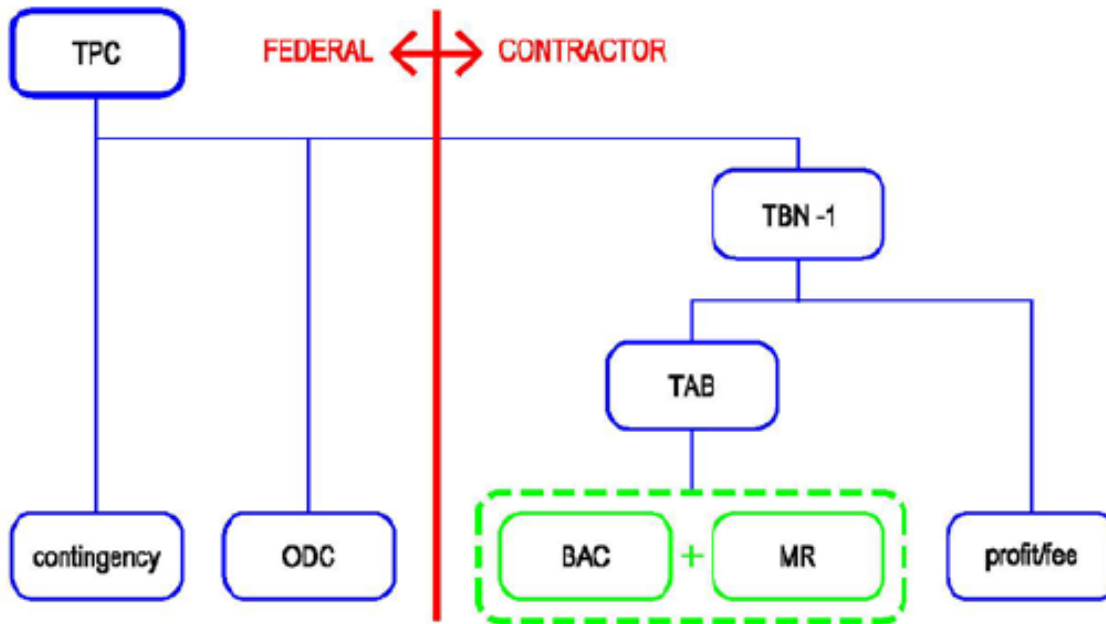
The quantitative method used to analyze project contingency and MR should consist of objective analysis of cost and schedule estimate uncertainties and discrete project risks. The analysis should aggregate the probability and consequences of individual risks, and cost and schedule uncertainties to provide an estimate of the potential project costs.

The quantitative risk analysis determines a risk-based project budget and completion date using statistical modeling techniques such as Monte Carlo, Quasi-Monte Carlo, sensitivity simulations, and other stochastic methodologies depending upon the project data.

While the Monte Carlo simulation is one standard used by DOE, alternate forms of quantitative analysis may be used. Other recognized forms of quantitative analysis include: decision trees, influence diagrams, system dynamics models, and neural networks. The figures below show the typical components of the DOE project performance baseline.

Total Project Cost Composition. Note: CL = Recommended Confidence Level

TPC Elements Chart



Acronyms

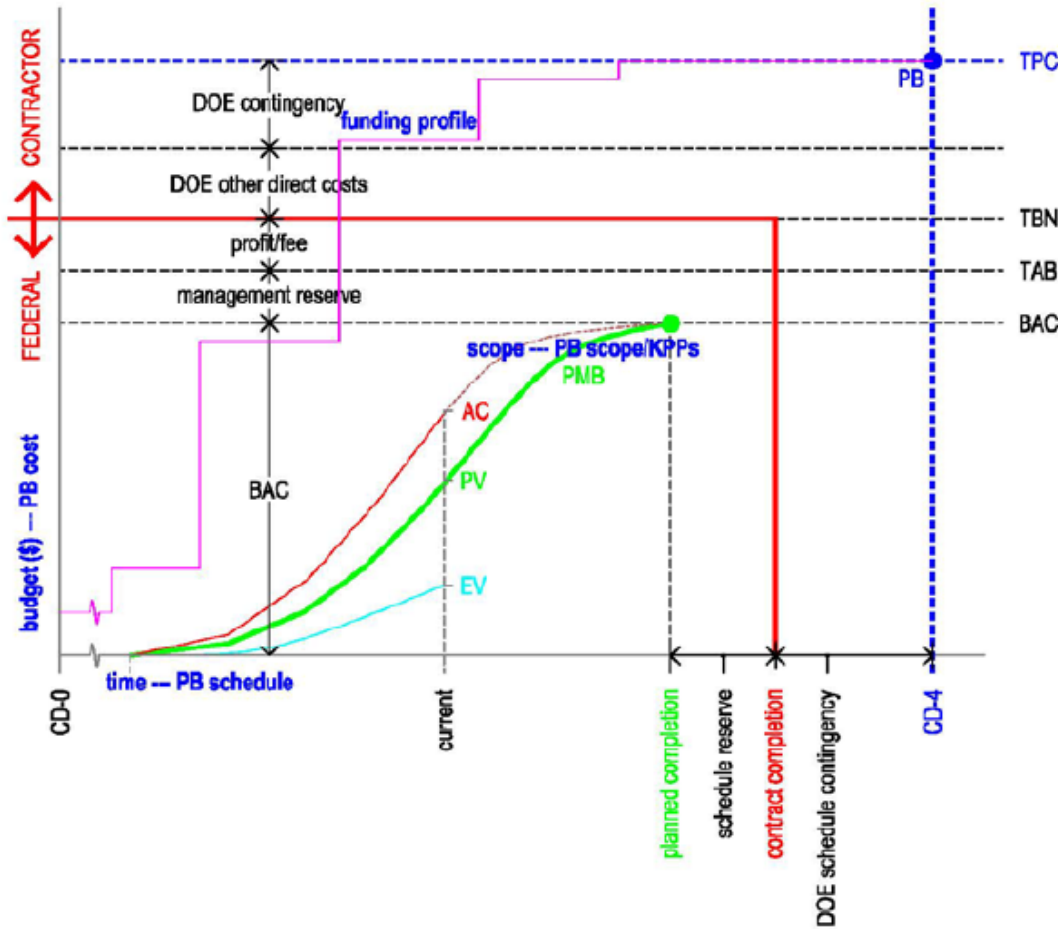
BAC	budget at completion
MR	management reserve
ODC	other direct cost
TAB	total allocated budget
TBN	total budget need
TPC	total project cost

DOE G 413.3-21A – cont'd

DOE and Contractor Budget Baseline

2018-04-11 v42 King

PB Figure (scope/KPPs, CD-4, TPC)



Acronyms

- AC actual cost
- BAC budget at completion
- CD critical decision
- EV earned value
- PB performance baseline
- PMB performance measurement baseline
- PV planned value
- TAB total allocated budget
- TBN total budget need
- TPC total project cost

Quantitative Contingency Analysis

DOE O 413.3B requires that DOE project estimates be developed based on qualitative and quantitative analysis of project risks and other uncertainties. The DOE qualitative and quantitative analysis process begins in the project's planning stage with the identification of project risks during the initial project planning phase prior to CD-0, Approve Mission Need. After CD-0, project development and planning documentation are prepared that includes the initial Risk Management Plan (RMP). During this phase of the project, development of the project risk register is initiated with the identification of potential project risks and enabling assumptions.

