Project Management Essential Library

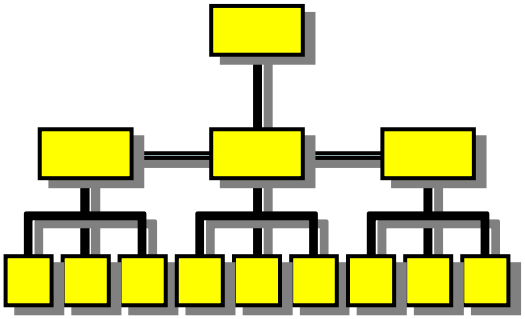
EFFECTIVE WORK BREAKDOWN STRUCTURES

MANAGEMENTCONCEPTS

WORK BREAKDOWN STRUCTURES

"A Work Breakdown Structure is a deliverable-oriented hierarchical decomposition of the work to be executed by the project team to accomplish the project objectives and create the required deliverables."[1]

A Work Breakdown Structure (WBS) is a fundamental project management technique for defining and organizing the total scope of a project, using a hierarchical tree structure. The first two levels of the WBS (the root node and Level 2) define a set of *planned outcomes* that collectively and exclusively represent 100% of the project scope. At each subsequent level, the children of a parent node collectively and exclusively represent 100% of the scope of their parent node.



A well-designed WBS describes planned outcomes instead of planned actions. Outcomes are the desired ends of the project, such as a product, result, or service, and can be predicted accurately. Actions, on the other hand, may be difficult to predict accurately. A well-designed WBS makes it easy to assign any project activity to one and only one terminal element of the WBS.

TYPES OF WORK BREAKDOWN STRUCTURES

Even though the term "Work Breakdown Structure" has been used as a label for all project scope hierarchical diagrams, there are, in practice, many types other than "deliverable" oriented structures.

[1] *A Guide to the Project Management Body of Knowledge*, (Newton Square, PA: Project Management Institute, 2004).

Verb-oriented WBS: a task-oriented WBS defines the deliverable of project work in terms of the actions that must be done to produce the deliverable. The first word in a given WBS element usually is a verb, such as, design, develop, optimize, transfer, test, etc.

Noun-oriented WBS: a deliverable-oriented WBS defines project work in terms of the components (physical or functional) that make up the deliverable. In this case, the first word in a given WBS element is a noun, such as, Module A, Subsystem A, Automobile Engine, Antenna, etc. Since the nouns are usually parts of a product, this WBS type is sometimes called a "Product Breakdown Structure (PBS). Deliverable-oriented WBS structures are the preferred type according to PMI's definition.

Time-phased WBS: a "time-phased" WBS is one that is used on very long projects. It breaks the project into major phases instead of tasks. In this type, a "rolling wave" approach is adopted and only the near-term phase is planned in detail.

Other WBS types may include organization-types, geographical-types, cost breakdown types, and profit-center types.

WBS DESIGN PRINCIPLES

The 100% Rule

One of the most important WBS design principles is called the 100% Rule. The *Practice Standard for Work Breakdown Structures (Second Edition)*, published by the Project Management Institute (PMI) defines the 100% Rule as follows:

> *The 100% Rule...states that the WBS includes 100% of the work defined by the project scope and captures ALL deliverables – internal, external, interim – in terms of the work to be completed, including project management. The 100% rule is one of the most important principles guiding the development, decomposition and evaluation of the WBS. The rule applies at all levels within the hierarchy: the sum of the work at the "child" level must equal 100% of the work represented by the "parent" and the WBS should not include any work that falls outside the actual scope of the project, that is, it cannot include more than 100% of the work… It is important to remember that the 100% rule also applies to the activity level. The work represented by the activities in each work package must add up to 100% of the work necessary to complete the work package.*

Planned Outcomes, Not Planned Actions

If the WBS designer attempts to capture any action-oriented details in the WBS, he/she will likely include either too many actions or too few actions. Too many actions will exceed 100% of the parent's scope and too few will fall short of 100% of the parent's scope. The best way to adhere to the 100% Rule is to define WBS elements in terms of outcomes or results. This also ensures that the WBS is not overly prescriptive of methods, allowing for greater ingenuity and creative thinking on the part of the project participants. For new product development projects, the most common technique to assure an *outcome-oriented* WBS is to use a product breakdown structure (PBS).

> The best way to adhere to the 100% Rule is to define WBS elements in terms of outcomes or results.

Feature-driven software projects may use a similar technique which is to employ a feature breakdown structure. When a project provides professional services, a common technique is to capture all planned deliverables to create a *deliverable-oriented* WBS. Work breakdown structures that subdivide work by project phases (e.g. Preliminary Design Phase, Critical Design Phase) must ensure that phases are clearly separated by a deliverable (e.g. an approved Preliminary Design Review document, or an approved Critical Design Review document).

Level 2 is the Most Important

Of all the levels on a WBS, Level-2 is often the most important because it determines how actual costs and schedule data are grouped for future project cost and schedule estimating. A project manager may find it useful to know how much it took to design (major work element) a product after it had been completed so that the data can be used for future analogous estimating. In other cases, the project manager may want to know how much a major part of the product actually cost after the project was completed. For this a PBS would be used. Level-2 is therefore used to capture “actuals” from a project for future estimating purposes.

The Four Elements in Each WBS Element

Each WBS element, when completed should contain the following four items:

1. The scope of work, including any “deliverables.”
2. The beginning and end dates for the scope of work.
3. The budget for the scope of work.
4. The name of the person responsible for the scope of work.

By using a WBS in this manner the project manager can approach a complex project and decompose it into manageable, assignable portions. There is minimal confusion among project members when this technique is used.

Mutually-exclusive Elements

In addition to the 100% Rule, it is important that there is no overlap in scope definition between two elements of a WBS. This ambiguity could result in duplicated work or miscommunications about responsibility and authority. Likewise, such overlap is likely to cause confusion regarding project cost accounting. If the WBS element names are ambiguous, a WBS dictionary can help clarify the distinctions between WBS elements

It is important that there is no overlap in scope definition between two elements of a WBS.

How Far Down?

The WBS is decomposed down to the work package level. A work package is the lowest level in the WBS, and is the point at which the cost and schedule for the work can be reliably estimated.[2]

A question to be answered in the design of any WBS is when to stop dividing work into smaller elements. If a WBS terminal elements are defined too broadly, it may not be possible to track project performance effectively. If a WBS terminal elements are too granular, it may be inefficient to keep track of so many terminal elements, especially if the planned work is in the distant future. A satisfactory tradeoff may be found in the concept of *progressive elaboration* which allows WBS details to be progressively refined before work begins on an element of work.

An effective limit of WBS granularity may be reached when it is no longer possible to define *planned outcomes*, and the only details remaining are

One form of progressive elaboration in large projects is called *rolling wave planning* which establishes a regular time schedule for progressive elaboration. In reality, an effective limit of WBS granularity may be reached when it is no longer possible to define *planned outcomes*, and the only details remaining are actions. Unless these actions can be defined to adhere to the 100% Rule, the WBS should not be further subdivided.

[2] PMBOK

The 40-Hour Rule of Decomposition

Another rule-of-thumb for determining how far down a WBS should be decomposed is called the "40 Hour Rule." Generally, when a project has been decomposed down to an element that has about 40 hours of allocated direct labor, there is no need to decompose further. The 40 Hour Rule is based on a 40-hour work week. Because of this, most WBS diagrams are not symmetrical. Some legs may go down to Level-4 while others may go down to Level-5.

The 4% Rule of Decomposition

Gary Heerkens suggests a 4% Rule for decomposing a WBS. With this rule a WBS is adequately decomposed when the lowest element is about 4% of the total project. [3] For a 26-week schedule, the lowest element should be about one week. For a $2.6M project, the lowest level should be about $104K.

WBS Identification Numbering

It is common for WBS elements to be numbered sequentially to reveal the hierarchical structure. For example *1.3.2 Rear Wheel* identifies this item as a Level 3 WBS element, since there are three numbers separated decimal point. A coding scheme also helps WBS elements to be recognized in any written context.

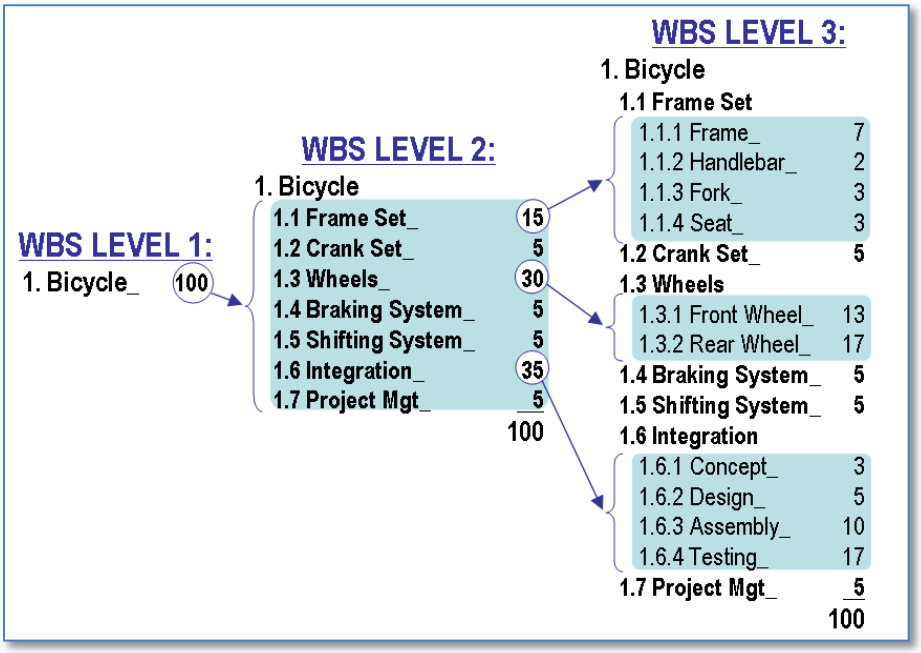


Figure 1 WBS Construction Example

The above WBS is from PMI's *Practice Standard for Work Breakdown Structures (2nd Edition)*. This image illustrates an objective method of employing the 100% Rule during WBS construction.

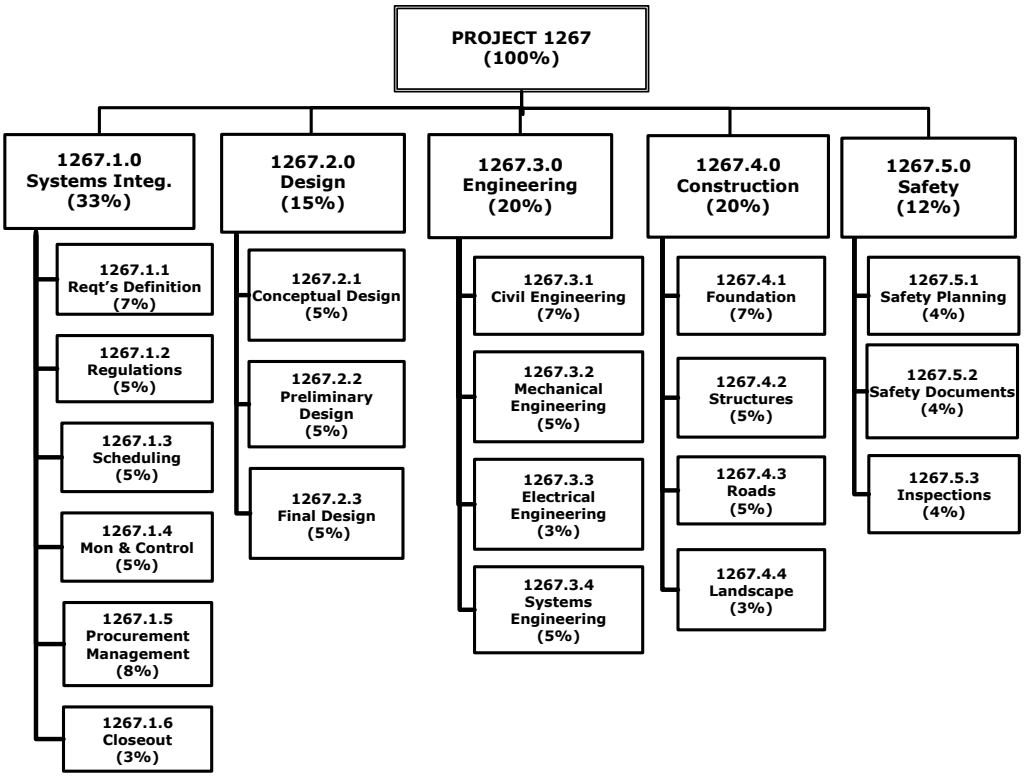
[3] Gary R. Heerkens, *Project Management* (New York, NY: McGraw-Hill Publishers, 2002) p. 103, 122.

Figure 1 shows a WBS construction technique that demonstrates the 100% Rule quantitatively. At the beginning of the design process, the project manager has assigned 100 points to the total scope of this project, which is designing and building a custom bicycle. At WBS Level 2, the 100 total points are subdivided into seven comprehensive elements. The number of points allocated to each is a judgment based on the relative effort involved; it is NOT an estimate of duration. The three largest elements of WBS Level 2 are further subdivided at Level 3, and so forth. The largest terminal elements at Level 3 represent only 17% of the total scope of work. These larger elements may be further subdivided using the *progressive elaboration* technique described above.

In this example, the WBS coding scheme includes a trailing "underscore" character ("_") to identify terminal elements. This is a useful coding scheme because planned project schedule activities (e.g. "Install inner tube and tire") will be assigned to terminal elements instead of parent elements.

It is recommended that WBS design be initiated with interactive software (e.g. a spreadsheet) that allows automatic rolling up of point values. Another recommended practice is to discuss the point estimations with project team members. This collaborative technique builds greater insight into scope definitions, underlying assumptions, and consensus regarding the level of granularity required to manage the project.

Another example of a Project WBS using the 100% Method is shown below.



COMMON PITFALLS AND MISCONCEPTIONS

A WBS is not an exhaustive list of work. It is instead a comprehensive classification of project scope.

A WBS is not a project plan or a project schedule and it is not a chronological listing. It is considered poor practice to construct a project schedule (e.g. using project management software) before designing a proper WBS. This would be similar to scheduling the activities of home construction before completing the house design. Without concentrating on planned outcomes, it is very difficult to follow the 100% Rule at all levels of the WBS hierarchy. It is not possible to recover from an improperly defined WBS without starting over, so it is worthwhile to finish the WBS design before starting a project plan or project schedule.

A WBS is not an organizational hierarchy. Some practitioners make the mistake of creating a WBS that shadows the organizational chart. While it is common for responsibility to be *assigned* to organizational elements, a WBS that shadows the organizational structure is not descriptive of the project scope and is not outcome-oriented.

Short-term memory capacity should not dictate the size and span of a WBS tree structure. Some reference material suggests that each WBS level be limited to 5-9 elements because that is a theoretical limit to short-term memory. It is far more important to construct a logical grouping of planned outcomes than to worry about the limits of short-term human memory.

WBS updates, other than progressive elaboration of details, require formal change control. This is another reason why a WBS should be outcome-oriented and not be prescriptive of methods. Methods can and do change frequently, but changes in planned outcomes require a higher degree of formality. If outcomes and actions are blended, change control may be too rigid for actions and too informal for outcomes.

WBS Checklist

- ❑ The top element of the WBS is the overall deliverable of the project, and all stakeholders agree with it.
- ❑ The first two levels of the WBS (the root node and Level 2) define a set of planned outcomes that collectively and exclusively represent 100% of the project scope.
- ❑ The WBS elements are defined in terms of outcomes or results. (Outcomes are the desired ends of the project, and can be predicted accurately).
- ❑ Each WBS element has an identification number assigned which identifies its relative position within the structure.

- ❑ The WBS encompasses everything that will ultimately comprise the project deliverable, and all deliverables in the project are included.
- ❑ Each WBS element contains the following four items:
    - The scope of work, including any "deliverables."
    - The beginning and end dates for the scope of work.
    - The budget for the scope of work.
    - The name of the person responsible for the scope of work.
- ❑ There is no overlap in scope definition between two elements of a WBS.
- ❑ The WBS is not a project plan or a project schedule, and it is not a chronological listing.
- ❑ In the judgment of all parties involved, the WBS has been decomposed and it is no longer possible to define planned outcomes--the only details remaining are actions.
- ❑ The WBS is not an exhaustive list of work. It is instead a comprehensive classification of project scope.
- ❑ The WBS is not an organizational hierarchy.
- ❑ In the judgment of all parties involved, the WBS is neither over-simplified or overly complex. It provides an adequate graphical or outline form for viewing the overall scope of the project.

Where to Get More Information

- Carl L. Pritchard. *Nuts and Bolts Series 1: How to Build a Work Breakdown Structure*. ISBN 1-890367-12-5
- Dennis P. Miller, *Visual Project Planning & Scheduling, Second Edition (2002)*. ISBN 0-9640630-2-6 (Note: This e-book is essential a facilator's guide for planning a project based on the WBS.)
- Gary R. Heerkens. *Project Management*. (New York, NY: McGraw-Hill Publishers, 2002). ISBN 0-07-137952-5.
- Gregory T. Haugan. *Effective Work Breakdown Structures (The Project Management Essential Library Series)*. ISBN 1-56726-135-3.
- Project Management Institute. *Project Management Institute Practice Standard for Work Breakdown Structures, Second Edition (2006)*. ISBN 1-933890-13-4 (Note: The Second Edition is an extensive re-write of the Practice Standard).
- Robert Wysocki. *Effective Project Management: Traditional, Adaptive, Extreme*. Indianapolis, IN: Wiley Publishing, 2003.