At CD-1, the baseline scope is refined enough to develop a preliminary baseline cost range and schedule. The RMP continues to evolve as the project scope is refined, new risks are added to the risk register and existing risks are re-examined and the project knowledge base increases. In preparation for the CD-2, the performance baseline estimate is refined to include costs to be incurred in executing the risk handling strategies. The baseline estimate is also evaluated, and adequate contingency allowance incorporated, to determine the project budget needed to provide an appropriate CL so that the project execution will be successful as defined in DOE O 413.3B.

This document assumes Monte Carlo methodologies will be used to develop the cost and schedule baselines. The diverse and unique nature of DOE projects characterized by an assortment of distinct technologies, physical locations, project duration, and project size has a significant impact on the risk profile that makes it impossible to establish a prescriptive procedure or single quantitative risk model for determining a project's contingency needs. Consequently, only a basic framework is used to outline considerations essential in the development of DOE contingencies.

Cost and Schedule Risk Models

Contingency risk models are used to evaluate the probability and effects of risk impacts, and estimate uncertainties on project cost and schedule performance baselines. The results of the risk analysis are used to establish the cost and schedule contingency needed to provide a suitable confidence level for DOE project success. The analyses may use one or more risk models to evaluate the cost impacts and the associated schedule impacts.

For each risk, a percent or percentage distribution is assigned to the probability (the likelihood of the risk occurring), a dollar value or dollar value distribution is assigned to the cost impact, and a schedule duration impact or schedule duration distribution is assigned to the affected activity in the schedule.

In general the concept is implemented as: $EV = \sum PR_i \times CIR_i$ (or SIR_i)

Where: EV = Expected Value of cost impact (or duration impact) of all risks

PR_i = Probability distribution function of a risk occurring

CIR_i = Cost Impact distribution function of a risk occurrence

SIR_i = Schedule Impact distribution function of a risk occurrence.

[Note: **Σ** is not the summation of individual expected values for each risk, but represents a stochastic process (e.g., Monte Carlo simulation) using the collective probabilities and cost/schedule impacts for all identified risk events.]

Sample Risk Register

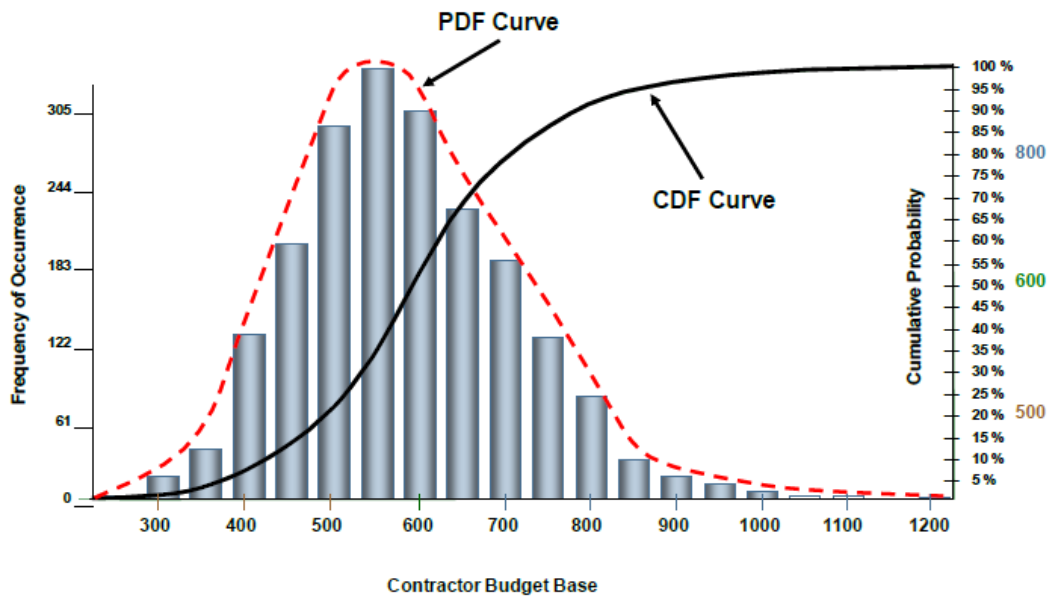
Risk #	Owner	Risk Description	Residual Risk									
			Likelihood	Consequence	Risk Score/Rank	Probability (%)	Cost Impacts (\$)			Schedule Impacts (Days)		
							Best Case	Most Likely	Worst Case	Best Case	Most Likely	Worst Case
T47	Federal	Nonperformance of contract to provide shielded overpack containers leads to project delays and cost.	Unlikely	Significant	Moderate	40	850,000	3,000,000	6,000,000	0	0	0
T52	Federal	Overnight organizations interpret requirements different than implementation, leading to cost and schedule impacts.	Likely	Significant	Moderate	60	–	3,000,000	6,000,000	0	30	90
T12	Contractor	Failure of crane results in delayed removal of canisters, impacting schedule.	Unlikely	Marginal	Low	40	100,000	200,000	1,400,000	1	2	14
T61	Contractor	Calibration services are unavailable causing shut down of operations.	Very Unlikely	Marginal	Low	10	100,000	410,000	715,000	1	4	7
T266	Contractor	Hot cell cannot be designed to meet active ventilation strategy increasing design and construction costs.	Very Unlikely	Critical	Moderate	10	3,200,000	7,000,000	20,000,000	30	60	150

The figure above is a sample from a DOE construction project risk register showing the residual risk data elements used for modeling the probability of occurrence (probability percentage) and the triangular distribution representing a three-point estimate of the anticipated range of cost and schedule impacts (the assumption in this example is of a triangular distribution of cost and schedule impacts; other distributions can be used, such as step, rectangular, etc.).

DOE G 413.3-21A – cont'd

The results of Monte Carlo analyses are generally summarized by a probability distribution function (PDF) and a cumulative distribution function (CDF), as shown in the figure below. The PDF represents the distribution of the analytical model outcomes. As an example, the Monte Carlo analysis may be designed to estimate the cost or duration of a project. The PDF represents the number of times a certain cost or duration is achieved. The CDF is a statistical function based on the accumulation of the probabilistic likelihoods of the analytical analysis. In the case of the DOE risk analysis, it represents the likelihood that at a given probability the project cost or duration will be at or below a given value. As an example, the x-axis might represent the range of potential project cost values evaluated by the Monte Carlo simulation, and the y-axis represents the project's probability of success.

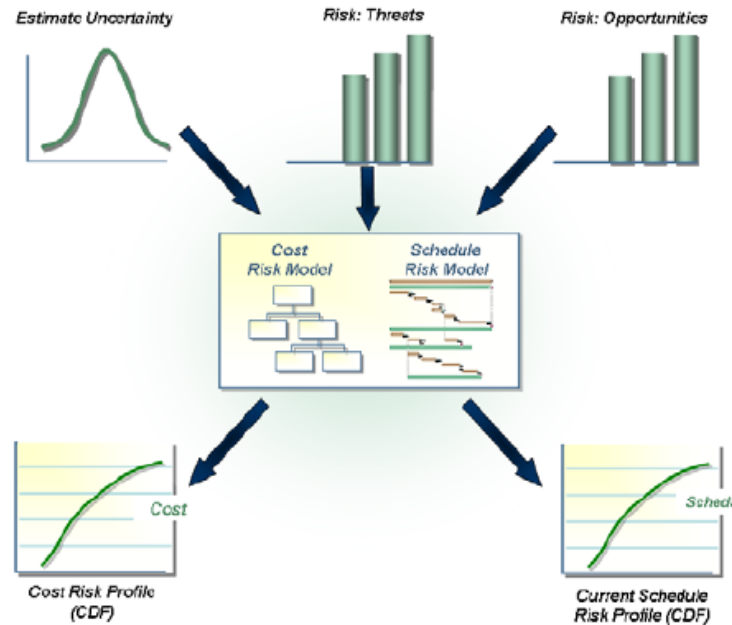
Sample
PDF
and
CDF
Curves



DOE G 413.3-21A – cont'd

An advantage of an integrated cost and schedule risk model is the ability to capture schedule-related costs impacts, such as LOE support activities that increase project costs as schedule-related risk impacts delay or extend work efforts. Ideally, the integrated risk model is based on a life-cycle resource-loaded critical path schedule to which cost and schedule risks and cost and schedule uncertainties are applied. Integrated risk models increase the flexibility of the risk analysis and reduce the amount of manual coordination needed to model cost and schedule risk impacts.

Project risks and the associated cost and schedule impacts are the primary inputs to the risk model and are maintained within the project's risk register. The figure below depicts a conceptual risk model showing typical inputs and outputs.



Conceptual
Risk
Analysis
Process

An important consideration when identifying project risks is the careful analysis of the assumptions upon which the cost estimate and schedule are predicated. Each assumption made by the estimator, scheduler, or the project team should be analyzed by the IPT to determine if there is a risk (threat or opportunity) that the assumption may not be valid or representative of the actual conditions realized during project execution.

In such cases, the probability of alternative situations should be assessed and the impacts of those situations occurring should be quantified and analyzed. These impacts can be an important element in both the cost and schedule risk models and the determination of cost and schedule contingency allowances appropriate for the project.

It should also be noted that Monte Carlo simulations are based on estimates of probability of occurrence and estimated impacts when risk events do occur. As such, the quality of the output is dependent on the quality and accuracy of these inputs. Inaccurate estimates of either probability or impact will lead to erroneous project probability outputs and misstatement of needed contingency allowances and/or CL.

Another issue that can lead to poor Monte Carlo analysis results is a failure to identify significant project risks. Only if all significant risks are identified and properly evaluated can the Monte Carlo model be expected to provide realistic forecasts of project outcomes and the contingency allowances needed to achieve the desired CL.

Cost Risk Model

DOE capital asset projects should be estimated to provide a CL which is adequate to support project success and reflects evaluation of all project risks, with reasonable estimates of cost and schedule impacts.

Risk models should include all risks (DOE, contractor and subcontractor assumed risks). The risk cost model should provide an estimate of the performance baseline with a CL range of 70 -90 percent for success (recommended), which includes the contractor's CBB, profit/fee, and government contingency and other direct costs.

The contractor MR is determined by the contractor and represents the amount of the CBB that will be used for project management purposes for accomplishing the work scope within the contractor's PMB.

When developing risk models, care should be exercised to assure the risk models are developed using appropriate performance baseline information and project risk assumptions.

The recommended cost risk model should:

- Include all risks, especially significant risks;
- Use reasonable estimates of cost impacts;
- Include estimate uncertainties (cost and schedule) that are within the project baseline;
- Contain enough detail to allow identification of risk owners;
- Contain enough detail to allow project risks to be associated with the WBS they affect;
- Include a provision for uncertainty ranges in cost escalation rates for the project;
- Allow correlated risks that affect multiple cost elements, e.g., escalation rates, to be modeled at a high level to preserve the dependent relationship among correlated risks;
- Include sufficient information to estimate costs associated with uncertainties in task durations consistent with the schedule risk model;
- Allow for inclusion of threats and opportunities; and,
- Allow risk impacts to be placed in the appropriate fiscal year to support the identification of annual contingency budgeting and reporting requirements.

Schedule Risk Model

Schedule risk models should be based on the project performance baseline schedule. If practical, the schedule risk model should be developed to include the schedule impacts of all risks that impact the project, as well as any schedule duration uncertainties.

The recommended schedule risk model should:

- Include all significant risks;
- Use reasonable estimates of schedule impacts;
- Contain enough detail to allow identification of risk owners;
- Contain enough detail to distinguish among schedule activities that have different degrees of schedule uncertainty and should include estimate uncertainties;
- Contain enough detail to allow specific risk events to be associated with the schedule activity that they affect;
- Estimate the schedule impact on LOE activities so cost increases associated with schedule slippages can be calculated and incorporated into the contingency estimates; and,
- Allow for alterations in activity duration that result from implementation of risk handling strategies or opportunities.

Sensitivity Analysis

The GAO-09-3SP, GAO Cost Estimating and Assessment Guide, states that, “As a best practice, sensitivity analysis should be included in all cost estimates because it examines the effects of changing assumptions and ground rules.” DOE endorses this best practice and believes it to be a vital element and consideration when developing a cost estimate. Since uncertainty cannot be avoided, it is necessary to identify what cost elements present the most risk and if, possible, cost estimators should quantify the risk.

Only when decision makers fully understand the results of sensitivity analyses, combined with the results of the uncertainty and risk analyses, can they ensure they made the best choices at either a programmatic or project level.

A sensitivity analysis “considers all activities associated with one cost estimate. If a cost estimate can be sorted by total activity cost, unit cost, or quantity, sensitivity analyses can determine which activities are cost drivers to answer the question: ‘If something varies, what most affects the total cost of the project?’” A tailored analysis may be needed to avoid overly burdensome or repetitive site wide impacts arising in lower level estimates down to the work package level.

Uncertainty about the values of technical parameters is common initially in design and development and can result in inaccurate assumptions. Some examples of cost drivers that GAO has identified include:

- A shorter or longer economic life
- Testing requirements
- Volume, mix or pattern of workload
- Changes in performance characteristics
- Potential requirements changes
- Acquisition strategy
- Configuration changes
- Labor rates.
- Higher or lower learning curves
- Testing requirements
- Alternative assumptions
- Down-scoping a project

The cost practitioner should always include the assumptions that are most likely to change, such as an assumption that was made for lack of knowledge or one that is outside the control of the program or project office. The sensitivity analysis addresses some of the estimating uncertainty by testing discrete cases of assumptions and other factors that could change. By examining each assumption or factor independently, while holding all others constant, the cost estimator can then evaluate the results to discover which assumptions or factors most influence the estimate. It is important to understand and be able to communicate the potential impact from variations in key assumptions and estimate cost drivers.

GAO recommends incorporating a five-step process that will result in a credible sensitivity analysis:

- Step 1.** Identify key cost drivers, ground rules, and assumptions for sensitivity testing
- Step 2.** Re-estimate the total by choosing one of the identified cost drivers or assumptions and varying it between two set amounts. The amounts chosen may represent maximum and minimum, various performance thresholds, or alternative assumptions; ranges should be documented during data collection and cost estimating
- Step 3.** Document the results
- Step 4.** Repeat Steps 2 and 3 until all factors identified in Step 1 have been independently tested
- Step 5.** Evaluate results to determine which drivers affect the cost estimate the most

To identify the key cost drivers and critical assumptions, there are several recommended approaches:

- Research and appropriately reference historical data, industry benchmarks, and other relevant data sources to determine the ranges of values a sensitivity analysis should consider. It is not a best practice to merely use arbitrary plus or minus values or other approaches that do not have a sound basis. However, in the absence of relevant data, use the expert opinion of suitably qualified subject matter experts.
- Examine the sub-elements or assumed values that contribute to the cost estimate value.
- Review all assumptions made and documented in the basis of estimate to isolate those assumptions that seem most uncertain or most critical to the viability of the resultant estimate.
- Evaluate the results of the sensitivity output from the Monte Carlo simulation model that assessed cost estimate uncertainty and risks when time permits. Visual output depicted from “tornado charts” show the relative contribution of each simulation-model variable to the final cumulative probability profile. It should be noted, however, that the elements highlighted in such tornado charts may or may not be the most critical elements for a true sensitivity analysis and usually do not represent an all-inclusive listing of such elements.