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1. WORK BREAKDOWN STRUCTURE HANDBOOK OVERVIEW

1.1 PURPOSE

DOE Order 413.3B, Program and Project Management for the Acquisition of Capital Assets, dated November 29, 2010, briefly reference the requirement for preparing a WBS in the context of planning and monitoring DOE projects. Furthermore, the Government Accountability Office (GAO) Cost Estimating and Assessment Guide states "Establishing a product-oriented WBS is a best practice because it allows a program to track cost and schedule by defined deliverables, such as a hardware or software component. This allows a program manager to more precisely identify which components are causing cost or schedule overruns and to more effectively mitigate the root cause of the overruns.[1]" This handbook presents suggested guidelines for effectively understanding, preparing, and presenting a product oriented WBS. It provides the consistent framework and guidance for DOE Federal Project Directors (FPD) to define their project WBS (PWBS) and is valuable guidance to DOE contractors in their application and extension of a contract WBS (CWBS) and subcontractor WBS (SWBS). This guidance is appropriate for all types of DOE projects regardless of acquisition phase (e.g., Initiation, Definition, Execution, and Transition / Closeout).

This handbook applies to all types of projects subject to DOE Order 413.3B. Some examples of project types in this handbook include the construction of buildings, tanks, silos, ponds, power transmission, process, scientific, and technical equipment; as well as the removal of facilities and systems through site remediation and Decontamination and Decommissioning (D&D) efforts. DOE project leadership teams are encouraged to further develop, modify, and expand the WBS constructs for their project type using a similar approach (product-oriented) when possible.

1.2 DEFINITION

A WBS is a product-oriented hierarchical structure that may be composed of products, material, equipment, engineering, services, data, support facilities, and related tasks that make up a project. It is a product-oriented grouping of project scope elements shown in graphical display to organize and subdivide the total work scope of a project. The WBS defines the product(s) to be developed and/or produced. It relates the elements of work to be accomplished to each other and to the overall project end product. In other words, the WBS is an organized method to breakdown a product into sub-products at lower levels of detail. It provides a consistent and visible framework for items and contracts within a project. This handbook offers uniformity in definition and consistency of approach for assembling a project WBS. The benefit of uniformity in work breakdown structures will be realized through improved communication and informed decision making throughout the acquisition process.

WBS's are developed at varying levels of detail. Generally, at a minimum, the number of levels employed should be sufficient to identify and measure work progress, assigned responsibility, and enable effective management and reporting to project oversight. The number of levels to which work is decomposed varies depending on the project's size and complexity, technical maturity, organizational constraints, and management's assessment of need. It is critical for WBS product elements identified as high-cost, high-risk, and/or high technical interest to be defined at lower levels of detail to provide sufficient visibility and enable effective management. A suitably structured WBS

[1] GAO Cost Estimating and Assessment Guide, GAO-09-3SP, March 2009, Chapter 8, page 65.

will also facilitate accurate and meaningful cost collection that is valuable in predicting performance in similar efforts and allow comparisons between like activities across the complex.

This handbook offers uniformity in definition and consistency of approach for developing all levels of the WBS. Generating and applying uniform structures improves communication between the Government, industry, and other stakeholders during the acquisition process. It also provides guidance to industry in extending the CWBS.

1.3 BENEFITS

The WBS serves as a coordinating medium, providing a basis for effective communication throughout the acquisition process. It is a common link, which unifies planning, scheduling, cost estimating, budgeting, contracting, configuration management, and performance reporting disciplines. Performance data (cost, schedule, and technical) are routinely generated for reporting purposes. The WBS is the organizing structure used to summarize data for successive levels of management and provide accurate information on projected, actual, and current status of the individual elements. When appropriately structured and used in conjunction with sound engineering principles, cost estimating, Earned Value Management System (EVMS), integrated scheduling, and risk management, the WBS allows for project status to be continuously visible to identify, coordinate, and implement changes necessary for desired results. The product-oriented WBS assists in several ways during the project phases to include:

- Segregates a project into its components, clarifying the relationship among the components, and clarifying the relationship of the tasks to be completed—to each other and to the end product.
- Facilitates effective planning and assignment of management and technical responsibilities.
- Provides a common basis and framework for the Integrated Master Plan (IMP) and the Integrated Master Schedule (IMS) facilitating consistency in understanding project cost and schedule performance and assigning to the appropriate project phase. Since the link between the requirements, WBS, the statement of work, IMS and the IMP provides insights into the relationship between cost, schedule and performance; all items can be tracked to the same product oriented WBS element.
- Aids status tracking and alignment of technical efforts, risks, resource allocations, expenditures, and cost/schedule/technical performance.
- Allows for program status to be continuously visible so that the FPD and contractor can identify, coordinate, and implement changes necessary to achieve desired results.
- Improves the organization and presentation of contractor Basis of Estimates (BOEs).
- Provides a common thread for Earned Value (EV) data metrics analysis as part of a contractor EVMS and the Resource Loaded Schedule (RLS), allowing consistency in understanding project cost and schedule performance. Product-oriented WBSs facilitate the use of discrete EV performance measurement techniques, as opposed to Level of Effort (LOE), by aligning tasks directly to delivered products.
- Allows DOE to capture cost across numerous projects by using a common product-oriented structure that facilitates the development of metrics and benchmarks.

2. WBS OVERVIEW

The WBS is defined, developed, and maintained throughout project phases based on a disciplined application of the systems engineering process. Linkage between the requirements specification, WBS, Statement of Work (SOW), Performance Measurement Baseline (PMB), and RLS provide specific insights into the relationship among scope, schedule, budget, and performance. This relationship allows all items to be tracked to the same WBS elements. The detailed technical objectives are defined and specified work tasks are assigned to each WBS element. Labor, material, and support required to attain project objectives are added incrementally. Common elements among the categories of projects in DOE may include (but are not limited to) Integration, Assembly, Test and Checkout; Support Equipment and Facilities; System Test and Evaluation; Project Administration/Project Management; and System Design and Engineering

There are three fundamental and interrelated WBS levels that break down the total project scope by level of responsibility and detail: the PWBS, the CWBS, and the SWBS. These three structures should follow the same product-oriented approach at varying levels of detail, and sum to the top hierarchy (total project scope).

2.1 PROJECT WBS

The WBS framework allows the project to be separated into logical component parts and making the relationship of the parts clear. It defines the project in terms of hierarchically related action-oriented elements. Each element provides logical summary points for assessing technical accomplishments and for measuring cost and schedule performance.[2] The PWBS encompasses an entire effort (total scope) which may consist of one or more projects or subprojects necessary to meet overall project objectives (see Figure 2-1 for a simplistic illustration where several projects are involved and each project is comprised of several interacting or interdependent discrete systems). Each system can be further broken down into a further set of interacting or interdependent discrete components. In the case of several subprojects under one project, each individual subproject has its own individual PWBS that links to the parent PWBS. The PWBS provides a framework for specifying project objectives and organizing scope. It defines the project in terms of hierarchically related, product-oriented elements and includes Government activities (i.e., Project Office Operations, Government Furnished Equipment (GFE), etc.). Each element provides logical summary levels for assessing technical accomplishments; supporting the required event-based technical reviews, and for measuring cost and schedule performance.

[2] Environmental Cost Element Structure, developed by the Environmental Cost Engineering Committee (EC2), April 2002, page 2.

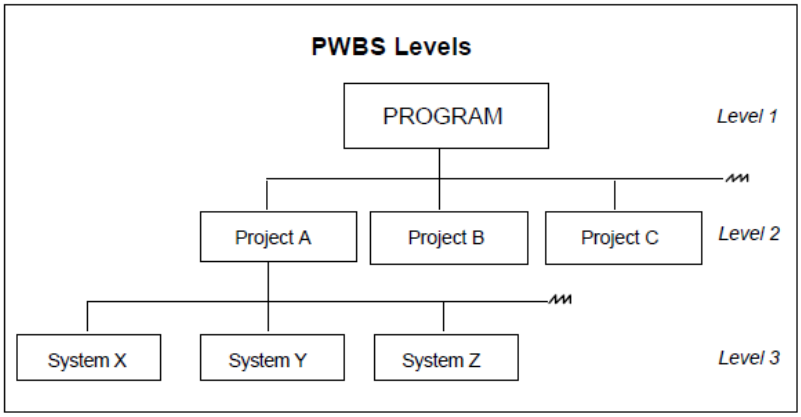


Figure 2-1. PWBS example involving several projects/systems

The PWBS notionally consists of at least three levels with associated definitions provided via a WBS dictionary (Section 3.6). The dictionary contains uniform terminology, definitions, and placement in the product-oriented hierarchical structure.

2.2 CONTRACT WBS

A CWBS is the Government approved structure for the contract scope reporting level and any discretionary extensions to lower levels for reporting or other purposes. It includes all product elements (hardware, software, data, or services) for which the contractor is responsible. The CWBS includes the contractor's discretionary extension to lower levels, in accordance with Government direction and the Contract SOW. This comprehensive CWBS forms the framework for the development of the contractor's cost and schedule performance baseline, and the contractor's management control system. The contractor is responsible for expanding the PWBS to create the CWBS and for developing a CWBS dictionary. CWBS elements provide a structure for planning, budgeting, collecting costs and assessing project performance, thus facilitating compliance with the EVMS requirement as required. See Figure 2-2 for an example of a PWBS with a CWBS beneath one of the project elements (systems). Variations of this simplistic example can be tailored to the different forms of contracting within DOE within any given level of the WBS. For example, DOE may have a general contractor or a Managing and Operating (M&O) contractor at the project level.

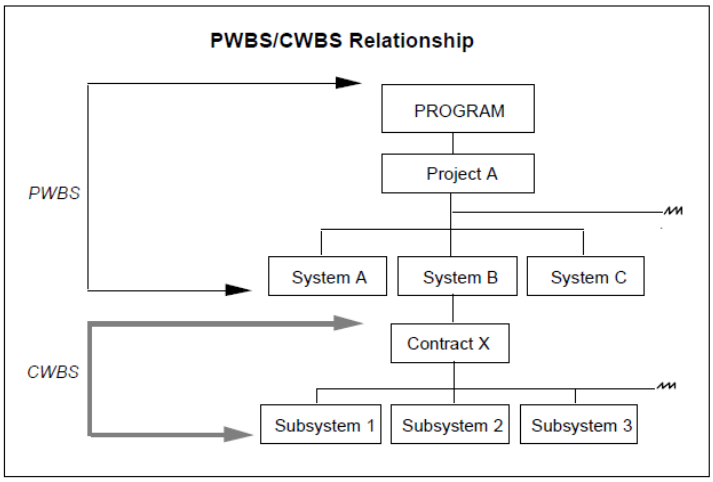
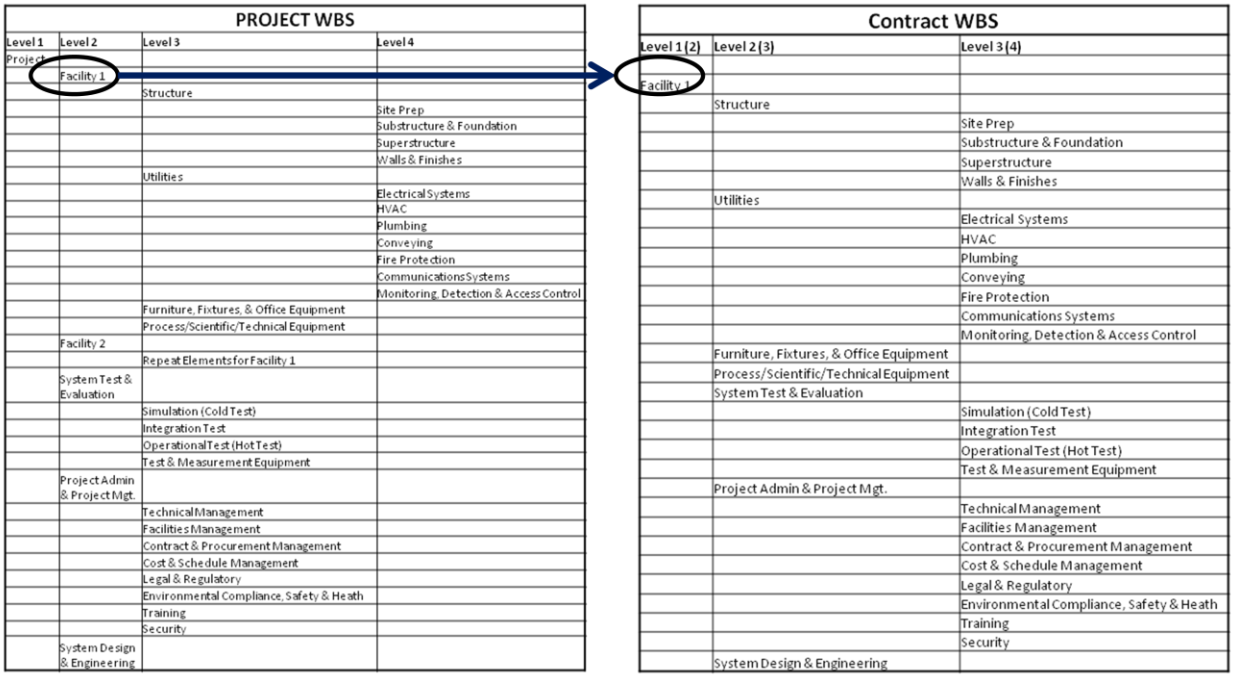


Figure 2-2. PWBS and CWBS Relationship

The CWBS should be aligned to the PWBS. Contracts for specific WBS elements that are in the PWBS will become Level 1 CWBS elements with all applicable Level 2 Common WBS elements included, resulting in the CWBS. The following Figure 2-3 depicts the relationship of the PWBS and CWBS at level 2.

The data from the various project contracts supports the FPD in evaluating contractor performance, preparing budgets, and preparing life-cycle cost estimates for future contracts.



PROJECT WBS			
Level 1	Level 2	Level 3	Level 4
Project			
	Facility 1		
		Structure	
			Site Prep
			Substructure & Foundation
			Superstructure
			Walls & Finishes
		Utilities	
			Electrical Systems
			HVAC
			Plumbing
			Conveying
			Fire Protection
			Communications Systems
			Monitoring, Detection & Access Control
		Furniture, Fixtures, & Office Equipment	
		Process/Scientific/Technical Equipment	
	Facility 2		
		Repeat Elements for Facility 1	
	System Test & Evaluation		
		Simulation (Cold Test)	
		Integration Test	
		Operational Test (Hot Test)	
		Test & Measurement Equipment	
	Project Admin & Project Mgt.		
		Technical Management	
		Facilities Management	
		Contract & Procurement Management	
		Cost & Schedule Management	
		Legal & Regulatory	
		Environmental Compliance, Safety & Heath	
		Training	
		Security	
	System Design & Engineering		

Contract WBS		
Level 1 (2)	Level 2 (3)	Level 3 (4)
Facility 1		
	Structure	
		Site Prep
		Substructure & Foundation
		Superstructure
		Walls & Finishes
	Utilities	
		Electrical Systems
		HVAC
		Plumbing
		Conveying
		Fire Protection
		Communications Systems
		Monitoring, Detection & Access Control
	Furniture, Fixtures, & Office Equipment	
	Process/Scientific/Technical Equipment	
	System Test & Evaluation	
		Simulation (Cold Test)
		Integration Test
		Operational Test (Hot Test)
		Test & Measurement Equipment
	Project Admin & Project Mgt.	
		Technical Management
		Facilities Management
		Contract & Procurement Management
		Cost & Schedule Management
		Legal & Regulatory
		Environmental Compliance, Safety & Heath
		Training
		Security
	System Design & Engineering	

Figure 2-3. PWBS and CWBS Relationship

2.3 SUBCONTRACT WBS

Prime contractors should require significant subcontractors to use a WBS to fulfill contractual EV reporting requirements (References: DOE O 413.3B, Appendix C, Earned Value Management System; and DOE G 413.3-10A, *Earned Value Management System*). The prime or associate contractor is responsible for incorporating WBS requirements into its subcontract. Figure 2-4 below provides an example of a CWBS and its relationship to the Subcontract WBS (SWBS). This relationship show how the prime contractor may further break down the CWBS to manage subcontracted work. It is the contractor's decision to determine how this will be accomplished and should be documented in the contractor and subcontractor plans. In the figure below, a subcontractor is awarded a contract by a prime contractor, and the SWBS is an extension of the CWBS maintained by the prime contractor. Replacing the words "Project" and "Contract" from the Figure 2-3 above with "Contract" and "Subcontractor" respectively, the flow down to the WBS requirement can be shown in the Figure 2-4 below. In this case the Project WBS could be both the Project and the Contract WBS.