In summary, GAO best practices for sensitivity analysis necessitates satisfying the following tests:

- The cost estimate was accompanied by a sensitivity analysis that identified the effect of changing key cost driver assumption and factors:
 - Well-documented sources that support the assumptions or factor ranges used in analyses;
 - The sensitivity analysis was part of a quantitative risk assessment and was not based on arbitrary plus or minus percentages;
 - Cost-sensitive assumptions and factors were further examined to see whether design changes should be implemented to mitigate risk;
 - Sensitivity analysis was used to create a range of best-and worst-case costs;
 - Assumptions and performance characteristics listed in the technical baseline description, as well as ground rules and assumptions, were tested for sensitivity, especially those assumptions and characteristics least understood or at risk of changing; and,
 - Results were well documented and presented to management for decisions.

DOE G 413.3-21A – cont'd

- The following activities were taken during the sensitivity analysis:
 - Key cost drivers were identified;
 - Cost elements representing the highest percentage of cost were determined and their parameters and assumptions were examined;
 - The total cost was re-estimated by varying each parameter between its minimum and maximum range;
 - Results were documented and the re-estimate was repeated for each parameter that was a key cost driver; and,
 - Outcomes were evaluated for parameters most sensitive to change.
- The sensitivity analysis provided a range of possible costs, a point estimate, and a method for performing what-if analysis.

Estimate Uncertainty

Estimate uncertainty is part of the risk analysis process for the development of contingency estimates as was illustrated in the figure above. Estimate uncertainties are fundamental contributors to cost growth and are expected to decrease over time as the project definition improves and the project matures. Estimate uncertainty is a function of, but not limited to, the quality of the project scope definition, the current project life-cycle status, and the degree to which the project team uses new or unique technologies. Estimate uncertainties occur throughout the DOE baseline. One approach to account for estimate uncertainty is to use uncertainty ranges established by the professional societies such as ACE International, table below, or other estimating guidance. Estimate uncertainty contributes to both cost and schedule contingency.

The table below could be used for both cost and schedule estimate uncertainty and should be done separately for evaluating quantitative impacts on project contingency.

Estimate Uncertainty Range as a Function of Estimate Class

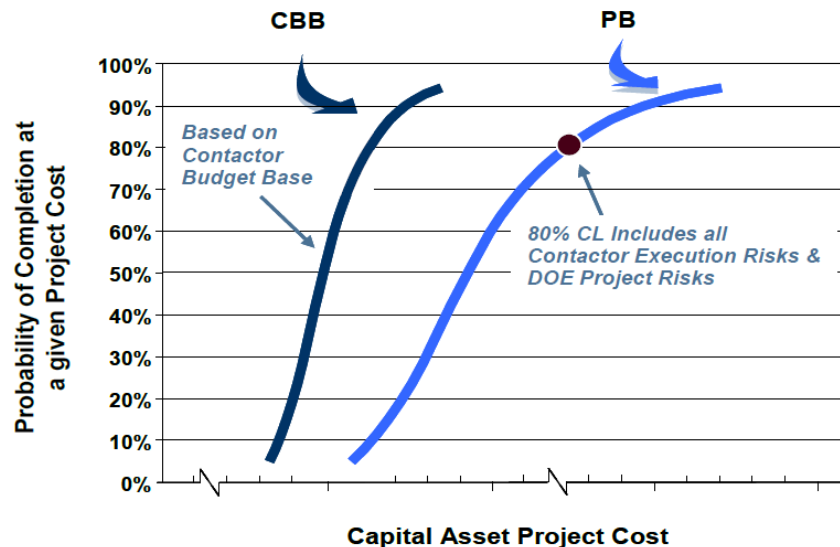
Class of Cost Estimate	Estimate Uncertainty (Low Range)	Estimate Uncertainty (High Range)
Class 5 – Concept Screening	-20% to -50%	+30% to +100%
Class 4 – Study or Feasibility	-15% to -30%	+20% to +50%
Class 3 – Budget Authorization	-10% to -20%	+10% to +30%
Class 2 – Control or Bid	-5% to -15%	+5% to +20%
Class 1 – Check Estimate	-3% to -10%	+3% to +15%

Determining Cost Contingency Amounts

A common method to evaluate risk model results is the use of CDF curves, also referred to as S-curves. For a cost risk model, the S-curve represents the probability of completing the project at or below a given project cost baseline. In this example the x-axis represents the range of potential project cost values estimated by the Monte Carlo simulation and the y-axis represents the probability of project success. The figure below illustrates two S-curves for a hypothetical project. The S-curve on the left is based on the CBB and the S-curve on the right is for the DOE capital asset project performance baseline and includes both the contractor and DOE risks.

S-Curves of Contractor CBB and DOE Performance Baseline

Probabilistic Projection of Cost using Monte Carlo Analyses



Determining Schedule Contingency

The DOE schedule contingency is based on the same risks used in the development of the DOE cost contingency. The DOE schedule contingency requirements should be analyzed using a resource-loaded and logically tied schedule, so that impacts to overall schedule duration along the critical path can be fully assessed. As risks and uncertainties are realized, the critical path for the project may possibly change; the model needs to accommodate such situations.

Schedule activities that are affected by an identified risk or duration uncertainty are modeled in the schedule risk analysis with an appropriate probability distribution. The calculation of schedule contingency is an iterative process requiring an initial analysis of the schedule to determine the base schedule contingency values followed by a revision of the schedule to adjust work scope to meet the existing selected key milestones and deliverable dates.