Contract WBS		
Level 1 (2)	Level 2 (3)	Level 3 (4)
Facility 1		
	Structure	
		Site Prep
		Substructure & Foundation
		Superstructure
		Walls & Finishes
	Utilities	
		Electrical Systems
		HVAC
		Plumbing
		Conveying
		Fire Protection
		Communications Systems
		Monitoring, Detection & Access Control
	Furniture, Fixtures, & Office Equipment	
	Process/Scientific/Technical Equipment	
	System Test & Evaluation	
		Simulation (Cold Test)
		Integration Test
		Operational Test (Hot Test)
		Test & Measurement Equipment
	Project Admin & Project Mgt.	
		Technical Management
		Facilities Management
		Contract & Procurement Management
		Cost & Schedule Management
		Legal & Regulatory
		Environmental Compliance, Safety & Heath
		Training
		Security
	System Design & Engineering	

Subcontract WBS		
Level 1 (3)	Level 2 (4)	Level 3 (4)
Site Prep		
	Grading & Landscaping	
	Roads, Parking Lots and Walkways	
	Site Utilities	
	Support Equipment & Facilities	
		Support Equipment
		Support Facilities
	System Test & Evaluation	
	Project Admin & Project Mgt.	
		Technical Management
		Facilities Management
		Contract & Procurement Management
		Cost & Schedule Management
		Legal & Regulatory
		Environmental Compliance, Safety & Heath
		Training
		Security
	System Design & Engineering	

Figure 2-4. CWBS and SWBS Relationship

3. WBS DEVELOPMENT AND DOCUMENTATION

The WBS may span one or more of the categories, elements, or systems that define the project at the highest level in the WBS. The DOE project management office may define the WBS product-oriented modules and elements that best describe their particular projects based on the appendices found at the back of this handbook. The structure may be extended to lower levels to include subsystems or components to link subsystems or components to the parent system. However, a WBS should not be decomposed to piece parts or attempt to display low level purchased items normally included in a vendor Bill of Material (BOM).

The WBS should accurately and completely represent the system that is being developed and/or procured. The WBS should include only those elements that are part of the logical decomposition of the system. The WBS is intended to structurally illustrate a clear understanding of the technical objectives and the end item(s), end state, or end product(s) of the work to be performed.

The project plan (scope, schedule, and budget) is usually defined in the Project Execution Plan (PEP). The PEP should include guidance on development of a product-oriented WBS. Ultimately, the WBS is approved through the Critical Decision (CD) Process[3] as it evolves. The WBS is integral to cost and schedule reporting required by implementation of a contractor's EVMS[4], and is an integral tool for uniform data collection, analysis and management.

The primary challenge is to develop a WBS that defines the logical relationship between all project elements without constraining the contractor's ability to effectively execute the project. A secondary challenge is to balance the project definition aspects of the WBS relative to formal reporting requirements.

3.1 PREPARING A PROJECT WBS

Early in the Definition phase, systems engineering efforts transform the required capability outlined in the Initiation phase to top level alternative product solutions. For example, suppose the capability required is to "safeguard highly enriched uranium (HEU)." The objective is clear and can be met through numerous capabilities. Systems engineers perform tradeoffs, which ultimately define the preliminary system level functions. In this case, the systems that will "safeguard HEU" must have storage capability, address the proper level of physical security, and protect the environment from accidental release. The Project WBS is not formed around these functional requirements, but is developed based on the products which are expected to satisfy these requirements.

3.2 SELECTING WBS ELEMENTS

The WBS provides a framework for specifying the technical objectives of the project by defining the project in terms of hierarchically related, product-oriented elements. Each element of the WBS provides logical summary points for assessing technical accomplishments and for measuring cost and schedule performance accomplished in attaining the specified technical objectives. A properly structured WBS will readily allow complete aggregation of cost, schedule, and performance data

[3] Appendix A.4, DOE Order 413.3B Program and Project Management for the Acquisition of Capital Assets
[4] Section 2.f.1, DOE G 413.3-10A, Earned Value Management System (EVMS)

from lower elements up to the project level. Lower level (i.e., "children") elements, when aggregated together should represent the higher level (i.e., "parent") elements. Users of this handbook should always apply the 100% rule[5], which states the next level of decomposition of a WBS element (child level) must represent 100% of the work applicable to the next higher level (parent). If an "other" category is utilized to capture several small constituent elements for completeness, every effort should be made to ensure it represents the least effort at that **element level** and is less than 10% of the total work value (labor and material) for that **element level**.

DOE Projects can be described using various combinations of WBS modules tailored to their complexity and technologies. The appendices found in this handbook contain standard WBS structures for typical DOE projects and should be used as appropriate.

3.3 USE OF COMMON ELEMENTS

The following are common WBS elements (defined in Appendix L) that can be applied to various types of projects:

Integration, Assembly, Test & Checkout
Support Equipment and Facilities
System Test and Evaluation
Project Administration/Project Management
System Design and Engineering
Operations and Support

In order to support uniform cost estimating and data comparisons among DOE projects, there is an interest in establishing this set of common elements as a standard or commonly accepted WBS building module similar to the Department of Defense's MIL-STD-881C[6]. Careful consideration should precede any additions to, or alterations of, this list of common elements and the general definition of scope for them (see Appendix L). Managers should be vigilant during execution to ensure that multiple levels of Common Elements do not cause the overall cost of management, or other cross-cutting costs, to increase disproportionately.

3.4 BUILDING BLOCK APPROACH

Many projects will use a combination of the structures listed in the appendices of this document (the list is not all inclusive and could be further expanded/modified by the DOE projects). These structures may be used as building blocks of WBS development, and should be logically assembled into a comprehensive project WBS. Depending on the project, any given building block may be at a higher, lower, or equal level to another given building block. The resulting hierarchy of building blocks will typically require the insertion of "parent" level WBS elements at various levels in order to logically assemble the required building blocks. WBS development is typically an iterative process. It is recommended that a block diagram first be assembled in order visualize the modules required to logically complete the contract scope needed by the PM to effectively manage contract execution and reporting.

[5] GAO Cost Estimating and Assessment Guide, GAO-09-3SP, March 2009, Chapter 8, page 65.
[6] MIL-STD-881C, Department of Defense Standard Practice, Work Breakdown Structures for Defense Materiel Items, 3 October 2011; Section 1.5.4 Common Elements.

Figure 3-1 provides a depiction of the use of WBS Handbook appendices as building blocks for a project level WBS. **Note** - the use of Common Elements to track cost, schedule, and performance can occur at varying levels within a single WBS.

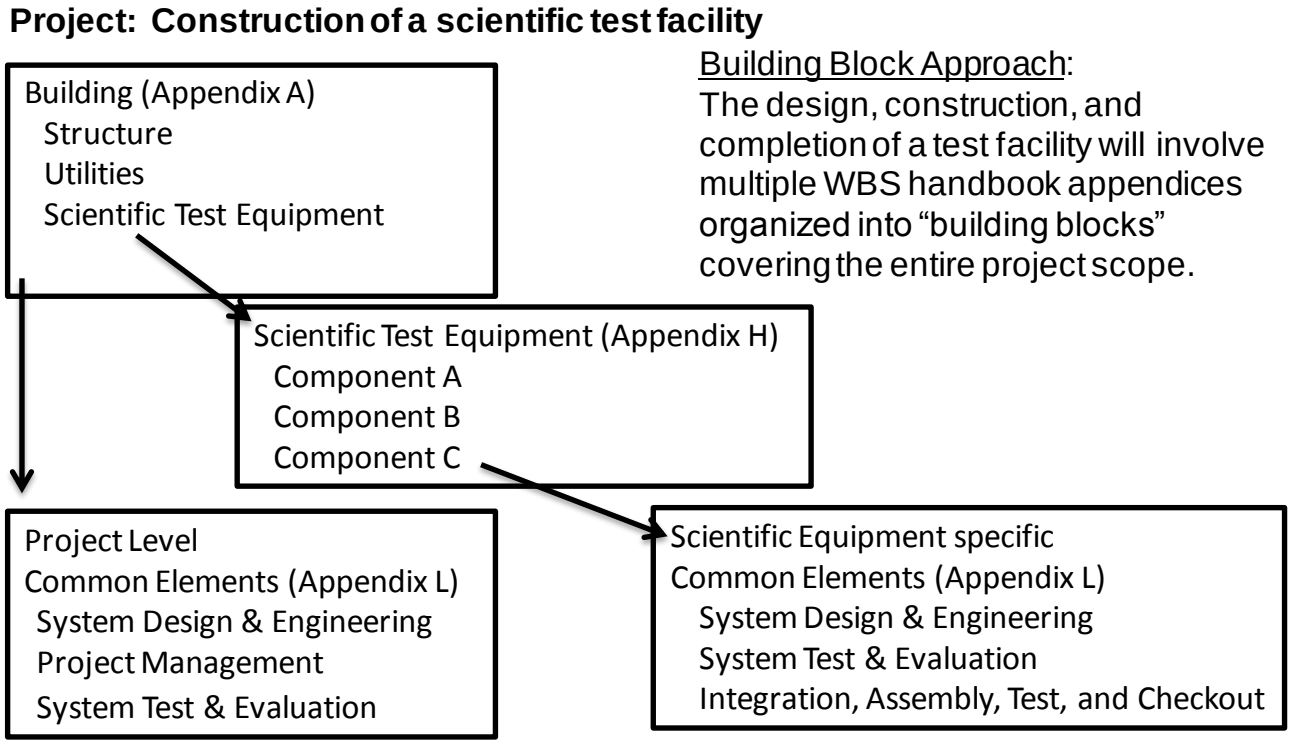


Figure 3-1. Example of WBS Building Block Approach

3.5 DETERMINING APPROPRIATE WBS LEVELS

A PWBS should define the logical relationships among all WBS elements to an appropriate level of indenture that does not constrain the Project Manager's or the contractor's ability to define or manage the project and resources. In other words, the CWBS should be tailored to fit the contractor's scope of work. If the Government considers some project elements to be high risk and require greater visibility, the project WBS must be taken to a lower level of detail. The CWBS should then be extended to lower levels based on the way the contactor plans to manage the work. It includes all the elements for which the contractor is responsible (facilities, hardware, software, data, or services). A secondary goal to consider when defining the details of a WBS is to use a systematic and standardized method for gathering cost data across all projects. Having actual historical data to support project management and cost estimates for similar DOE projects is a valuable resource. As a result, the PWBS details should mirror the appendices found in this handbook and conform to a product-oriented relational tree.

3.6 WBS DICTIONARY

A WBS dictionary defines the scope contained within each PWBS and CWBS element. At a minimum, it must define scope in detail to the control account level in terms of content of work to be performed. The WBS dictionary should include a description of the discrete work scope for the

element within the context of its parent element work scope forming an integrated whole. It provides a list of all elements included at a given level and notes elements that are important for the parent element functional capability, but not included at that level. The dictionary describes the element deliverables and scope that will comprise the element resources and cost. If there are important or unique aspects of the element to particular phases of the project, these should be referenced. It may also provide a link to detailed technical definition documents. The WBS dictionary should be updated as required based on contract changes and should reflect the current scope of each of the elements throughout the project's life. All projects should also have a current WBS index, providing a listing of the hierarchical relationship of elements throughout the project. The following are examples of good and poor definitions:

Good Definition Example

Tank/Silo Vessel The Tank/Silo vessel is the main Tank/Silo container. This includes the metal, plastic, concrete or wood structure of the container, and shielding and insulation integrated into the container structure. It includes the combination of labor that results in the design, development, construction, and/or operation of the Tank/Silo Vessel. This includes any Professional, Engineering, and Scientific Labor (e.g., engineers, analysts, programmers, scientists, and architects), Craft/Trades Labor (boilermakers, pipefitters, sheet metal workers, insulators, electricians, welders, etc.), General Labor, and Management and Administrative Labor. This does not include support structure for the tank/silo superstructure, any piping or conveying systems for loading and unloading equipment, or insulation and shielding not integrated into the container structure (access and finishes).

Poor Definition Example

Tank/Silo Vessel This element includes the tank/silo vessel.

3.7 ADDITIONAL CONSIDERATIONS

System Test and Evaluation (ST&E) is addressed as a common element in Appendix L of this handbook, rather than a discrete sub-element within the modules detailed in the other appendices. This allows flexibility to insert the ST&E element at appropriate levels of the WBS, as specified by the requiring activity. For example, a need may exist to uniquely track System Test efforts separate from operational readiness (hot and cold) evaluation activities. As a result, the WBS may require separating these three sub-elements of System Test and Evaluation. To the extent possible, the definition for common elements should be identical across the WBS elements in which they appear, facilitating aggregation and comparison of these costs. One should include software related scope

with applicable equipment as software developed to reside on specific equipment must be identified as a subset of that equipment.

3.8 COMMON MISTAKES IN WBS DEVELOPMENT

Use of elements that are not products. An accelerator system is clearly a product, as are buildings, ponds, and towers. On the other hand, items such as requirements analysis, drawings, surveillance, steel rebar stock, and direct costs, are (normally) not considered final end products. Requirements analysis is an engineering functional effort; drawings are deliverables associated with low levels of the WBS; surveillance is a project phase; steel rebar stock is a material resource; and direct cost is an accounting classification. Thus, none of these elements are appropriate WBS elements associated with capital asset projects.

Numerous DOE projects focus on clean-up activities (site remediation) where the true end product is more of an end state. Appendix K provides as example of a WBS that can be used in support of these types of projects. **Note** - there is a common element structure to capture project level activities such as design engineering, requirements analysis, etc. that is not easily allocable to one specific lower level WBS element.

Using project acquisition phases. Phases of acquisition (e.g., Initiation, Definition, and Execution) and funding sources (e.g., Project Engineering and Design (PED), Construction, Other Project Costs (OPC), and Total Estimated Cost (TEC) are inappropriate WBS elements.

Use of cost classifications. Recurring, nonrecurring, direct, indirect, ODCs, material, labor; OPC, TEC, etc are all cost classifications or budgets and are not products to be used as WBS elements. Nonrecurring and recurring classifications are elements of cost (e.g., non-recurring engineering) rather than product-oriented elements. They are estimated separately to keep one-time nonrecurring costs from distorting the costs for recurring production units.

Use of the project organization/functions to establish WBS elements. The WBS structure should be planned such that Control Accounts are segregations of work scope for which a single Control Account Manager is responsible. The control account is the point where the WBS tasks and OBS responsibility intersect. It is defined as the point where a single functional organization or integrated product team has responsibility for work defined to a single WBS element. The WBS should not reflect specific functional managers, specialties, or activities that may be needed across multiple WBS elements. The key objective here is accountability for products.

Do not include cost saving efforts, such as Six Sigma or Performance Excellence initiatives, warranty, etc. as part of the WBS. These efforts should be included in the cost of the item they contribute to, not captured separately. Do not include taxes, depreciation, or other overheads. These items are indirect costs that should be allocated to the product elements through the proper application of overhead rates.

Do not treat meetings, travel, computer support, etc. as separate WBS elements. These activities are part of the WBS elements with which they are associated. Do not include rework, retesting and refurbishing of existing scope as separate WBS elements. They should be treated as part of the original WBS element.

4. WBS EVOLUTION

Throughout every project, system engineering should lead the evolution of a WBS. This function includes developing system specifications, functional specifications, or a set of configuration items through requirements analysis, functional analysis and allocation, synthesis and systems analysis, and controls. The important factor is satisfying total project cost, schedule, and performance requirements at an acceptable level of risk. The PWBS should guide development early in the project's phase. It will evolve through iterative analysis of the project objective, assessments, functional design criteria, project scope, technical performance requirements, and other technical documentation. The documentation should describe the entire plan to design, build/implement, and support the system, facility, and/or site throughout its life cycle.

Consistent with the project in general, the PWBS is determined in the planning stages and flowed to the contractor via the CWBS. The PWBS is developed and maintained based on the systems engineering efforts throughout the project's life cycle. After the PWBS has been approved (through the DOE Critical Decision Process in DOE Order 413.3B), it should be extended to the contractor via the CWBS and SWBS, as applicable, to better define the complete project scope. The integration of the PWBS, CWBS, and SWBS form a complete WBS, which will be used throughout the life of the project. Figure 4-1 provides a depiction of the WBS evolution throughout the project acquisition process. Project WBSs that involve site remediation, and decommissioning, and demolition of existing facilities will also evolve as the project matures, but are not included in the following figure.

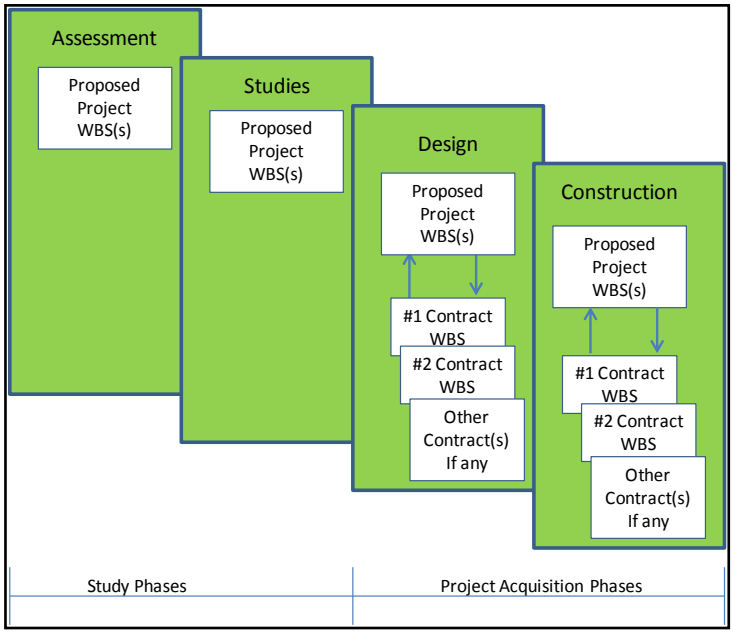


Figure 4-1. WBS Evolution throughout Project Acquisition Process

Figure 4-2 provides an illustration of the Acquisition Management System for those projects subject to DOE O413.3B requirements.

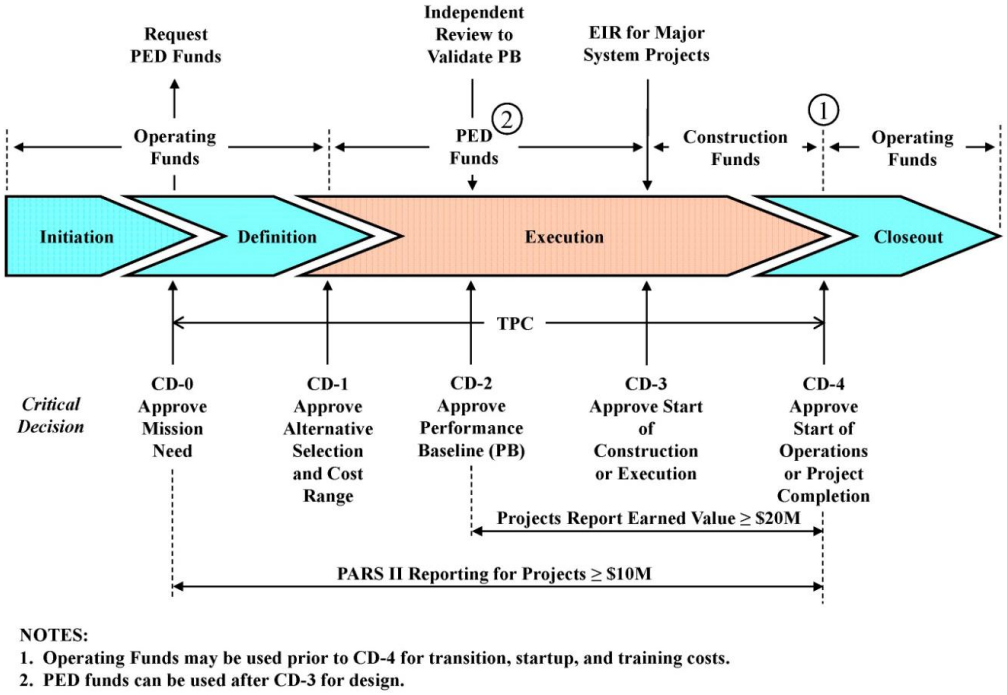


Figure 4-2: The DOE Acquisition Management System for Capital Assets

4.1 PROJECT INITIATION PHASE

During the Initiation phase, the project is mainly a concept and therefore the project WBS is in an early stage of development. The result of the mission need statement provides the basis for the initial PWBS.

4.2 DEFINITION PHASE

During the Definition phase the project is broken into component parts and a detailed PWBS is developed. Concept alternatives are analyzed to arrive at a recommended alternative. The recommended alternative is then further defined to generate rough order of magnitude cost and schedule estimates. The Project WBS is refined during this phase in support of these activities.

When the Definition phase is initiated, detailed planning is accomplished which further defines the required capability. Through this process, the systems engineering efforts will generate a recommended alternative that provides the essential functions and capability at the optimum life-cycle cost, consistent with required performance, scope, schedule, and cost. For example, in Figure 4-3, the functional requirements are assigned under a project, meeting the capability requirement of "Safeguard HEU".

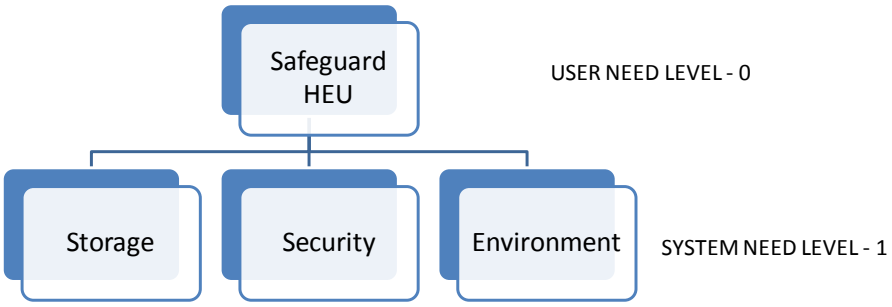


Figure 4-3. Functional Requirements in the Concept Refinement Phase

The Definition phase should describe the system and the configuration items that make up the system. Once the system concept is determined, then major subsystems and configuration items can be identified and lower level functions defined, so that lower level system elements can be created. In this example, using a cost effectiveness tradeoff, the process determined that a new facility can meet the required capability. The new facility is functionally able to store, secure, and protects the Highly Enriched Uranium from accidental release. The relationship of the functions shown in the previous example can now be translated into products that will meet the capability requirement. It is at this time that the preliminary Project WBS can be defined.

Generically, the PWBS defines the products(s) to be designed, developed, and/or delivered. Figure 4-4 shows the hierarchical relationship of the Facility Construction Project to the Structure, Utilities, and Equipment elements, and to other project elements.

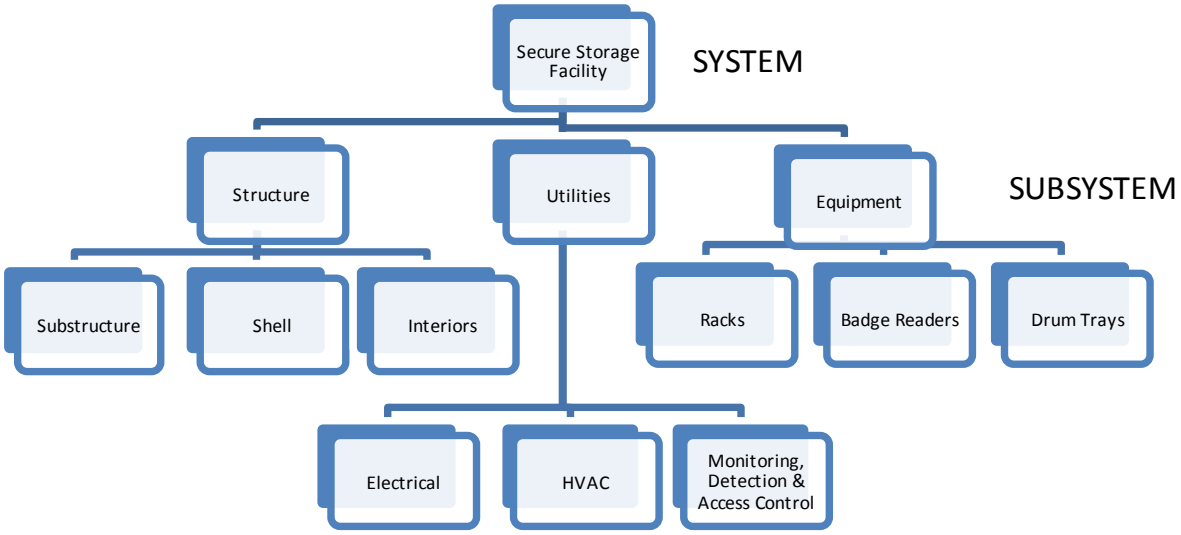


Figure 4-4. Identification of Configuration Items

4.3 EXECUTION PHASE

The WBS is further defined in the Execution phase, where preliminary, intermediate, and final designs are developed, the performance baseline is established, and the acquisition executive provides approval for start of construction. The CWBS provides lower level definition of the PWBS to better define the complete contract scope. The CWBS may be extended further by the subcontractor to support management control and reporting.

4.4 CLOSEOUT PHASE

The CWBS from the execution phase is maintained current throughout project execution and closure. The WBS dictionary definitions contained in the appendices distinguish any content differences between phases for a given WBS element. When major modifications occur, the CWBS can be updated to reflect the modified project/contract. The same product-oriented structure used throughout these phases may also be applied to project operations.

5. CONSIDERATIONS FOR OTHER ACQUISITION ACTIVITIES AND DISCIPLINES

This section discusses in general how a WBS relates to specific acquisition activities and disciplines.

5.1 CONTRACTING

Contract Solicitation and Proposal
The WBS used for a solicitation is structured by selecting appropriate elements from the approved Project WBS. The Contract Line Item Number (CLIN), configuration items, contract SOW tasks, contract specifications, and contractor responses will be expressed in terms of the WBS to enhance its effectiveness in satisfying the objectives of the particular acquisition. The relationship of the contract SOW to the CWBS elements and the CLINs should be clearly traceable. However, there may not always be a one-to-one relationship, nor is it required.

Specifications and Drawings
The specifications and drawings resulting from the progressive steps of the systems engineering process provide the basis for the PWBS, the CWBS, and its extensions.

Contractor Management Control System
The Contract WBS should serve as the framework for the contractor's management control system. That system should provide auditable and traceable summaries of internal data generated by its performance measurement procedures.

Life-Cycle Cost
Life-cycle cost (LCC) is the total cost for the design, construction, execution, and disposal. LCC commences at the project initiation and ends with decommissioning and disposition.

Procurement
The following areas should relate to elements of the Project WBS: specifications, structure of SOWs, Contract WBS, CLIN structure, Contract Performance Reports (e.g. Format 1), RLS, configuration items, technical and management reports, and Government-furnished equipment.

Reporting
All project status reporting requirements should be consistent with the Project WBS.

Contract Statement of Work (SOW)
The CWBS structure provides a framework for defining the project technical objectives. Together with the contract SOW, the CWBS aids in establishing an indentured data listing (specification tree), defining configuration items, and planning support tasks. The SOW is the document that describes, in clear and understandable terms, what products are to be delivered or what services are to be performed by the contractor. Preparation of an effective SOW requires a thorough understanding of the products and services needed to satisfy a particular requirement. An explicitly written SOW or Performance Work Statement (PWS) facilitates effective contractor evaluation. Upon contract award, if the SOW is absorbed into the CWBS and Performance Management Baseline (PMB), and if the associated tasks and schedule are absorbed into the RLS, the RLS and the EV data metrics component of the contractors' EVMS become better indicators of contractor performance.

The CWBS must address all requirements of the contractor SOW. It also provides a logical arrangement of SOW elements, serving as a convenient checklist to ensure the contractor addresses all necessary project elements and meets specific contract reporting needs.

Request for Proposal
When preparing a Preliminary CWBS, the FPD should select the CWBS elements that apply to the contract and include the CWBS in the request for proposal (RFP). This is the first time for open dialogue between the Government and potential contractors. Innovative ideas or promising alternative solutions should be considered for inclusion in the RFP. The RFP will include a Contract WBS and the initial WBS dictionary. The RFP should instruct potential contractors to extend the selected Contract WBS elements to define the complete contract scope, consistent with the contractor's proposed approach for managing the project.

RFP Solicitation Requirements. CLINs, configuration items, contract work statement tasks, contract specifications, and contractor responses should relate to the CWBS to enhance its effectiveness in fully describing acquisition objectives. It is important to coordinate the development of the Project WBS with the development of the SOW to ensure consistency in document structure. The extended CWBS will form a complete Project WBS to provide a consistent framework throughout the acquisition cycle.

Contractors are expected to extend the Contract WBS to the appropriate lower level that satisfies critical visibility requirements and does not overburden the management control system. A preliminary CWBS should be included in the RFP, and the contractor should submit its proposed CWBS with the proposal. The proposal should be generally based on the CWBS provided in the RFP, although contractors should be encouraged to suggest changes needed to meet essential RFP requirements or to enhance the effectiveness of the CWBS in satisfying project objectives.

Integrated Cost, Schedule, Technical Performance and Risk Management

Planning tasks by WBS elements serves as the basis for mapping the technical baseline, for estimating and scheduling resource requirements, and mitigating risks. By breaking the total product into successively smaller entities, FPDs can ensure all required products are identified in terms of cost, schedule, and performance goals in order to reduce risk. Time phasing performance budgets, assigning them to work segments, and identifying responsible units produces a plan against which actual performance can be measured. Corrective action can be taken to resolve deviations from the plan. This integrated approach to work planning also simplifies identifying the potential cost and schedule impacts of proposed technical changes.

5.2 EARNED VALUE MANAGEMENT SYSTEM

Cost performance measurement involves routine comparison of actual costs with time-phased budgets, analysis of performance variances, and follow-up corrective action. When planned tasks are captured in a WBS element structure and time-phased as they are expected to be accomplished, the budgets associated with those tasks become the project performance measurement baseline, which will be measured by the EVMS. An EVMS is a key integration tool that supports more effective

project management and is reviewed by DOE as part of the ongoing management and oversight of capital asset projects.

EV data metrics are reported using a Contract Performance Report (CPR) consistent with the Department of Defense (DOD) CPR Format 1 to the Project Assessment and Reporting System II (PARS II) system in accordance with DOE Order 413.3B. These provide contract cost and schedule performance data that can be used to identify problems early in the contract and forecast future contract performance. These reports are the primary communication between the contractor and the project director on cost and schedule trends to date, and to permit assessment of their effect on future performance. These reports consist of the following: WBS, Organizational Categories, Baseline Changes, and Explanation and Problem Analyses. The CPR Format 1 provides data to measure cost and schedule performance by product-oriented Contract WBS elements, for the hardware, software, data, and services the Government is buying.

The RLS is a time-phased schedule that serves as a tool for time phasing work and assessing technical performance. Schedule activities in the RLS are traceable to the CWBS elements used in a contractor EVMS, allowing commonality for integrated project assessment of cost, schedule, technical performance, and associated risks.

Contractor's Organizational Structure

The CWBS should not be unnecessarily influenced by a contractor's project organization structure. The contractor can organize its CWBS according to corporate standards and still effectively use a valid, product-oriented WBS. The National Defense Industrial Association (NDIA) Program Management Systems Committee (PMSC) EVMS Intent Guide[7] provides insight into the American National Standards Institute / Electronic Industries Alliance-748B (ANSI) Standard for EVMS. This Intent Guide further expands the 32 ANSI guidelines with additional insight, attributes, and objective evidence outputs for which contractor business processes should comply. ANSI Guidelines 1 – 5 address contractor organization, and are applicable to developing the contract WBS. Specifically, Guideline 1 addresses the WBS and Guideline 2 addresses the Organizational Breakdown Structure (OBS). For these ANSI Guidelines, the NDIA PMSC EVMS Intent Guide states the following:

Guideline 1: "A WBS is a direct representation of the work scope in the project, documenting the hierarchy and description of the tasks to be performed and their relationship to the product deliverables. The WBS breaks down all authorized work scope into appropriate elements for planning, budgeting, scheduling, cost accounting, work authorization, measuring progress, and management control. The WBS must be extended to the level necessary for management action and control based on the complexity of the work."

Guideline 2: "Assign organizational responsibility for the project work. An OBS is used to facilitate the assignment of responsibility, accountability, and authority for all tasks to be performed. An OBS is a direct representation of the organizational hierarchy and provides a description of the organizations established to provide resources as well as to plan and perform the work tasks. The OBS identifies the organization responsible for each segment of work, including subcontracted and intra-organizational effort. The assignment of lower-level work segments to responsible managers should provide key control points for management purposes. Each Control Point is called a Control

[7] NDIA PMSC, *Earned Value Management Systems Intent Guide*, (Arlington, VA: National Defense Industrial Association, May 2011).

Account (CA). When effort is subcontracted, the applicable subcontractor is identified and related to the appropriate WBS element(s) and/or organization charged with acquiring the subcontracted item.

The point where the WBS tasks and OBS responsibility intersect forms the basis for the Control Account. The concept of intersecting the WBS and OBS is introduced in Guideline 3. The Control Account is defined in Guideline 5, but also impacts nearly all of the remaining 32 ANSI Guidelines. The role of the Control Account is described in more detail in the next section.

Control Account Level

To provide the contractor project manager with technical, schedule, and other needed resource information, the management control system must be aligned to a single WBS element and organizational unit. The WBS level at which the management control system is established is primarily a function of the size and/or complexity of the project and the type of product required by the contract. The responsible organizational level is a function of the company's management span of control and upper management's desire to delegate the responsibility for WBS elements to lower management levels. In identifying control accounts, the contractor is expected to establish organizational responsibilities at meaningful and appropriate levels. Otherwise, the contractor's existing management control systems and responsibility assignments may be affected adversely.

Virtually all aspects of the contractor's management control system (i.e. technical definition, budgets, estimates, schedules, risk management, work assignments, accounting, progress assessment, problem identification, and corrective actions) come together at the control account level. Performance visibility is directly relatable to this level of detail.

As the end product is subdivided into smaller sub products at lower WBS levels, the work effort required by each element can be identified and assigned to functional organizational units. The contractor will assign management responsibility for technical, schedule, and other performance criteria at lower levels within the WBS. The management control system will keep the lower levels of the WBS visible as it interfaces with the organization. At the juncture of the WBS element and organization unit, control accounts are established and performance is planned, measured, recorded, and controlled. To this end, the technical requirements for the work and work product must be specified; the work scheduled, budgeted, and performed; and attainment of specified technical requirements verified.

As Figure 5-1 illustrates, at some level in a contractor's organization there is the point at which a control account is managed. Likewise, in any WBS the same point exists. Therefore, every part of a WBS is visible or accessible regardless of the contractor's organization.