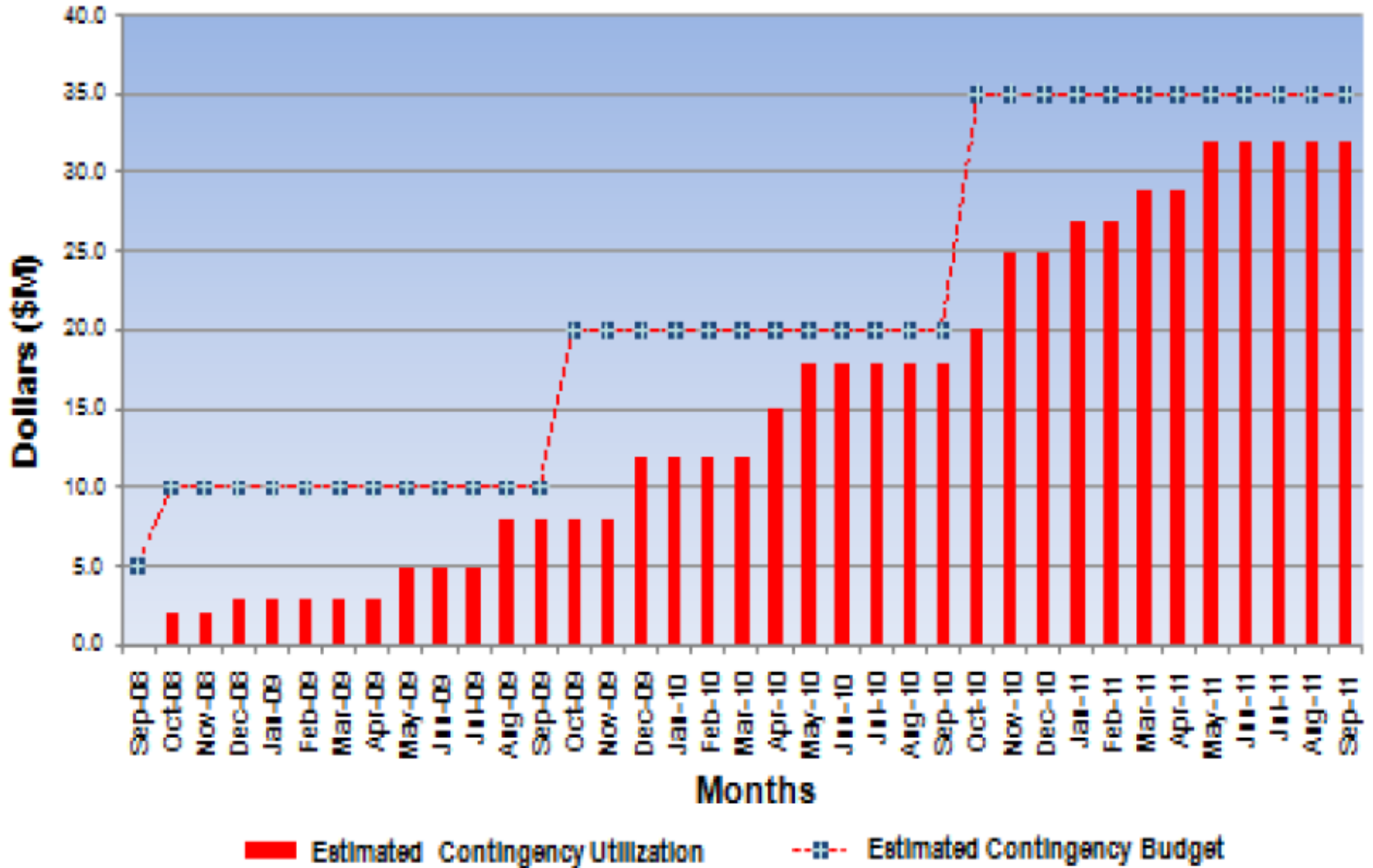
DOE schedule contingency needs to be added to the overall critical path of the project. This can be completed by applying the DOE schedule contingency incrementally before key milestones or in total before the project completion date. **In this way, forecasted completion dates (individual milestones and/or overall project) can be established based on a probabilistic determination of the expected completion date should project risks be realized.** This differs from contractor schedule margin, which cannot add time or schedule duration to the contracted end date.

Risk Model Outputs

To support the required budgeting, management, and reporting requirements of the project, the contingency analysis should provide the following:

- The contingency analysis models should be able to produce a PDF and a CDF for the project
- The contingency analysis models should be able to produce a PDF and a CDF for each selected milestone
- The models should be capable of performing a sensitivity analysis for project cost and schedule elements. Risk analysis sensitivity results are typically presented as tornado diagrams that provide an analytical and visual representation of risk event impacts
- Ideally, the model should place resulting contingencies in a time frame to allow for fiscal year budgeting of DOE contingency. The figure below illustrates how contingency budget projections can be depicted

Contingency Budget Projection



Unknown-Unknowns

Because there may not be viable means to quantify certain “unknown-unknowns”, IPTs may not be expected to set aside contingency for them. Unknown-unknowns could be major schedule changes or unknown design factors, unanticipated regulatory standards or changes, additions to project scope definition (changes outside a project’s intended scope), force majeure situations, or program budget reductions. These may be considered programmatic risks, which could be applicable to all projects within a respective specific Program.

However, there should be clear communication between the project team and their sponsoring Program to communicate and agree to the bounding assumptions for the project.

Furthermore, Programs are advised to include appropriate allowances for programmatic contingencies (for risks and events that occur outside project space but that may in fact impact on project execution) in their overall portfolio budgets.

Contingency Adequacy Evaluation

Numerous tools exist to analyze the adequacy of the contingency valuation that has resulted from the qualitative and/or quantitative analysis of the risks. Various costs estimating guidance documents have been compiled by industry and are available in texts and journals (e.g., AACE International), and are updated on a regular basis.

These references provide percent ranges of the base that a contingency should represent in order to be considered adequate. Further, the contingency value should be commensurate with the maturity and type of the project, project size, and risks, including technical and technology uncertainties.

It should be cautioned that the recommended contingency levels in these documents do not provide a basis for the recommended confidence levels (70 – 90 percent) in this Guide for the derivation of contingency and management reserve by quantitative risk analysis.

If a quantitative risk analysis will not be conducted, estimates for cost and schedule contingency should be provided. As a general rule, the IPT should use various inputs to determine those values. Those inputs may be, but should not be limited to:

- Historical records (considering actual costs and time impacts for certain events);
- Subject matter experts;
- Delphi techniques;
- Interviews of staff, crafts, retirees, and others familiar with similar work activities at the site or similar sites; and,
- Technical records such as safety analysis documents including the risk and opportunity assessment, quality assessments, and environmental assessments.

As the information is gathered and finalized, the data should be analyzed for bias and perception errors. While the data will not be systematically used for a quantitative analysis, it should still be analyzed and perceptions scrutinized.

Cost Estimate Review

Cost estimates should be reviewed for quality and reasonableness before release. Reviews can be either objective, subjective, or a combination of both. As a minimum, all estimates should address the review criteria listed in Appendix D.

DOE cost estimates, and the BOEs that support them, should include an assessment of the realism and reasonableness of the primary cost elements comprising the cost estimate. Such an assessment evaluates the relative percentages of the total proposed cost baseline and the underlying BOE for each of the significant cost elements. Additionally, primary cost drivers within the estimate consistent with a product oriented WBS, should be identified and compared to established benchmarks for similar items or activities.

Such efforts will facilitate independent reviews of cost estimate reasonableness by competent qualified personnel who have not been involved in preparing the estimate. This review should provide an unbiased check of the assumptions, productivity factors, and cost data used to develop the estimate. An independent cost review is a vital step in providing consistent, professionally prepared cost estimates (Step 7, GAO 12 Key Steps Development Process, GAO-09-SP). The review should be documented to indicate:

- The name of the reviewer(s) – Office/Agency/Contractor it belongs
- The date of the review
- Review comments and comment disposition

Estimate Reconciliation

Reconciliation may be necessary to account for changes made between CDs or other life-cycle project milestones. Reconciliations should be organized by WBS and cover all aspects of project documentation (cost estimate, basis of estimate, schedule, and risks).

In general, reconciliation should recognize or focus on specific changes in scope, basis of estimate, schedule, and risks. There should be an understanding that, as time progresses, more and better information is expected to be available and used as project or cost estimate documentation.

Reconciliations are necessary to mitigate budget shortfalls and may be used to correct deficiencies identified during internal or external reviews.