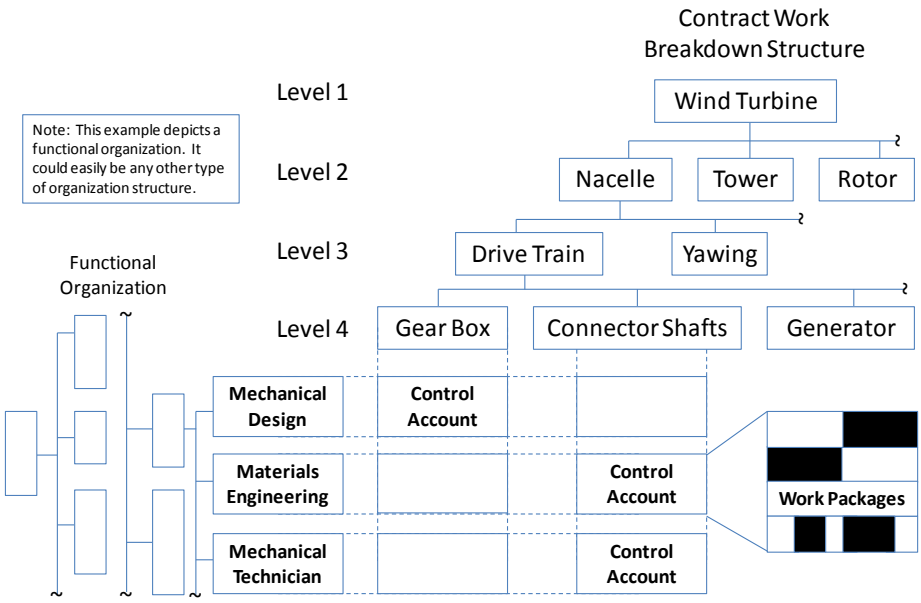


Figure 5-1. Control Account and Work Package Organization

For example, the management information needed by the Government to provide oversight to the development of a wind turbine is available at the control account level, which is part of that effort's WBS. The information the contractor needs to manage this effort is available in the same control accounts, which in this example are a part of the contractor's Material Engineering Department.

Figure 5-2 illustrates the same example but uses an Integrated Project Team (IPT) structured organization and its interface with the Contract WBS. IPT staff and other resources may report to and come through functional organizations, but contract tasking and EVMS reporting should be managed by product-focused Control Account Managers (CAM) who are accountable for specific WBS items.

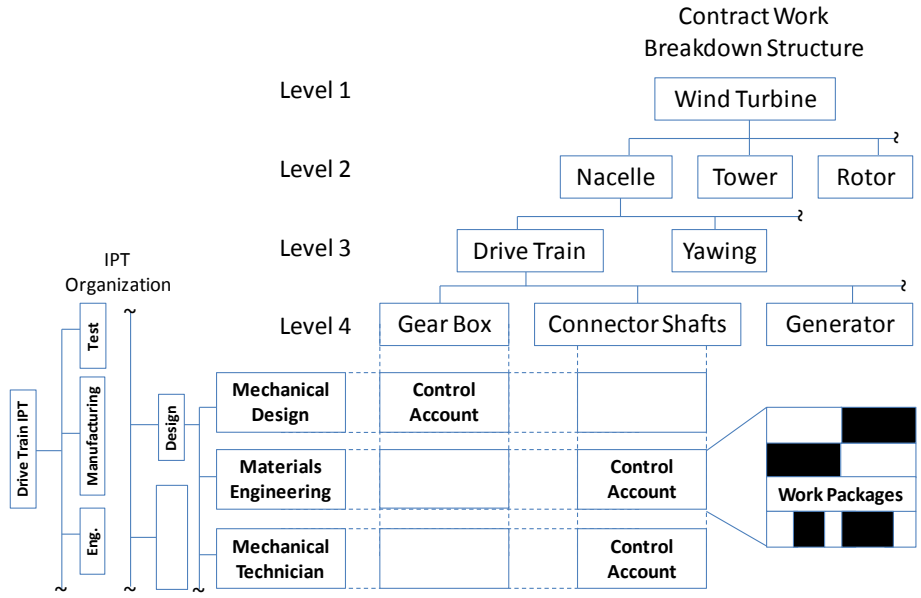


Figure 5-2. IPT intersection with contract WBS

Performance Measurement Baseline

The Performance Measurement Baseline (PMB) is an event-based plan consisting of a hierarchy of project events, with each event being supported by specific accomplishments, and each accomplishment associated with specific criteria to be satisfied for its completion. The Baseline Plan should provide sufficient definition to allow for the tracking of the completion of required accomplishments for each event, and to demonstrate satisfaction of the completion criteria for each accomplishment. Baseline Plan events are not tied to calendar dates. Each event is completed when its supporting accomplishments are completed and when this is evidenced by the satisfaction of the criteria supporting each of those accomplishments. The Baseline Plan is a relatively top-level document in comparison with the RLS. For projects required to use DOE O 413.3B there is an overarching Project Execution Plan (PEP) document for the overall management of the project which includes the scope, cost and schedule baseline for the project from which the contractor PMB is derived following contract negotiations (References: DOE G 413.3-5A, *Performance Baseline Guide*, DOE G 413.3-15, *Project Execution Plans*, and DOE G 413.3-10A, *Earned Value Management System*).

Resource Loaded Schedule (RLS)

The RLS flows directly from the PMB and supplements it with additional levels of detail. It incorporates all of the Baseline Plan's events, accomplishments, and criteria. To these activities it adds the detailed tasks necessary to support the Baseline Plan criteria along with each task's duration and its relationships with other tasks. The RLS supports multiple views (i.e. Event-Based, WBS Based, etc) to support the user's needs. This network of integrated tasks, when tied to the start date (for example, contract award for a project), creates the task and calendar-based schedule that is the RLS. The RLS should be defined to the level of detail necessary for day-to-day execution of the project.

PMB/RLS Linkage

The RLS is directly traceable back to the Baseline Plan and, where applicable, should also be traceable to the project's WBS, SOW, EVMS, and Risk Management System. In general, the Baseline Plan can be thought of as the top-down planning tool and the RLS as the bottom-up execution tool for those plans. It should be noted, however, the primary purpose of the RLS is as a scheduling tool. It serves as a forecasting tool used to track technical performance and time phase the budget.

5.3 COST ESTIMATING

Use of the WBS for cost estimating facilitates project and contract management. The WBS aids project management in planning, coordinating, controlling, and estimating the various products and services. It provides a common framework for tracking the estimated and actual costs during the performance of each contract. The data from the various project contracts support the DOE project director in evaluating contractor performance, preparing budgets, and preparing project life-cycle cost estimates for future contracts. Contractors may also analyze the technical, programmatic, performance, and cost data organized under the WBS to improve the accuracy and credibility of their future proposals (Basis of Estimates).

The WBS, as the cornerstone of the cost estimating process, provides a logical breakdown of tasking necessary to accomplish project objectives. DOE is committed to using historical project cost,

technical, and programmatic data to estimate the cost of ongoing and future DOE projects. Cost estimating data is reported through the Project Assessment and Reporting System (PARS II). The WBS for DOE projects is approved through the Critical Decision (CD) process described in Appendix A of the DOE Order 413.3B.

The use of common product oriented building blocks for WBS development by the DOE programs can help define high-level milestones and cost driver relationships that can be repeated in future applications. The use of common WBS building blocks can assist programs in identifying common risks to make better decision where to apply contingency and identify where systemic problems are occurring, like integration and test.

6. SUMMARY

This handbook presents suggested guidelines for effectively understanding, preparing, working with, and presenting a WBS. It focused on product-oriented WBS with a separate structure to capture common elements. The appendices provide detailed examples of WBS structures for different project types. The appendices are not all inclusive and not all elements are required, but uses of such common product structures help facilitate comparisons and databases.

A WBS developed for a project that is not based on the suggested product-oriented guidance outlined in this handbook may not meet DOE's needs for consistent collection of uniform project data. Contractors may extend the WBS's outlined in the handbook by adding additional elements, provided the additional elements are meaningful product-oriented indentures of a higher-level element. The same WBS should be utilized for the PMB, RLS, Risk Management, EVMS, and other basis for data reporting as applicable.

During each phase of the project, the WBS continues to provide the framework for delineating the areas of responsibility and defining tasks required to meet the requirements of the contract.

The suggested guidance is appropriate for use with any WBS developed for all project phases - Initiation, Definition, Execution and Transition/Closeout.

This handbook delineated the overlapping responsibilities of DOE FPDs and contractors relative to the execution of a WBS.

Desired results:

- Enhanced product-oriented WBS (uniform approach) included in contractor instructions for reporting and management purposes.

- Improved product-oriented data collection leading to better use of data in support of cost estimating endeavors across DOE.

- Product-oriented WBS captures cost and schedule performance associated with the true end item deliverable.

REFERENCES

1. Decommissioning Handbook, *Procedures and Practices for Decommissioning (DOE/EM-0383)*, Prepared by Office of Environmental Management (EM), dated January 2000.

2. DOE O 413.3B, *Program and Project Management for the Acquisition of Capital Assets*, dated November 29, 2010.

3. DOE G 413.3-2, *Quality Assurance Guide for Project Management*, dated June 27, 2008.

4. DOE G 413.3-4A, *Technology Readiness Assessment Guide*, dated September 15, 2011.

5. DOE G 413.3-5A, *Performance Baseline Guide*, dated September 23, 2011.

6. DOE G 413.3-7A, *Risk Management Guide*, dated January 18, 2011.

7. DOE G 413.3-10A, *Earned Value Management System (EVMS)*, dated March 13, 2012.

8. DOE G 413.3-13, *Acquisition Strategy Guide for Capital Assets Projects*, dated July 22, 2008.

9. DOE G 413.3-15, *Guide for Project Execution Plans*, dated September 12, 2008.

10. DOE G 413.3-16A, *Project Completion/Closeout Guide*, dated October 26, 2011.

11. DOE G 413.3-18A, *Integrated Project Teams Guide for Formation and Implementation*, dated February 3, 2012.

12. DOE G 413.3-20, *Cost Estimating Guide*, dated May 9, 2011.

13. Environmental Cost Element Structure, developed by the Environmental Cost Engineering Committee (EC2), dated April 2002.

14. Government Accountability Office (GAO) Cost Estimating and Assessment Guide, GAO-09-3SP, dated March 2009

15. MIL-STD-881C, Department of Defense Standard Practice, *Work Breakdown Structures for Defense Materiel Items*, dated October 3, 2011.

16. NDIA PMSC, Earned Value Management Systems Intent Guide, dated May 2011

17. The DoD Defense Acquisition Guidebook, dated January 10, 2012

18. Operating and Support Cost-Estimating Guide, Office of the Secretary of Defense Cost Analysis Improvement Group, dated October 2007.

ACRONYM LIST

A

A/E	Architect/Engineer
AE	Acquisition Executive
AACEI	American Association of Cost Estimation International
ANSI	American National Standards Institute
APM	DOE Office of Acquisition and Project Management
ASTM	American Society for Testing and Materials

B

BOM	Bill of Material
BWR	Boiling Water Reactor

C

CA	Control Account
CAM	Control Account Manager
CD	Critical Decision
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CLA	Controlled Limited Area
CLIN	Contract Line Item Number
CPR	Contract Performance Report
CWBS	Contract Work Breakdown Structure

D

D&D	Decommissioning and Decontamination
DOD	Department of Defense
DOE	Department of Energy

E

EIA	Electronics Industries Alliance
EV	Earned Value
EVM	Earned Value Management
EVMS	Earned Value Management System

F

FPD	Federal Project Director

G

GFE	Government Furnished Equipment

H

HAER	Historic American Engineering Record
HEBT	High Energy Beam Transport
HEU	Highly Enriched Uranium
HVAC	Heating, Ventilating, and Air Conditioning

I

IPT	Integrated Project Team

L

LCC	Life Cycle Cost
LEBT	Low Energy Beam Transport
LOE	Level of Effort

M

M&O	Managing and Operating

N

NDIA	National Defense Industrial Association
NEPA	National Environmental Policy Act
NHPA	National Historic Preservation Act
NRC	Nuclear Regulatory Commission

O

O&S	Operating and Support
OBS	Organizational Breakdown Structure
OPC	Other Project Cost

P

PARS II	Project Assessment and Reporting System II
PED	Project Engineering and Design
PEP	Project Execution Plan
PMB	Performance Measurement Baseline
PMSC	Program Management Systems Committee
PWBS	Project Work Breakdown Structure
PWR	Pressurized Water Reactor
PWS	Performance Work Statement

R

RCRA	Resource Conservation and Recovery Act
RF	Radio Frequency
RFP	Request for Proposal
RLS	Resource Loaded Schedule

S

SOW	Statement of Work
SWBS	Subcontract Work Breakdown Structure

T

TEC	Total Estimated Cost
TPC	Total Project Cost

W

WBS	Work Breakdown Structure

APPENDICES OVERVIEW

One of the objectives of this handbook is to provide examples of product-oriented WBS modules for typical DOE projects where common building blocks can be extracted for future use in WBS development for other projects as suggested in the uniform approach to WBS development in Section 0 of this document. The building blocks approach can also be utilized for developing parametric cost estimating relationships to support project cost estimating. DOE projects are encouraged to develop and expand their own portfolio of building blocks to support the suggested uniform approach for WBS development. Examples of some WBS modules and definitions describing these facilities, hardware, software, and common elements could follow (DOE projects should tailor their particular WBS modules):

A. Building
B. Tanks and Silos
C. Tunnel
D. Wells
E. Site Works
F. Cap and Liner
G. Ponds and Basins
H. Process/Scientific/Technical Equipment
I. Power Generation
J. Power Transmission
K. Decommissioning and Decontamination
L. Common Elements

A. **Buildings** – includes office spaces, factories, processing facilities, towers, pads, and other structures used for DOE related purposes. They can be treated as an individual facility or complexes (groups of buildings). This also includes the facility structure and utilities, equipment in the facility related to its primary mission(s), support equipment, furniture, and fixtures.

B. **Tanks and Silos** - Tanks and silos include vessels and structures for storage, treatment, or processing of gases, liquids, sludges, slurries, and solids. Included are standalone tanks/silos, tank/silo complexes, tanks/silos within a facility, or tank/silo support equipment.

C. **Tunnels -** Tunnels include underground passageways for transportation, material handling, access, science projects, utility distribution, hazardous material and waste storage, and other purposes.

D. **Wells -** Wells include both extraction and injection wells, and both horizontal and vertical wells. This structure may be used for standalone wells, well fields or complexes, or wells within a facility.

E. **Site Works** – Site Works include roads, parking lots, walkways, railways, grading, landscaping, berms, earthworks, drainage and erosion control, site electricity, water supply, sewers, gas lines, heating and cooling distribution, lighting, communications, security equipment, and fencing.

F. **Cap and Liner** – Cap and liner systems include landfills, waste sites (Resource Conservation and Recovery Act (RCRA) and Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA)) and other remediation structures used to contain or encapsulate both hazardous and/or radioactive soil, debris, and other solid waste temporarily or as a permanent remediation solution. This also includes liners with no caps and caps with no liners.

G. **Ponds and Basins** – These are retention and detention basins, treatment ponds, lagoons, or other holding areas used for storage and treatment of storm water, wastewater, liquid waste, sludge, or slurries.

H. **Process / Scientific / Technical Equipment** – This appendix should be used as an example of a product-oriented WBS associated with a specific type of scientific equipment. As an example, the WBS provided is associated with a **Particle Accelerator System.** A particle accelerator is a device that uses electromagnetic fields to propel charged particles to high speeds and to contain them in well-defined beams. Included are many configurations of particle accelerators, including low energy, high energy, linear (linacs) and circular (cyclotrons and synchrotrons).

I. Power Generation – Applies to power generation plants that produce electrical power by converting the energy released from the nucleus of an atom, typically via nuclear fission (e.g. Nuclear Power Plant). It includes specific modules for both pressurized water reactors and boiled water reactors, and a universal module for all other types of nuclear power plants.

J. Power Transmission – The power transmission system includes all equipment necessary to deliver electricity from power plants to distribution substations.

K. Decommissioning and Decontamination (D&D) Efforts – There are projects within the DOE that focus attention on the Decommissioning and Decontamination of buildings and sites. These efforts usually do not follow a traditional product-oriented WBS due to the nature of the work completed.

L. Common Elements - The efforts associated with common elements should be placed at the level where they support a specific element. Common elements can be found at all levels of a WBS. Not all common elements will be applicable at every level of the WBS.

APPENDIX A: BUILDINGS

Overview

Buildings include office spaces, factories, green houses, processing plants, towers, pads, and other structures used for DOE related purposes. They can be treated as an individual entity or a group of buildings (complex). This WBS includes building structure and utilities, equipment in the facility related to its primary mission(s), support equipment, furniture, and fixtures. This WBS does not include site preparation activities, which can be found in Appendix E Site Works.

Note: This WBS is consistent with the Standard Classification for Building Elements and Related Sitework – UNIFORMAT II (E1557-09), published by the American Society for Testing and Materials (ASTM).

LEVEL 1	LEVEL 2	LEVEL 3
Major Group Elements	**Group Elements**	**Individual Elements**
A Buildings	A1 Structure	A1.1 Foundation
		A1.2 Basement
		A1.3 Superstructure
		A1.4 Exterior Enclosure
		A1.5 Roofing
		A1.6 Interior Construction
		A1.7 Stairs
		A1.8 Interior Finishes
	A2 Utilities	A2.1 Electrical Systems
		A2.2 Heating, Ventilating, and Air Conditioning (HVAC)
		A2.3 Plumbing
		A2.4 Conveying
		A2.5 Fire Protection
		A2.6 Communication Systems
		A2.7 Monitoring, Detection, and Access Control Systems
	A3 Furniture, Fixtures, & Office Equipment	A3.1 General Equipment
		A3.2 Furnishings
		A3.3 Process / Scientific / Technical Equipment
	A4 Demolition	A4.1 Building Element Demolition
		A4.2 Hazardous Component Abatement

WBS Element Definitions

A Building

Includes structure, utilities, infrastructure, equipment (hardware/software), data, and services. This WBS covers building design, development, construction, operations, maintenance, renovation, deactivation, decommissioning, decontamination, dismantlement, and surveillance.