Cost Estimate Documentation

A well-documented estimate is one of GAO's best practices for high-quality cost estimates for the following reasons:

- 1. Complete and detailed documentation is essential for validating and defending a cost estimate.**
2. Documenting the estimate in detail, step by step, provides enough documentation so that someone unfamiliar with the program/project could easily recreate or update it.
- 3. Good documentation helps with analyzing changes in program costs and contributes to the collection of cost and technical data that can be used to support future cost estimates.**
4. A well-documented cost estimate is essential if an effective independent review is to ensure that it is valid and credible. It also supports reconciling differences with an independent cost estimate, improving understanding of the cost elements and their differences so that decision makers can be better informed.

Documentation should be organized into an indexed repository, either physical or digital, with a document control plan and, preferably, a documentation engineer/administrator. To the extent practical, the documentation index should be consistent with the WBS for the project for ease of reference.

Cost Estimate Package

A cost estimate package or report should be prepared for all cost estimates. Each estimate package should contain the same categories of information and the same types of documentation; only the level of detail in the estimate package varies. The contractor in coordination with the IPT determines the format used to present this information. **A cost estimate package or report supporting baselines, management decisions, and budgetary documents should include the following information.** A graded approach to cost estimate packaging and reporting should be used when documenting cost estimates for other purposes.

- **Estimate Purpose Statement**—the reason the estimate was prepared including - Determine the estimate's purpose -The level of detail required -Determine who will receive the estimate -Identify the overall scope of the estimate.
- **Technical Scope Summary**—summary of the technical scope of the project including what is included in the project **as well as what is not included.**

- **Qualifications and Assumptions**—the key project qualifications and cost assumptions that provide a “bounding” of the estimate and scope. Specifically, the assumed condition under which the estimator believes the project work scope will be performed should be defined. The qualifications and assumptions may describe the types of work expected, the amount of work expected, the source of various materials, conditions in which the work is to be performed (winter, contaminated building, etc.), and any other information that significantly influences the estimate but is not clearly identified in the technical scope description. **Major assumptions and exclusions that affect the project or the accuracy of the estimate are also described.** Concrete examples of scope assumptions include, but are not limited to changes in the seismic criteria, safety criteria, materials, method of construction, siting, orientation, construction methods assumed, and open air versus enclosed D&D.

In completing this activity, the estimator should identify areas where work scope descriptions have deficiencies, or where key information is missing and has to be assumed. Vital information concerning the project is also identified for those reviewing or using the estimate.

Qualifications and assumptions should be described and documented at the most detailed level practical, and they should be clearly described so an individual not intimately involved with the project can understand the estimate’s basis.

- **Overall Basis of Estimate**—the dollar amount indicated in a cost estimate is meaningless without understanding the quality of information that led to developing the estimate. With all estimates, the basis is communicated at a higher level in a summary document and at a more specific level within the estimate.

Include in the estimate package a high level summary explaining the genesis for the source information for the estimated resources and a breakdown of cost estimate basis. For example, a breakdown may indicate that 30% is vendor quote, 20% engineering judgment, 30% historical data, and 20% cost database/cost books.

The basis should also describe the design basis, the planning basis (significant features and components, proposed methods of accomplishment, and proposed project schedule), the risk basis, supporting research and development requirements (important when new technologies are contemplated for certain components, equipment or processes), special construction or operating procedures, site conditions, the cost basis, and any other pertinent factors or assumptions that may affect costs.

If the estimate is prepared in support of another formal document that addresses these issues (i.e., a Conceptual Design Report or definitive design document), separate documentation is not required but reference to the original documentation must be made. If the estimate is a standalone document, or deviates substantially from a previous estimate scope, the above issues should be addressed and included in the estimate basis.

- **Estimate Summary and Detail Reports**—a presentation of the estimate details in a variety of ways (e.g., sorted by labor type, by WBS etc.)
- **Technical Scope Detail**—a statement of the details of the technical scope necessary for a thorough understanding of the work. This may be by reference to specific technical documents.
- **Estimate Specific WBS and WBS Dictionary**—a decomposition of the organization and related cost estimates.

The initial basis for any cost estimate should be documented at the time the estimate is prepared. The basis should describe or reference the purpose of the project element, the design basis, the planning basis (significant features and components, proposed methods of accomplishment, and proposed project schedule), the risk basis, supporting research and development requirements (important when new technologies are contemplated for certain components, equipment or processes), special construction or operating procedures, site conditions, the cost basis, and any other pertinent factors, assumptions, or inclusions that may affect costs.

If the estimate is prepared in support of another formal document that addresses these issues (i.e., a Conceptual Design Report or definitive design document), separate documentation is not required. If the estimate is a standalone document, or deviates substantially from a previous estimate scope, the above issues should be addressed and included in the estimate basis.

At the WBS level, include quantities, applicable rates and costs. Also, include sources of information, such as historical costs, industry standards, published price lists; cost databases, informal budgetary information, cost estimating relationships, etc. for the WBS.

At the WBS level, include the resource and Crew Listing—a listing of the type of resources used in the estimate.

- **Method and Justification for Use of Indirect Rates**—an explanation of how indirect rates were selected and applied.
- **Method and Justification for use of Allowances**—an explanation of how allowances were determined and applied.
- **Method and Justification for use of Escalation**—an explanation of the escalation rates used, how they were obtained, why they were selected and how they were applied.
- **Schedule**—a time-frame for the work to assist in understanding how escalation was applied. The schedule should reflect the same technical scope and cost as the estimate.
- **Risk Register**—discusses sources of risk and uncertainty, including critical assumptions, associated with the estimate. Identifies major risks within the scope of work and how those risks are mitigated. The basis for contingency reserves and how they were calculated is fully documented.

DOE G 413.3-21A – cont'd

- **Sensitivity Analysis**—describes the effect of changing key cost drivers and assumptions independently. Identifies the major cost drivers that should be closely monitored.
- **List of Participants**—lists contacts for questions about the estimate. Estimate preparers and reviewers should be identified in the cost estimate documentation.
- **Documentation of Review and Approval**—demonstrates that the estimate was reviewed and approved.
- **Location of Estimate Files and Reference Information**—identifies the locations copies of the estimate, review the original, and review information that was not included in the estimate package. The cost estimate package should include documentation providing the location of the estimate, historical data, technical scope, worksheets and any other pertinent information used to prepare the estimate.
- **Documentation of Changes to the Estimate**—clarifies how and where the estimate was changed, eliminating the need to review the entire estimate. Cost estimates should be updated or modified as necessary. Updates should be promptly documented when significant changes occur.

Cost Classification

A specific definition of items to be included as direct costs and indirect costs should be included at the discretion of the DOE program offices and field offices and/or determined by their contractor's financial system. This would also apply to activities under either Other Project Costs (OPC) or Total Estimated Cost (TEC) (**refer to DOE O 413.3B for definitions and requirements for these terms as they apply to projects**).

It is important to assure that there is no double counting of costs estimated as direct, indirect, or overhead. Generally, all cost estimates should include:

- **Direct costs**
- **Indirect costs**
- **Contingency**
- **Escalation**

Estimate Maintenance

It is important to maintain estimates over the life cycle of the project or program. For projects, the cost estimate is a key element in establishing the Performance Baseline. The project cost performance baseline consists of a project's TPC, which includes various contract prices, non-contract costs, profit/fee, and contingency.