A1 Structure

Facility Structure includes the foundation, basement, superstructure, exterior enclosure, roofing, interior construction, stairs, and all interior finishes.

A1.1 Foundation

Includes wall and column foundations up to level of top of slab on grade; pile caps; foundation excavation, backfill and compaction, footings, perimeter insulation, drainage, and anchor plates.

A1.2 Basement
Includes excavation for construction of basement, backfill and compaction; excavation support system and basement walls.

A1.3 Superstructure
Includes interior wall and floor frames, floor slabs and decks, inclined and stepped floors, expansion and contraction joints, balcony construction, exterior stairs and fire escapes.

A1.4 Exterior Enclosures
Includes exterior wall construction with facing materials, exterior applied finishes, exterior load-bearing wall construction, exterior louvers and screens, exterior sun control devices, balcony walls and railings, exterior windows, store fronts, curtain walls, and exterior painting of windows.

A1.5 Roofing
Includes roofing coverings (membranes, shingles, and tiles), coatings, waterproofing, expansion joints, vapor retarders, roof and deck insulation, flashings and trim, gutters, and downspouts. Also includes skylights, roof hatches, gravity roof ventilators, and smoke vents.

A1.6 Interior Construction
Includes partitions, doors and door frames, chalk and tack boards, lockers, toilets and bath accessories, storage shelving, fabricated toilet partitions, compartments and cubicles, and closet specialties.

A1.7 Stairs
Includes stair treads, risers, landings, and handrails.

A1.8 Interior Finishes
Includes concrete wall finishes, wall plastering and wallboard, tile and terrazzo, paintings, wall coverings, acoustic wall treatments; flooring (tile, carpet, painting and staining, masonry, etc.), and ceiling finishes (plaster, wallboard, metal strip ceilings, etc).

A2 Utilities
Includes electrical systems, heating, ventilation and air conditioning (HVAC), plumbing, conveying, fire protection, communication systems, and security/access control systems.

A2.1 Electrical Systems
Covers electrical service and distribution to include transformers, switchboards, circuit panels, circuit breakers, monitoring, conduit, and wiring. It also includes lighting fixtures and devices.

A2.2 Heating, Ventilating, and Air Conditioning
This element covers numerous forms of heating, cooling, and ventilation. It includes energy supplies such as oil, gas, coal; steam, hot, and chilled water supply; solar and wind energy. It also includes heat generation to include boilers (and required piping and fittings), primary pumps, and auxiliary equipment. Cooling portion of this WBS includes chillers, cooling towers and evaporative coolers, condensing units, related piping and fittings, pumps, and insulation. Air distribution systems include supply and return air systems and handling units, ventilation and exhaust systems, and heat

recovering equipment, auxiliary equipment such as secondary pumps, related piping and ductwork. This element also includes control systems covering heating, cooling, exhaust, and ventilation systems.

A2.3 Plumbing
This element includes water closets, urinals, lavatories, sinks, showers, bathtubs, drinking fountains. This element also includes related pipes and fittings, valves, hydrants, domestic water supply equipment, sanitary waste related equipment (floor drains, pipes, fittings, etc.) and rain water drainage.

A2.4 Conveying
Includes passenger and freight elevators, lifts, moving walks, escalators, hoist/cranes, conveyors, dumbwaiters, pneumatic tube systems, chutes, turntables.

A2.5 Fire Protection
Includes sprinklers, standpipes, fire extinguishers, exhaust hood, dry chemical systems, foam generating systems, clean agent systems, carbon dioxide systems.

A.26 Communication Systems
Includes call systems, telephone systems, local area networks, public address systems, intercommunication systems, television systems.

A2.7 Monitoring, Detection & Access Control Systems
Includes facility fire detection and alarm systems, facility security detection and alarm systems.

A3 Furniture, Fixtures & Office Equipment
Includes fixed furnishings (artwork, casework, window treatments, fixed seating, grilles, mats, fixed interior landscaping), movable furnishings (moveable artwork, rugs, mats, furniture, accessories, movable interior landscaping), and fittings (chalk & tack boards, lockers, toilet & bath accessories, storage shelving, handrails, fabricated cubicles).

A3.1 General Equipment
Includes commercial, institutional, and vehicular equipment as well as equipment related to maintenance, food service, recreation, planetarium, observatory, and agricultural equipment that relate to the primary building purpose.

A3.2 Furnishings
Includes both fixed furnishings (artwork, window treatments, etc.) and movable furnishings (rugs, seating.etc.).

A3.3 Process/Scientific/Technical Equipment
This element includes the facility equipment necessary to achieve the facility's primary mission, such as glove-boxes for handling nuclear material, accelerator equipment, tanks in a processing/storage facility, and treatment equipment. Each major equipment system should have its own WBS inserted below this element based on the specific equipment. This element may not apply in all cases.

A.4 Demolition

Includes the effort associated with demolition of existing buildings and removal of hazardous building materials and components associated with building refurbishments and/or modernization efforts.

A4.1 Building elements demolition
Includes demolition of existing building components in order to complete a building restoration project and/or refurbishment.

A4.2 Hazardous component abatement
Includes removal or encapsulation of hazardous building materials and components associated with building refurbishments and/or modernization efforts.

APPENDIX B: TANKS AND SILOS

System Overview

Tanks and silos include vessels and structures for storage, treatment, or processing of gases, liquids, sludges, slurries, and solids. This may be used for standalone tanks/silos, tank/silo complexes, tanks/silos within a facility, or tank/silo support equipment.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements	LEVEL 3 Individual Elements
B Tanks and Silos	B1 Structure	B1.1 Vessels
		B1.2 Substructure & Foundation
		B1.3 Superstructure
		B1.4 Access and Finishes
	B2 Utilities	B2.1 Electrical Systems
		B2.2 Heating, Ventilating, and Air Conditioning
		B2.3 Plumbing
		B2.4 Conveying
		B2.5 Fire Protection
		B2.6 Communication Systems
		B2.7 Monitoring, Detection, and Access Control Systems
		B2.8 Loading and unloading equipment
	B3 Equipment	

Element Definitions

B Tanks and Silos

Includes structure, utilities, infrastructure, and equipment (hardware/software) to include data and services for storage, treatment, or processing of gases, liquids, sludges, slurries, and solids. This WBS may be used for standalone tanks/silos, tank/silo complexes, or tanks/silos within a facility. If the tank or silo is within a facility, the tank or silo should be included as process/technical equipment within that facility, and the general facility utilities should be reported separately from the specific tank/silo utilities.

B1 Structure

The main tank/silo vessel, load-bearing and non-load-bearing support structures, walls, foundation, slabs and interiors.

B1.1 Vessel

The main Tank/Silo container. This includes the metal, plastic, concrete or wood structure of the container, and shielding and insulation integrated into the container structure.

B1.2 Substructure & Foundation

Below-grade structure, slab, and foundation. This includes the tank/silo site grading, excavation, backfill, underpinnings, pads, and load-bearing sub-grade walls. If a sump for collecting leaks or storm water is built into the foundation, this includes the foundation work for that sump.

B1.3 Superstructure
Above-grade structure that is load-bearing support for the main tank/silo. This includes beams, columns, girders, anchor rods, hoop rings, floors, load-bearing walls, joists, above-grade slabs, roof structure, and conveyor shafts.

B1.4 Access and Finishes
Non-load-bearing structure and finishes. This includes interior and exterior walls and finishes (including those below-grade), roof coverings, doors and windows, stairs, access structures, ladders, catwalks, manholes, support structures for equipment, insulation and shielding that is not integrated into the tank/silo vessel, and fireproofing.

B2 Utilities
Tank/silo systems in the areas of general utilities, including electrical, plumbing, conveying, fire protection, communication and monitoring, detection & access control. Equipment directly related to the primary mission(s) of the tank (including piping or conveying systems to load/unload the tank/silo, and heating/cooling systems) should be reported under Process/Scientific/Technical Equipment.

B2.1 Electrical Systems
Tank/silo Electrical Systems. This includes electrical service and distribution, lighting and branch wiring, emergency systems, power generation systems, power protection systems.

B2.2 Heating, Ventilating, and Air Conditioning Systems
This element covers numerous forms of heating, cooling, and ventilation associated with tanks and silos (if required). It includes energy supplies such as oil, gas, coal; steam, hot, and chilled water supply; solar and wind energy. It also includes heat generation to include boilers (and required piping and fittings), primary pumps, and auxiliary equipment. Cooling portion of this WBS includes chillers, cooling towers and evaporative coolers, condensing units, related piping and fittings, pumps, and insulation. Air distribution systems include supply and return air systems and handling units, ventilation and exhaust systems, and heat recovering equipment, auxiliary equipment such as secondary pumps, related piping and ductwork. This element also includes control systems covering heating, cooling, exhaust, and ventilation systems.

B2.3 Plumbing
General tank/silo support plumbing. This includes plumbing fixtures, domestic water distribution, sanitary waste systems, storm water drainage systems, gas distribution, pool equipment, and fountain piping systems & devices.

B2.4 Conveying
General support conveying systems for the tank/silo. This includes passenger and freight elevators, lifts, moving walks, escalators, hoist/cranes, conveyors, dumbwaiters, pneumatic tube systems, chutes, and turntables. This does not include conveying equipment for loading and unloading of the tank/silo materials.

B2.5 Fire Protection
This includes sprinklers, standpipes, fire extinguishers, exhaust hood, dry chemical systems, foam generating systems, clean agent systems, carbon dioxide systems.

B2.6 Communication Systems
This includes call systems, telephone systems, local area networks, public address systems, intercommunication systems, television systems.

B2.7 Monitoring, Detection & Access Control Systems
Monitoring equipment for the tank/silo and the surrounding area. This includes equipment for operations, fire detection and alarm systems, security detection and alarm systems.

B2.8 Loading and Unloading Equipment
The system for transportation of material into, within, and out of the tank or silo. This includes pumps, piping, conveyors, seals, and movement monitoring equipment. This does not include piping or pumps for general utilities.

B3 Equipment
This element includes additional equipment not covered in the categories above necessary to achieve the primary mission(s) of the tank or silo, such as treatment equipment or a radiation shielding system. Each major equipment system should have its own structure at this level based on the specific equipment. Refer to Appendix H for an example of a product oriented structure involving scientific equipment.

APPENDIX C: TUNNELS

System Overview

Tunnels include underground passageways for transportation, material handling, access, science projects, utility distribution, and other purposes.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements	LEVEL 3 Individual Elements
C Tunnels	C1 Structure	C1.1 Substructure & Foundation
		C1.2 Shell
		C1.3 Walls and Finishes
	C2 Utilities	C2.1 Electrical Systems
		C2.2 Heating, Ventilating, and Air Conditioning
		C2.3 Plumbing
		C2.4 Conveying
		C2.5 Fire Protection
		C2.6 Communication Systems
		C2.7 Monitoring, Detection, and Access Control Systems
		C2.8 Loading and unloading equipment
	C3 Equipment	

WBS Element Descriptions

C Tunnels

The complex of structure, utilities, infrastructure, equipment (hardware/software), data, and services associated with a tunnel. All equipment and fixtures directly related to the primary mission(s) of the tunnel (such as drum conveyor or accelerator equipment) should be captured in an application-specific WBS structure under Process/Scientific/Technical Equipment.

If the sole mission of the tunnel is utilities distribution around a site, the data should be captured instead under Site Utilities in Site Works (appendix E); if the sole mission of the tunnel is road, walkway, or rail access, the data should be capture instead under Roads, Parking Lots, and Walkways. In both cases, this WBS may be used as a child to Site Utilities or Roads, Parking Lots and Walkways if the tunnel is high-cost or high-interest.

C1 Structure

Tunnel Structure includes the load-bearing and non-load-bearing structures, walls, foundation, slabs and interiors.

C1.1 Substructure & Foundation

Tunnel hole, slab, and foundation. This includes tunnel site grading, excavation, boring, drilling or blasting, backfill, pads, and underpinnings.

C1.2 Shell

Tunnel load-bearing structure. This includes beams, columns, girders, floors, load-bearing walls, roof, and joists.

C1.3 Walls and Finishes
Non-load-bearing structure and finishes. This includes walls, doors and windows, stairs, access structures, ladders, catwalks, manholes, support structures for equipment, insulation and shielding, fireproofing, and waterproofing.

C2 Utilities
All tunnel systems in the areas of electrical, heating, ventilating, HVAC, plumbing, conveying, fire protection, communication and monitoring, detection & access control. Utilities and equipment directly related to the primary mission(s) of the tunnel (such pipes for waste transportation or conveyors for drums) should be reported in an application-specific WBS structure under Process/Scientific/Technical Equipment.

C2.1 Electrical Systems
Includes electrical service and distribution, lighting and branch wiring, emergency systems, power generation systems, power protection systems.

C2.2 Heating, Ventilating, Air Conditioning (HVAC) Systems
Includes energy supply, heating and cooling generation and distribution systems, terminal and package units, active confinement systems, controls and instrumentation, systems testing and balancing.

C2.3 Plumbing
Includes plumbing fixtures, domestic water distribution, sanitary waste systems, storm water drainage systems, gas distribution, pool equipment, fountain piping systems & devices.

C2.4 Conveying
Includes passenger and freight elevators, lifts, moving walks, escalators, hoist/cranes, conveyors, dumbwaiters, pneumatic tube systems, chutes, turntables.

C2.5 Fire Protection
Includes sprinklers, standpipes, fire extinguishers, exhaust hood, dry chemical systems, foam generating systems, clean agent systems, carbon dioxide systems.

C2.6 Communication Systems
Includes call systems, telephone systems, local area networks, public address systems, intercommunication systems, and television systems.

C2.7 Monitoring, Detection & Access Control Systems
Includes tunnel fire detection and alarm systems, tunnel security detection and alarm systems.

C2.8 Loading and Unloading Equipment
The system for transportation of material into, within, and out of the tunnel. This includes pumps, piping, conveyors, seals, and movement monitoring equipment. This does not include piping or pumps for general utilities.

C3 Equipment

This element includes additional equipment not covered in the categories above necessary to achieve the primary mission(s) of the tunnel. Each major equipment system should have its own structure at this level based on the specific equipment. Refer to Appendix H for an example of a product oriented structure involving scientific equipment.

APPENDIX D: WELLS

System Overview

Wells include both extraction and injection wells, and both horizontal and vertical wells. This structure may be used for standalone wells, well fields or complexes, or wells within a facility.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements	LEVEL 3 Individual Elements
D Wells	D1 Structure	D1.1 Substructure D1.2 Above Grade Structure
	D2 Utilities	
	D3 Equipment	D3.1 Piping and Pumps D3.2 Tanks D3.3 Monitoring Equipment D3.4 Other Equipment

WBS Element Descriptions

D Wells

The complex of well structure, utilities, infrastructure, equipment (hardware/software), data, and services covering both extraction and injection wells, and ground water monitoring wells. This WBS may be used for standalone wells, well fields or complexes, or wells within a facility. If the well is part of a treatment facility, the well should be included as process/technical equipment within that facility, and the general facility utilities should be reported separately from the specific well utilities.

D1 Structure

The Well Structure includes the well casing, and surface structures. The Above-grade Structure element below is used for capturing a smaller-scale well house or other structure to support the well, and not a complete treatment facility. If there is no above-grade structure or the well is treated as process equipment in a treatment facility, the Well Structure element should be used as a Level 2 parent element (with no children elements) to capture the substructure.

D1.1 Substructure

Below-grade well structure includes coring and boring, backfill, well casing, grout, well screen, gravel pack, slabs, and pads.

D1.2 Above-Grade Structure

Above-grade structure of the well includes a well house. This element may not apply in all cases.

D2 Utilities

General well utilities. This includes electrical, fire protection, communication systems, and security monitoring, and access control.

D3 Equipment
Well systems and equipment necessary to achieve the primary mission(s) of the well.

D3.1 Piping and Pumps
Systems for extracting from or injecting to the well.

D3.2 Tanks
Storage tanks or other vessels related to the well. This element may not apply in all cases.

D3.3 Monitoring Equipment
Equipment for monitoring the well. This includes flow meters, pressure gauges, and contamination monitoring.

D3.4 Other Equipment
This element includes any additional equipment not covered in the categories above necessary to achieve the primary mission(s) of the well, such as treatment equipment. Each major equipment system should have its own WBS at this level based on the specific equipment. This element may not apply in all cases.

APPENDIX E: SITE WORKS

This appendix provides an example of the Work Breakdown Structure and Definitions for projects for site works, site utilities, general site grading and landscaping, berms and earthworks, drainage and erosion control, trenches, ponds, basins, lagoons, waste pits, cap and liner systems, and landfills. Site Works include roads, parking lots, walkways, railways, grading, landscaping, berms, earthworks, drainage and erosion control, site electricity, water supply, sewers, gas lines, heating and cooling distribution, lighting, communications, security equipment, and fencing.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements
E Site Works	E1 Roads, Parking Lots, and Walkways
	E2 Grading and Landscaping
	E3 Berms, Drainage, and Erosion Control
	E4 Trenches
	E5 Site security
	E6 Utilities

WBS Element Definitions

E Site Works
This element involves the complex of structure, utilities, infrastructure, equipment (hardware/software), data, and services associated with site work. The Site Works WBS should be included with construction projects, decommissioning and demolition activities, remediation and restoration projects, or as a standalone project for general site alterations or improvements. A facility complex would include site works for each facility being constructed (reported with that specific facility) as well as site works that affects all facilities (reported as general site work). Similarly, a pond or basin may have site works for berms, floodwalls, or landscaping (reported with that specific pond or basin).