Project baselines in turn are key elements of overall program planning and budgeting, including portfolio management. As projects are identified and defined, and the cost estimates and baselines evolve, they become key inputs into the management of the program's life cycle. This may involve multiple projects and/or operational activities (e.g., construction of facilities to treat waste, decommissioning of treatment facilities, waste management, surveillance and maintenance). As such, **active maintenance of all estimates is essential – they need to reflect the latest and most realistic projections of cost and resource requirements to facilitate effective program planning.**

The need to make changes to a cost estimate generally results from determining that the estimate no longer accurately portrays the expected cost for the work. The means to formally control changes to a cost estimate are dependent on the purpose of the estimate. Estimates supporting project baselines must be changed and approved through a formal baseline change process (refer to DOE O 41.3.3B, Appendix A, Section 6, Baseline Management).

DOE G 413.3-21A – cont'd

Changes require documentation, and as each estimate is updated, modified, or revised, an audit trail must be maintained to show the relationship between the new estimate and the previous estimate. The reason(s) for each change should be identified and may include such things as modification of scope, unexpected increases in labor rates, schedule extensions, variance in escalation rates, project reprioritization, etc. All such changes should be identified in a manner that will permit verification of the specific quantitative change(s) in the cost estimate.

Changes may be documented by the use of addenda, officially approved change request documents, or by completion of a new estimate. The method used depends upon the magnitude of the estimated change and the underlying causes. All estimate changes should include the appropriate level of indirect costs, escalation, and allowances, as dictated by the phase of the project when the change was identified.

The process of officially revising and updating cost estimates supporting project baselines frequently involves the use of change requests. Change requests are the official means by which all changes to the cost baseline should be documented. Change requests are prepared using standard contractor procedures and forms, which describe proposed changes to approved technical, cost and/or schedule baselines.

As work is authorized to proceed, cost estimates inform budget development. There is a distinction between cost estimates and budget allocations. **The cost estimate provides the expected cost while the budget forms the basis for measuring work execution over time.** If the cost changes due to scope changes, funding profile changes, or other drivers, the cost estimate may need to be updated to support development of a new budget.

COST ESTIMATING OUTPUTS

This Guide defines traditional output from the Cost Estimating Process. Outputs include, the traditional change control process, economic and cost-benefit analysis, value engineering, earned-value, and final project cost reports.

Cost Estimate Interfaces

Cost estimate development is initiated into a process through one-time or iterative inputs. Potential one-time inputs may include (but are not limited to) the project charter, project execution plan, acquisition strategy, and acquisition plan. All of these are inputs to the cost estimating process.

Other inputs may evolve through the cost estimating process and use the outputs from the cost estimating process, such as the risk assessment (primarily risk identification and impact assessment), schedule, and scope development. **Input from cost estimating peers may improve the quality of a cost estimate, and peer reviews should be required before external reviews are conducted.**

The cost estimate output provides a key interface to other project processes, including the planning/scheduling, project control, risk management, and project approval processes.

Presenting the Estimate to Management

Cost estimates are a primary input into the DOE decision-making and project approval CD process. A cost estimate is not considered valid until DOE management has approved it. Since many cost estimates are developed to support a DOE budget request or make a decision between competing alternatives, **it is vital that a high quality cost estimate be intentionally planned to anticipate management concerns and inspire confidence in the desired outcome.**

The preferred presentation format is designed to allow management to gain confidence in the practitioner's cost estimating process and the estimate itself:

1. Cost practitioner should initially convey how the estimate was developed, including risks associated with the underlying data and methods. The presentation should contain enough detail for easy defense as to why the estimate is credible, well-documented, accurate and comprehensive.
2. **The presentation should be clear and complete**, making it easy for those unfamiliar with the estimate to comprehend its level of competence. The presenter should focus on the key cost drivers and the final cost estimate's outcome. Slides with visuals should be available to answer more probing questions. A GAO best practice is to provide the presentation in a consistent format to facilitate management's understanding the completeness of the cost estimate, as well as its high quality. A decision maker who is familiar with the presentation format is better able to concentrate on the presentation's content, and on the cost estimate, rather than focusing on the format itself.

3. Results should be communicated succinctly to fortify management confidence in the ground rules, methods, and results and in the process that was followed to develop the estimate. The presentation must include program and technical information specific to the program, along with displays of budget implications, contractor staffing levels, and related industrial base considerations. The following elements are recommended for inclusion in the presentation:
- Title page, presentation date and the name of the person(s) receiving the presentation;
 - Estimate purpose – why it was developed and what approval is needed;
 - A brief program overview – its physical and performance characteristics and acquisition strategy, sufficient to understand its technical foundation and objectives;
 - **Estimating ground rules and assumptions;**
 - Copies of the cost estimate both at the detail level and rolled up WBS level;
 - LCCE time phased in constant-year dollars and tracked to any previous estimate;
 - For each WBS cost element, show the estimating method for cost drivers and high value items;
 - Show a breakout of cost elements and their percentage of the total cost estimate to identify key cost drivers;

DOE G 413.3-21A – cont'd

- Sensitivity analysis, interpreting results carefully if there is a high degree of sensitivity;
- Discussion of risk and uncertainty analysis, including:
 1. cost drivers, the magnitude of outside influences, contingencies, and the confidence interval surrounding the point estimate and the corresponding S curve showing the range within which the actual estimate should fall;
 2. other historic data for reality checks; and,
 3. how uncertainty, bounds, and distributions were defined;
- Comparison to an independent cost estimate, explaining differences and results;
- Comparison of the budget needs or LCCE, expressed in current-year dollars, to the funding profile, including contingency reserve based on the risk analysis and any budget shortfall and its effect;
- Concerns or challenges the audience should be aware of;
- Conclusions, recommendations, and associated level of confidence in the estimate; and,

DOE G 413.3-21A – cont'd

- When presenting LCCEs to management, the presenter should include separate sections for each program phase—research and development, procurement, operations and support, disposal—and should provide the same type of information as the cost estimate documentation contains. In addition, **the presentation should provide the summary information, main conclusions, and recommendations first, followed by detailed explanations of the estimating process.**
4. Cost practitioner should conclude the presentation by asking management to formally accept the cost estimate. **Acceptance, along with any feedback from management, should be acted on immediately and documented in the cost estimate documentation package.**

Baselines and Change Control

Cost estimates are normally organized by a WBS, account code, and/or some other standardized definition. Standard definitions of direct and indirect costs provide consistency in estimating costs and project reporting. This also benefits program/project management, independent estimates (Government estimates), reviews, and contract/project validations and cost/price analysis. The cost portion of the performance baseline consists of a project's TPC, including various contract prices, non-contract costs, and contingency.

As projects evolve, baselines are established and changes are managed against those baselines. Cost estimates supporting proposed or directed changes should contain the same level of quality as the primary baseline cost estimate.

Baselines are expected to remain intact throughout the project execution from approval at CD-2 to completion at CD-4. **Changes are expected to remain within the performance baseline as per the definition of a successful project at CD-4 in DOE O 413.3B.** Cost estimates for the baseline project are modified (updated) when changes are approved.

Analysis

Analysis includes decomposition and examination. In many cases, analysis will provide insight to a decision maker. Such is the case of cost benefit analysis. Cost-benefit analysis is a required element in capital planning within the Federal government. **Note that cost analysis and price analysis have different meanings.** This Guide focuses on cost analysis.

Analysis could be performed in the life of a project, including cost benefit analysis, cost-effective analysis, economic analysis, LCC analysis, sensitivity analysis and uncertainty analysis. **Analyses supporting CDs should be structured and formal; i.e., well documented.** Other analyses may be loosely structured and informal.

Normally, analyses require using similar cost estimate structures (i.e., separate cost estimates for each alternative considered); having all costs for all alternatives depicted; and comparing alternatives using net present value or annuities. Normally a written summary of the findings is also prepared to explain the analysis.

More information on cost estimating and analysis can be found through the Society for Cost Estimating and Analysis (SCEA) at <http://www.sceaonline.org/>.

More information on cost engineering can be found through ACE International, at <http://web.acei.org/>

COST ESTIMATING EXPECTATIONS

Summary of Expectations

A DOE cost estimate, regardless of purpose, classification, or technique employed, should demonstrate sufficient quality to infer that it is appropriate for its intended use, is complete, and has been subjected to internal checks and reviews.

It should also be clear, concise, reliable, fair, reasonable, and accurate, within some probability or confidence levels. In addition, it should follow accepted standards such as the GAO 12 steps of a high quality cost estimating process (GAO-09-3SP) in accordance with other guiding DOE policy. There could be more expectations, depending on the program, project, contract type, specific budget requirements, or other situations.

Organization of some cost elements may be specified (e.g. resources, material, other direct costs, and sub-contract costs). These coded costs facilitate development of management information and earned value assessments, and can provide extremely useful information as projects are completed. Industry standard codes are exemplified by the Construction Specifications Institute's Unifformat II and Masterformat, for construction projects. The environmental cost element structure (ECES), an ASTM standard for environmental projects, is another common coding structure. Project data sheets (PDSs) for budget formulation and other coding formats should be produced, according to program office requirements.

DOE G 413.3-21A – cont'd

More information on the Unifomat II can be found at <http://www.unifomat.com/>

More information on the Masterformat can be found at <http://www.masterformat.com/>

More information on the ECES can be found at

<https://www.emcbc.doe.gov/Office/ProjectManagement>

More information on OMB's Exhibit 300 forms can be found in OMB A-11, Part 7 at

https://www.whitehouse.gov/omb/circulars_a11_current_year_a11_toc

Lessons Learned

Lessons learned from experience are essential to structuring increasingly more accurate cost estimates. A reasonable expectation of a cost estimating process is that it systematically collects historical project information in real time, rather than being done at the last minute or by trying to recollect long after the fact.

Historical cost information can be collected as lump sum (representing some specific scope of work), unit cost, or productivity (hours per unit, or units per hour) information. Historical costs should be collected for analysis, normalization, and use in future project cost estimates. Lessons learned that can help cost estimators with future cost estimates may be generic in nature or specific to a site, location, contract type, etc. They may apply to a particular scope of work or a cost estimating technique. There are many ways to communicate lessons learned. **The point is to document what has been learned from the experience and share it with others, as appropriate.**

Independent Cost Estimates and Cost Reviews

The following requirements are described in DOE O 413.3B:

Prior to CD-0, for Major System Projects, or for projects as designated by the CE, PM will conduct an Independent Cost Review (ICR).

Prior to CD-1, for projects with a TPC \geq \$100M, PM will develop an Independent Cost Estimate (ICE) and/or conduct an ICR, as they deem appropriate.

Prior to CD-2, for projects with a TPC \geq \$100M, PM will develop an ICE. The ICE will support validation of the Performance Baseline (PB).

Prior to CD-3, for projects with a TPC \geq \$100M, PM will develop an ICE.

In addition to the specific requirements placed on PM in DOE O 413.3B, a project may be well-served by having its own cost estimate completed at various points in the development and execution of the project, no matter the size of the project (for projects less than \$100M). Comparison to an ICE is a key element in Step 7 of the GAO Best Practices.

All ICRs and ICEs should be developed by individuals or organizations that are truly independent of the project. This may be accomplished by issuance of contracts or task orders by PM, through another DOE direct contract vehicle, or directly by other DOE organizations. However, it may not be generally appropriate for the project proponents (i.e., a DOE site office, a DOE program office, or a DOE contractor) to conduct, or to contract for, and direct an ICE or ICR development.

In general, the types of reviews that DOE normally recognizes (the types of reviews may be modified/combined by the size, technology and complexity of the project) are the following:

Documentation Review—this type of review is not normally accomplished as an ICR/ICE, nor does it fulfill the requirements as specified in DOE O 413.3B, since it only consists of an assessment of the documentation available to support the estimate. It is merely an inventory of existing documents to determine that the required support documentation exists and to identify any missing data. **This type of review can be beneficial for a project team facing an upcoming EIR or ICE, to ensure readiness to proceed with those activities.**

Reasonableness Review—**this equates to the ICR as required in DOE O 413.3B.** For this review, the ICR team reviews all available project documentation, receives briefings from the project team, holds discussions with the project team, completes sufficient analysis to assess the reasonableness of the project assumptions supporting the cost and schedule estimates, ascertains the validity of those assumptions, assesses the rationale for the methodology used, and checks the completeness of the estimate, including appropriate allowances for risks and uncertainties. The result is a report that details the findings and recommendations.

Parametric Estimating Approach—this approach, in addition to incorporating all of the activities needed for a Reasonableness Review, uses parametric techniques, factors, etc., to analyze project costs and schedules, and is usually accomplished at a summary WBS level. The parametric techniques (including CERs and factors) should be based on accepted historical cost/schedule analyses. At a minimum, these tools should be based on historic estimates from which models have been derived, and, where possible, from actual completed projects. An estimate with a minimum of 75 percent of the TPC based on parametric techniques is classified as a parametric estimate.

Sampling Approach—this review also begins with the activities needed for a Reasonableness Review, but it also requires the ICE team to identify the key cost drivers. A “cost driver” is a major estimate element whose sensitivity significantly impacts TPC. Detailed, independent estimates should be developed for these cost drivers. Such estimates should include vendor quotes for major equipment, and detailed estimates of other materials, labor, and subcontracts. For the balance of the project costs, the project team’s estimate may be used (if deemed reasonable), or, if appropriate, parametric techniques may be used for certain portions of the project costs. An estimate which provides a detailed cost for all cost drivers is classified as a Sampling Estimate.

Bottom-up Estimating Approach—this is the most detailed and extensive ICE effort. It begins with the activities needed for a Reasonableness Review. In addition, this approach requires a detailed bottom-up independent estimate for both cost and schedule. This will require quantity take-offs/development, vendor quotations, productivity analysis, use of historical information, and any other means available to do a thorough and complete estimate of at least 75 percent of the project's cost. It may not be possible to do a completely independent estimate on some portions of the project estimate, and for those portions – which should not exceed 25 percent of the total estimate – the project estimate may be used if it has passed the test of reasonableness. In all cases, the total cost (TEC and TPC) should be developed.

ICEs will often involve a combination of the approaches and techniques described above, due to the varying levels and quality of information available. **The accuracy of the ICE will be subjectively determined based on the weighted evaluation of the information available.**

A key element of any ICE is a comprehensive reconciliation between the ICE and the project team estimate. Such reconciliation identifies areas of significant difference between the estimates and attempts to explain those differences. This information provides a useful basis for subsequent estimate (cost range or baseline) approval or identification of necessary estimate revision and refinement.