E1 Roads, Parking Lots and Walkways
This includes paving sub-base, paving & surfacing, curbs, roadside drainage ditches, gutters, rails, barriers, painted lines, signage, exterior steps, parking booths & related equipment.

E2 Grading and Landscaping
General site grading, landscaping, and restoration. This includes site clearing and site earthwork, fine grading & soil preparation, top soil & planting beds, seeding/sodding, planting, planters, and irrigation systems.

This does not include excavation related to construction or removal of a structure's foundation or returning a structure to grade as part of the Deactivation and Decommissioning phase [in that structure's WBS, use the Substructure and Foundation element]. This also does not include removal of soil during the Soil and groundwater Remediation phase.

E3 Berms, Drainage, and Erosion Control
This includes berms, floodwalls, gabion walls, soil stabilization structures, erosion control barriers, geotextiles used for stabilization, gullies, banks for ponds, basins and rivers, and other earthen and constructed barriers. This also includes soil used above-grade for structural support of a facility. It also includes floodplains, drainage ditches, and other drainage control walls and barriers.

E4 Trenches
Trenches include the load-bearing and non-load-bearing structures, walls, foundation, slabs and interiors. Utilities include systems in the areas of electrical, HVAC, plumbing, conveying, fire protection, communication, and monitoring, detection & access control.

E5 Site Security
Structures and equipment associated with security at the site. This includes fencing, walls, security lighting, alarms and monitoring equipment, guard houses, entry control facilities, and fire protection. This also includes a comprehensive Perimeter Intrusion Detection and Assessment System (PIDAS).

E6 Site Utilities
Utilities associated with the site or originating from the site. This includes site mechanical utilities (water supply, sanitary sewer, storm sewer, steam, heating/cooling/fuel distribution systems), site electrical utilities (electrical distribution, site lighting, site communications), and gas distribution.

APPENDIX F: CAP AND LINER

Cap and liner systems include landfills, waste pits, and other structures used to contain or encapsulate soil, debris, and other solid waste temporarily or permanently. This also includes liners with no caps and caps without liners.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements	LEVEL 3 Individual Elements
F Cap and Liner	F1 Cap	F1.1 Constructed Layer F1.2 Synthetic Layer F1.3 Natural Layer F1.4 Utilities
	F2 Liner	F2.1 Subgrade and Substucture F2.2 Synthetic Layer F2.3 Natural Layer F2.4 Utilities
	F3 Equipment	

WBS Element Definitions

F Cap and Liner
This WBS covers cap and liner design, development, and construction related activities. Element of this WBS include structures, utilities, equipment (hardware/software), data, and services over the lifecycle of a cap and liner system. If the cap and liner is part of a treatment facility, it is included as process/technical equipment within that facility. General facility utilities are reported separately from the cap and liner. If the cap and liner is not associated with a treatment/remediation facility, the treatment equipment is to be included as process equipment. Where a legacy cap and liner system is being remediated, the treatment facility/equipment used will have its own WBS and not reported as part of the cap and liner structure.

F1 Cap
The cap is a top covering over the waste/debris. The purpose of the cap is to prevent leakage, access, exposure or contamination and to promote proper drainage. This element may not apply in all cases.

F1.1 Constructed Layer
Concrete, asphalt, or other constructed layer used in the cap.

F1.2 Natural Layer
Caps composed of natural material include topsoil, vegetation, soil, clay, bentonite, and bio-intrusion barriers.

F1.3 Synthetic Layer
Caps composed of synthetic materials include geosynthetics, geomembranes, and other geotextiles. Synthetics do not include materials listed in constructed layer.

F1.4 Utilities
Utilities associated with the cap include piping, electrical, temperature control systems, leak detection, leak collection, drainage, fire protection, and monitoring.

F2 Liner
The liner is an engineered containment barrier beneath the waste/debris which prevents leakage of the contained materials to the environment and precludes groundwater from entering the containment. The liner also promotes proper collection of drainage within the waste/debris material for collection. This element may not apply in all cases.

F2.1 Subgrade and substructure
Sub-grade construction includes excavation, backfill, and installation of foundation materials such as concrete, asphalt, or other constructed layer.

F2.2 Synthetic Layer
Liners composed of synthetic materials include geosynthetics, geomembranes, and other geotextiles. Synthetics do not include materials listed in constructed layer.

F2.3 Natural Layer
Liners composed of natural material include topsoil, vegetation, soil, clay, bentonite, and bio-intrusion barriers.

F2.4 Utilities
Utilities associated with the liner include piping, electrical, temperature control systems, leak detection and collection, drainage, fire protection, and monitoring.

F3 Equipment
This element includes treatment equipment. Each major equipment system should have its own work breakdown structure. This element may not apply in all cases.

APPENDIX G: PONDS AND BASINS

These are retention and detention basins, treatment ponds, lagoons, or other holding areas used for storage and treatment of storm water, wastewater, liquid waste, sludge, or slurries.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements
G Ponds and Basins	G1 Subgrade and Substructure G2 Synthetic Layer G3 Natural Layer G4 Utilities G5 Equipment

WBS Element Definitions

G Ponds and Basins
This element covers retention and detention basins, treatment ponds, lagoons, waste pits, or other holding areas used for storage and treatment of storm water, wastewater, liquid waste, sludge, or slurries. This does not include soils, solids, solid waste, or debris (use Cap and Liner System WBS, appendix F). This WBS covers the full pond lifecycle, including design, development, construction, operations, maintenance, renovation, deactivation, decontamination, dismantlement, and surveillance.

If the pond or basin is part of a treatment facility, it should be included as process/technical equipment within that facility, and the general facility utilities should be reported separately from the specific pond or basin utilities. If the pond or basin is a standalone treatment/remediation structure, the treatment equipment should be included as process equipment below. If a legacy pond or basin is being remediated, the treatment facility/equipment used should have its own WBS, and should not be reported as part of the pond or basin structure.

G1 Subgrade and Substructure
Sub-grade constructed portion of the pond. This includes excavation, backfill, foundation, and concrete or asphalt layer.

For the Stabilization and Disposition phase, this includes filling in the subgrade area, restoring it to grade, and decontamination, removal and processing of the soil around the pond or basin.

G2 Natural Layer
Natural material used to line the pond/basin. This includes topsoil, vegetation, soil, clay, bentonite, and bio-intrusion barriers.

G3 Synthetic Layer
All synthetics used to line the pond or basin. This includes geosynthetics, geomembranes, and other geotextiles. This does not include concrete or asphalt.

G4 Utilities
Utilities supporting the pond/basin. This includes piping, electrical, temperature control systems, leak detection and collection, drainage, fire protection, and monitoring.

G5 Equipment
This element includes the equipment necessary to achieve the primary mission(s) of the pond or basin, such as treatment equipment or the filling/emptying system. Each major equipment system should have its own WBS inserted below this element based on the specific equipment. This element may not apply in all cases.

APPENDIX H: PROCESS/SCIENTIFIC/TECHNICAL EQUIPMENT

This appendix provides an example of the Work Breakdown Structure and Definitions for Process / Scientific / Technical Equipment. **Note** - this example may be significantly different from other projects that focus attention on designing and producing scientific equipment. The following suggested WBS module is addressed within this appendix.

WBS Structure

LEVEL 1	LEVEL 2	LEVEL 3
Major System Element	**Group Elements**	**Individual Elements**
H Particle Accelerator System	H1 Injection Subsystem	H1.1 Ion Source
		H1.2 Vacuum Chamber
		H1.3 Extractor
		H1.4 Magnets
		H1.5 Vacuum
		H1.6 Diagnostic / Monitoring
		H1.7 RF Power Subsystem
		H1.8 Controls & Power Conversion Subsystem
		H1.9 Lasers
		H1.10 Collimators
		H1.11 Support Structure
	H2 Accelerator Subsystem	H2.1 Vacuum Chamber
		H2.2 Magnets
		H2.3 Diagnostics / Monitoring
		H2.4 RF Power Subsystem
		H2.5 Cooling Subsystem
		H2.6 Support Structure
	H3 Insertion Devices	H3.1 Bending Magnets
		H3.2 Wave Length Shifters
		H3.3 Wigglers
		H3.4 Undulators
		H3.5 RF Power Subsystem
		H3.6 Support Structure
	H4 Beam Transport Lines (Low, High Energy, Dump)	H4.1 Magnets
		H4.2 Collimators
		H4.3 Diagnostics / Monitoring
		H4.4 Support Structure
	H5 Central Instrumentation and Control	

WBS Element Definitions

H Particle Accelerator System

A particle accelerator is a device that uses electromagnetic fields to propel charged particles to high speeds and to contain them in well-defined beams. There are many configurations of particle accelerators, including low energy, high energy, linear (linacs) and circular (cyclotrons and synchrotrons). All particle accelerators (whether linacs or circular) include an injector subsystem, an accelerator subsystem, and targets. Additionally, most particle accelerators employ the use of insertion devices in order to create specific beam characteristics, and beam transports used to transport the beam from the injection subsystem to the accelerator subsystem and from the accelerator subsystem to the desired target. Beam transports are also employed as dump lines in order to divert unwanted particles from the main beam line, or used for the purpose of commissioning, tune up and diagnostics.

H1 Injector Subsystem
The injector subsystem (sometimes referred to as the 'pre-accelerator') is the first stage of the accelerator that generates and focuses the particle beam. The primary components of the injector system are the ion source, extractor, and the low energy beam transport that steers, focuses and injects the particles into the main accelerator.

H.1 Ion Source
The ion source is an electro-magnetic device that is used to create charged particles. The technology to create ion sources for particle accelerators depends strongly on the type of particle that needs to be generated: electrons, protons, H- ion or a heavy ion.

Electrons are generated with an electron gun.
Protons are generated with a plasma-based device (e.g., a duoplasmatron or a magnetron).
H- ions are generated with a magnetron or a Penning source.
Heavy ions are generated with an electron cyclotron resonance ion source.

H1.2 Vacuum Chamber
A vacuum chamber is a series of hollow tubes that provide an atmospheric free environment through which particles can travel.

H1.3 Extractor
The extractor pulls charged particles from the ion source and provides the initial acceleration for injection to the main accelerator. A typical extractor is a Radio Frequency Quardrupole (RFQ), which is a vane-type accelerating structure that provides quadrupole focusing by electric fields near the axis.

H1.4 Magnets
Magnets include various configurations of material with magnetic properties used to bend, bunch, and focus the particle beam on route to the main accelerator. This element may include dipole, quadrupole, sextupole, octupole, and/or decapole magnets.

H1.5 Vacuum
The vacuum consists of the various rotary pumps and cold traps used to create and maintain an atmospheric free environment through which the particle beam can travel.

H1.6 Diagnostics/Monitoring
Diagnostics/Monitoring consists of the various sensors (e.g., joule meter probes, photodiodes, beam current monitors, beam profile monitors, video imaging, etc.) arrayed throughout the injection system used to monitor beam characteristics, and radiation emittance.

H1.7 RF Power Subsystem
The radio frequency power subsystem includes all the equipment necessary to convert the high-voltage AC prime power to suitably conditioned RF power for input to the injection system. Included are the klystron subsystems, high voltage power supply subsystems, RF power supply subsystems, transmitter subsystems, and transmission subsystems.

H1.8 Controls and Power Conversion Subsystem

The controls and power conversion subsystem includes the DC power supply, cabling, power supply control and control instrumentation, and the control software.

H1.9 Lasers
For photocathode RF gun injector systems, the laser provides ultraviolet light pulses in order to minimize emittance growth close to the cathode surface. The laser system includes the oscillator, temporal pulse shaper, pulse stretcher, amplifier, pulse compressor and frequency converter..

H1.10 Collimators
Collimators are devices that are very close to the beam, and scrape away particles that have gone slightly off track in order to prevent damage to the beam pipe and the magnets (a small fraction of the beam hitting a magnet might for example cause a quench). The collimator element includes the internal alignment system, jaw clamping system, cooling pipes, and the motorization and actuation system.

H1.11 Support Structure
The support structure secures the various injector system elements in place, providing stability and alignment. The support structure element includes brackets, supports, tables, and springs, actuators and other mechanical devices used for external alignment.

H2 Accelerator Subsystem
The particles from the injector system enter the accelerator system which uses a linear array of plates (or RF cavity resonators with drift tubes) to which an alternating high-energy field is applied. As the particles approach a plate they are accelerated towards it by an opposite polarity charge applied to the plate. As they pass through a hole in the plate, the polarity is switched so that the plate repels them and accelerates them towards the next plate.

H2.1 Vacuum Chamber
The vacuum consists of the various rotary pumps and cold traps used to create and maintain an atmospheric free environment through which the particle beam can travel.

H2.2 Magnets
Magnets include various configurations of material with magnetic properties used to bend, bunch, and focus the particle beam as it travels through the accelerator. This element may include dipole, quadrupole, sextupole, octupole, and/or decapole magnets.

H2.3 Diagnostics/Monitoring
The Diagnostics/Monitoring consists of the various sensors (e.g., beam current monitors, beam profile monitors, video imaging, etc.) arrayed throughout the accelerator system used to monitor beam characteristics, and radiation emittance.

H2.4 RF Power Subsystem
The radio frequency power subsystem includes all the equipment necessary to convert the high-voltage AC prime power to suitably conditioned RF power for input to accelerator system. Included are the klystron subsystems, high voltage power supply subsystems, RF power supply subsystems, transmitter subsystems, and transmission subsystems.

H2.5 Cooling Subsystem
The cooling subsystem includes the network of pipes connected to or built into the accelerator structures that provide a flow of water to transfer heat away. The cooling subsystem also includes water pumping systems, cooling towers, cooling ponds, spray ponds, cryogenic systems, chilled water, and/or air-cooled or other types of heat exchangers.

H2.6 Support Structure
The support structure secures the various accelerator system elements in place, providing stability and alignment. The support structure element includes brackets, supports, tables, and springs, actuators and other mechanical devices used for external alignment.

H3 Insertion Devices
Insertion devices include bending magnets, wave length shifters, undulators and wigglers that are magnetic devices that produce a special periodic field variation such as final focus before collision with a target, separation after collision, and beam cleaning.

H3.1 Bending Magnets
A bending magnet (i.e., dipole magnet) is a simple insertion device that bends the particle beam resulting in an increase in radiation.

H3.2 Wave Length Shifters
A wave length shifter is typically installed in a low energy storage ring in order to produce harder x-ray radiation. The wave length shifter consists of three ordinary dipole magnets with a high field central magnet and two lower field magnets with opposite field direction on either side.

H3.3 Wigglers
A wiggler is a series of magnets designed to periodically laterally deflect ('wiggle') a beam of charged particles in order to produce emission of broadband synchrotron radiation much like that of a bending magnet, but the intensity is higher due to the contribution of many magnet dipoles in the wiggler. A wiggler has the same components as an undulator, but has a broader spectrum of radiation.

H3.4 Undulators
Undulators are insertion devices used to oscillate particles in order to radiate energy. The undulator consists of a C-shaped or O-shaped housing that contains a periodic structure of dipole magnets and poles. Also included in this element are the vacuum chamber, clamps, pole side shims (trajectory shims), piezoelectric translators, and camshaft movers.

H3.5 RF Power Subsystem
The radio frequency power subsystem includes all the equipment necessary to convert the high-voltage AC prime power to suitably conditioned RF power for input to the insertion device. Included are the klystron subsystems, high voltage power supply subsystems, RF power supply subsystems, transmitter subsystems, and transmission subsystems.

H3.6 Support Structure
The support structure secures the various insertion system elements in place, providing stability and alignment. The support structure element includes brackets, supports, tables, and springs, actuators and other mechanical devices used for external alignment.

H4 Beam Transport Lines
The Beam Transport Lines element Includes both high energy and low energy beam transport lines (HEBT and LEBT).

H4.1 Magnets
Magnets include various configurations of material with magnetic properties used to bend, bunch, and focus the particle beam as it travels through the beam transport lines. This element may include dipole, quadrupole, sextupole, octupole, and/or decapole magnets.

H4.2 Collimators
Collimators are devices that are very close to the beam, and scrape away particles that have gone slightly off track in order to prevent damage to the beam pipe and the magnets (a small fraction of the beam hitting a magnet might for example cause a quench). The collimator element includes the internal alignment system, jaw clamping system, cooling pipes, and the motorization and actuation system.

H4.3 Diagnostics/Monitoring
The Diagnostics/Monitoring consists of the various sensors (e.g., beam current monitors, beam profile monitors, video imaging, etc.) arrayed throughout the beam transport lines used to monitor beam characteristics, and radiation emittance.

H4.4 Support Structure
The support structure secures the various beam transport line system elements in place, providing stability and alignment. The support structure element includes brackets, supports, tables, and springs, actuators and other mechanical devices used for external alignment.

H5 Central Instrumentation and Control
Central Instrumentation and Control represents the complex of equipment used to operate and maintain the particle accelerator. Included are substation monitoring and control panels, steering and focusing controls, power controls, shut off systems, security systems, and all related cabling, wiring, structural support and shielding.

APPENDIX I: POWER GENERATION

This appendix provides two examples of the Work Breakdown Structure and Definitions for projects for Power Generation (Nuclear Power Plant).

Nuclear Power Plant

Nuclear energy originates from the splitting of uranium atoms in a process called fission. Fission releases energy that can be used to make steam, which is used in a turbine to generate electricity. The fuel used in nuclear power plants is Uranium. Uranium is extracted from open-pit and underground mines. Once mined, the uranium ore is sent to a processing plant to be concentrated into a useful fuel (i.e., uranium oxide pellets). This uranium enrichment process generates radioactive waste. Enriched fuel is then transported to the nuclear power plant.

At the power plant, the uranium oxide pellets are bombarded with neutrons, causing the uranium atoms to split and release both heat and neutrons. These neutrons collide with other uranium atoms and release additional heat and neutrons in a chain reaction. This heat is used to generate steam, which is used by a turbine to generate electricity.

Two major types of nuclear power systems are the Pressurized Water Reactor (PWR) and the Boiling Water Reactor (BWR). In a PWR, ordinary water is used as both neutron moderators and coolant. PWRs keep water under pressure so that it heats, but does not boil. Water from the reactor and the water in the steam generator that is turned into steam never mix. In this way, most of the radioactivity stays in the reactor area. In a BWR, ordinary light water is used as both a moderator and coolant, like the PWR. However unlike the PWR, in a BWR, there is no separate secondary steam cycle. The water from the reactor is converted into steam and used to directly drive the generator turbine.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements	LEVEL 3 Sub-Group Elements	LEVEL 4 Sub-Elements	LEVEL 5 Individual Elements
I. Nuclear Power Plant	I1 Steam Generation System	I1.1 Containment Building	I1.1.1 Reactor Vessel	I1.1.1.1 Reactor Core
				I1.1.1.2 Fuel Rods
				I1.1.1.3 Control Rods
				I1.1.1.4 Coolant
				I1.1.1.5 Casing
			I1.1.2 Steam Generator / Heat Exchanger	
			I1.1.3 Pressurized Water Loop (Radioactive)	
			I1.1.4 Steam Lines	
			I1.1.5 Pressurizer	
			I1.1.6 Pump	
			I1.1.7 Containment Structure	
			I1.1.8 Cool Water Feed Line (Non-Radioactive)	
		I1.2 Condensers		
		I1.3 Circulator Pumps		
		I1.4 Compressors		
		I1.5 Feed Heaters / Economizers		
		I1.6 Cooling Towers		
		I1.7 Cool Water Lines		
	I2 Power Generation	I2.1 Turbines		
		I2.2 Generators	I2.2.1 Rotor	
			I2.2.2 Stator	

WBS Element Definitions

I Nuclear Power Plant
A facility in which heat produced in a reactor by the fissioning of nuclear fuel is used to drive a steam turbine.

I1 Steam Generation System
Includes equipment/devices necessary to boil water to create steam and complete the cycle by condensing the steam and returning it to a liquid state.

I1.1 Containment Building
The structure around the reactor core which is designed to protect it from outside intrusion and to protect those outside from the effects of radiation in case of any malfunction inside. It is typically a meter-thick concrete and steel structure.

I1.1.1 Reactor Vessel
A steel pressure vessel containing the coolant and reactor core. It is a device for containing and controlling a chemical reaction.

I1.1.1.1 Reactor Core
Part of a nuclear reactor containing the nuclear fuel components where the nuclear reactions take place. This includes the fuel, moderator and coolant.

I1.1.1.2 Fuel Rods
Metal rods in which uranium in the form of ceramic pellets are contained.

I1.1.1.3 Control Rods
Control rods are made with neutron-absorbing material such as cadmium, hafnium or boron, and are inserted or withdrawn from the core to control the rate of reaction, or to halt it. In some reactors, special control rods are used to enable the core to sustain a low level of power efficiently.

I1.1.1.4 Coolant
Serves the dual purpose of removing the heat from the reactor as well as transferring it to the electricity generation circuit. Includes commonly used coolants such as light water, heavy water, carbon dioxide, helium, nitrogen, sodium, sodium-potassium mixture.

I1.1.1.5 Casing
Includes the steel casing of the reactor vessel.

I1.1.2 Steam Generator/Heat Exchanger
Part of the cooling system where the primary coolant bringing heat from the reactor is used to make steam for the turbine. Note – Steam Generator/Heat Exchangers are not applicable in boiling water reactor systems.

I1.1.3 Pressurized water loop (Radioactive)
Primary cooling circuit which flows through the core of the reactor under very high pressure. Note – Radioactive pressurized water loops are not applicable in boiling water reactor systems.

I1.1.4 Steam Lines
Conduits that carry pressurized steam from the steam generation system to the turbine.

I1.1.5 Pressurizer
A separate vessel that is connected to the primary circuit (pressurized water loop) and partially filled with water which is heated to the saturation temperature (boiling point) for the desired pressure by submerged electrical heaters. Note –Pressurizers are not applicable in boiling water reactor systems.

I1.1.6 Pumps
Pumps used to move liquid throughout the pressurized water loop.

I1.1.7 Containment Structure
The physical structure around the reactor core which is designed to protect it from outside intrusion and to protect those outside from the effects of radiation in case of any malfunction inside. It is typically a meter-thick concrete and steel structure.

I1.1.8 Cool Water Feed Line (Non-Radioactive)
Water conduits that lead from the condensers into the Heat Exchanger/Steam Generator inside the Containment Structure.

I1.2 Condensers
A device or unit used to condense vapor into liquid.

I1.3 Circulator Pumps
Pumps used to move liquid throughout the cool water loop.

I1.4 Compressors
Compresses inlet air from the air intake system to create necessary pressure conditions.

I1.5 Feed Heaters/Economizers
Increases the temperature of the feed water by utilizing extraction steam from various stages of the steam generation process.

I1.6 Cooling Towers
Heat removal devices used to transfer process waste heat to the atmosphere. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or rely solely on air to cool the working fluid to near the dry-bulb air temperature.

I1.7 Cool Water Lines
Water conduits that lead from the cooling towers to the condensers.

I2. Power Generation System
A system that generates electricity from other forms of energy (e.g., steam). Includes Turbines and Generators.

I2.1 Turbines
A rotary engine in which the kinetic energy of a moving fluid (steam) is converted into mechanical energy by causing a bladed rotor to rotate.

I2.2 Generators
Converts rotational mechanical energy transferred from the turbine through the shaft, into electrical energy.

I2.2.1 Rotor
Rotating part of the generator that includes coils in which voltage is induced by motion through a magnetic field.

I2.2.2 Stator
Mechanical device consisting of the stationary part of a motor or generator in or around which the rotor revolves. Includes coils/laminates that produce a magnetic field.

APPENDIX J: POWER TRANSMISSION

A transmission system includes all equipment necessary to deliver electricity from power plants to distribution substations.

WBS Structure

LEVEL 1 Major Group Elements	LEVEL 2 Group Elements	LEVEL 3 Individual Elements
J Power Transmission Equipment	J1 Conductors	J1.1 Above Ground
		J1.2 Below Ground
	J2 Transmission Structures (poles, frames, etc)	
	J3 Distribution Transformers	
	J4 Substation / Switchyard	J4.1 Power Transformers
		J4.2 Compensators
		J4.3 Circuit Breakers
		J4.4 Electric Meters
		J4.5 Insulators

WBS Element Definitions

J Power Transmission Equipment
Includes all equipment (e.g., conductors, cables, etc) necessary to carry electricity from a generator to the grid for distribution.

J1 Conductors (Wires)
Metal conductors that carry electricity over a distance. This includes all wires throughout the PV power plant system (both above ground and underground) and includes insulation and shielding material.

J1.1 Above Ground (Conductors)
Includes all exposed conductors (wires).

J1.2 Underground (Conductors)
Includes conductors (wires) that are buried.

J2 Transmission Structures (Poles, Frames, etc.)
Includes all equipment/structures used to support conductors (wires), and other transmission devices, throughout the power transmission system.

J3 Distribution Transformers
A device that changes the voltage of alternating current electricity; it may step the voltage up or down, depending on the application. A transformer consists of an induction coil having a primary and secondary winding and a closed iron core. Distribution transformers are used for lower voltage distribution close to user connectivity.

J4 Sub Station/Switchyard
An electrical installation containing power conversion equipment, such as transformers, compensators, and circuit breakers.

J4.1 Power Transformers
A device that changes the voltage of alternating current electricity; it may step the voltage up or down, depending on the application. A transformer consists of an induction coil having a primary and secondary winding and a closed iron core. Power transformers are used for higher voltage transmission.

J4.2 Compensators
An electrical matching device to compensate for electrical impedance differences. Compensators monitor and adjust voltage to maintain a constant voltage.

J4.3 Circuit Breakers
A circuit breaker is an automatically-operated electrical switch designed to protect an electrical circuit from damage caused by overload or short circuit.

J4.4 Electric Meters
Meter for measuring the amount of electric power at any given point in an electrical circuit.

J4.5 Insulators
Insulators are utilized to isolate electrical distribution equipment from the steel supports and other equipment that have the ability to conduct current but are not intended to. They also protect the lines from the elements. Insulators are usually made from porcelain or glass.

APPENDIX K: DECOMMISSIONING AND DECONTAMINATION (D&D) EFFORTS

There are projects within the DOE that focus attention on the Decontamination and Decommissioning of buildings and sites. The following is a proposed WBS covering these activities. It is consistent with recent D&D efforts going on throughout the DOE. D&D regulatory drivers include requirements of: DOE, Nuclear Regulatory Commission (NRC), Department of Transportation (DOT), OSH&A, and the EPA. DOE Facilities fall under the National Environmental Policy Act (NEPA); National Historic Preservation Act (NHPA), Historic American Engineering Record (HAER) and State Historic Preservation Agencies. CERCLA, RCRA, at other federal legislation are applicable at DOE sites.

Note: This WBS is consistent with the Environmental Cost Element Structure (E2150-02), published by the American Society for Testing and Materials (ASTM).

WBS Structure

LEVEL 1	LEVEL 2	LEVEL 3
Major Group Element	**Group Elements**	**Sub-Group Elements**
K D&D	K1 Deactivation	K1.1 Facility Shutdown and Inspection K1.2 Pre-Decommissioning Projects K1.3 Planning/Regulatory Approval
	K2 Decommissioning	K2.1 Facilities/Infrastructure K2.2 Decontamination
	K3 Demolition & Removal	K3.1 Dismantling K3.2 Demolition K3.3 Sitework
	K4 Waste Management	K4.1 Waste Disposition K4.2 Waste Disposal
	K5 Demobilization	

WBS Element Definitions

K1 Deactivation

Deactivation is the process of transitioning a facility into a stable and known condition, including the removal of hazardous and radioactive materials to ensure protection of the workers, environment and the public, thereby limiting the need for the long-term cost of surveillance and maintenance. Typically, irreversible actions are not allowed, facility is shut down and staged for follow on actions, and nothing is allowed that violates licensing requirements. The scope of this WBS element includes the activities to prepare the building, structure, or plant for demolition that include isolation of hazardous energy (e.g., electrical isolation), mechanical systems operations (e.g., isolation and removal of "free liquids" such as water, sewer, cooling systems, etc.), and removal of non-radiological hazardous materials (asbestos, beryllium). Also includes the activities to remove the waste to approved disposition.

K2 Decommissioning

Decommissioning may be required when a facility's operating mission has ended, when a facility has reached the end of its design life/ technical obsolescence, when a facility can no longer function economically or safely, at the conclusion of a research program, due to changes in governmental

policy, or other reasons (security, accident, etc.). Not all facilities require Decommissioning. Facilities Requiring Decommissioning include:

Gaseous Diffusion Plants	Research Reactors
Power Reactors	Uranium Mining and Milling Facilities
Defense Production Facilities	Glove box Labs and other R&D labs
Fuel Processing Facilities	Waste Management Facilities
Hot Cell Facilities	Fuel Fabrication Facilities
Tritium Extraction Facilities	Industrial Facilities

Decommissioning is removing a facility or site safely from service and reducing residual radioactivity to a level that permits: 1) release of property for unrestricted use and license termination, or 2) release of property under restricted conditions and license termination. The scope of this WBS element includes the activities to prepare the building, structure, or plant for demolition that include removal and or reduction of radiological contaminates, or radiological contaminated equipment in order to achieve a level of radiological contamination necessary to conduct Demolition operations. Also includes the activities to remove the waste to approved disposition.

K3 Demolition & Removal
The scope of this WBS element includes activities to demolish the building, structure, or plant; size reduction, segregation, and load of the building waste to include dismantling of equipment and structures typically to allow for the completion of the decommissioning process by use of or some combination of thermal, mechanical or electrical removal methods. This also includes removal of below grade structures and infrastructure, as well as final grading and restoration of site.

K4 Waste Management
The scope of this WBS element is to provide for the activities to be performed after removal of the designated waste. These activities include packaging and handling, transportation and verification sampling and reports that will be used to document attainment of the remediation end-point and gain approval for final closure. Also included is any final contouring of soils and placement of vegetation that will remain.

K5 Demobilization
The scope of this WBS element is to provide the deactivation and demolition/removal of all facilities remaining that supported the D&D activities. These support facilities are required to be removed, relocated, and/or demolished from the site at the conclusion of the D&D Project. Also included may be the posting of long-term physical barriers or signage designed to provide protection to employees and or the public.

APPENDIX L: COMMON ELEMENTS

Elements defined in this Appendix are elements common to all DOE projects. The efforts associated with common elements should be placed at the level where they support a specific element. Common elements can be found at all levels of a WBS. Not all common elements will be applicable at every level of the WBS.

WBS Structure

LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4
Major Group Element	**Group Elements**	**Sub-Group Elements**	**Individual Elements**
L Common Elements	L1 System Design & Engineering	L1.1 System Definition and Design	
		L1.2 Requirements Management	
		L1.3 Reliability Engineering	
		L1.4 Human Systems Integration	
		L1.5 Configuration Management	
		L1.6 Data Management	
	L2 Project Administration & Facilities	A2.1 Technical Management	
		A2.2 Facility Management	
		A2.3 Contracts and Procurement Management	
		A2.4 Cost & Schedule Management	
		A2.5 Legal & Regulatory	
		A2.6 Environmental Compliance, Safety, & Health	
		A2.7 Training	
		A2.8 Security	
	L3 Support Equipment and Facilities	L3.1 Support Equipment	L3.1.1 Material Handling Equipment (e.g. Cranes)
			L3.1.2 Transfer Equipment (e.g. Fork Lifts/Trains/etc.)
			L3.1.3 Excavation Equipment
		L3.2 Support Facilities	L3.2.1 Temporary Facilities/Trailers
			L3.2.2 Assembly/Maintenance Facilities
			L3.2.3 Storage Facilities
			L3.2.4 Restroom Facilities
			L3.2.5 Support Treatment / Processing / Other
	L4 System Test & Evaluation	L4.1 Simulation (Cold Test)	
		L4.2 Integration Test	
		L4.3 Operational Test (Hot test)	
		L4.4 Test & Measurement Equipment	
		L4.5 Sampling and Monitoring	
		L4.6 Commissioning	
		L4.7 Operations Start-Up	
	L5 Integration, Assembly, Test, and Checkout		
	L6 Operations and Support	L6.1 Manpower	
		L6.2 Unit Operations	
		L6.3 Maintenance	
		L6.4 Sustaining Support	
		L6.5 Continuing Improvements	
		L6.6 Indirect Support	

WBS Element Definitions

L Common Elements

This WBS consists of activities take place on most if not all projects, to include Support equipment and facilities, systems test and evaluation, project management and administration, system design and engineering, and operations and support.

L1 System Design & Engineering

This WBS element contains all the resources associated with all engineering from functional specialists who provide technical planning, technical management, analysis, and support efforts for development and production activities. The Systems Engineering entity is responsible for the analysis, derivation, allocation, and traceability, of requirements and interfaces. Examples of System Design and Engineering include systems definition, system safety, algorithm development, human

engineering, and trade studies. Design and Engineering also applies to the "design" of demolition and remediation tasks.

L1.1 System Definition and Design
This element covers development of overall system designs, drawings, plans and program specifications. It also covers Design/Engineering support of both internal and external technical reviews.

L1.2 Requirements Management
This element ensures requirements traceability and version control for all program requirements starting with CD-2, and covering the system specification and lower level Configuration Item (CI) specifications.

L1.3 Reliability Engineering
The engineering process and series of tasks required to examine the probability of a device or system performing its mission adequately for the period of time intended under the operating conditions expected to be encountered.

L1.4 Human Systems Integration
The engineering process and the series of tasks required to define, as a comprehensive technical and engineering effort involving the integration of the human operator and maintainer requirements while attempting to minimize lifecycle cost and maximize total system performance.

L1.5 Configuration Management
This element supports the identification and management of the technical baselines (functional baseline, allocated baseline, initial product baseline, final product baseline).

L1.6 Data Management
This element identifies the essential technical data necessary for the definition and sustainment of the system reflected in the respective technical baselines.

L2 Project Administration/Project Management
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution to accomplish overall project objectives which are not associated with specific hardware elements and are not included in systems engineering.

L2.1 Technical Management
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution to accomplish technical project objectives which are not associated with specific hardware/equipment/facility elements and are not included in systems engineering. This includes technical designs, technical reports, risk management, interface management, requirements management, development of technical processes, upholding technical standards, etc.

L2.2 Facility Management
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution to effectively manage a project facility which are not associated with specific hardware/equipment/facility elements and are not included in systems engineering.

L2.3 Contracts and Procurement Management
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution designated to effectively manage contracts and procurements which are not associated with specific hardware/equipment/facility elements and are not included in systems engineering.

L2.4 Cost & Schedule Management
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution designated to effectively maintain the processes of evaluating, estimating, budgeting, monitoring, analyzing, forecasting, and reporting cost and schedule information. Many organizations throughout DOE refer to these activities as Project Controls.

L2.5 Legal & Regulatory
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution designated to effectively manage all legal and regulatory obligations for the construction of the facility.

L2.6 Environmental Compliance, Safety & Health
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution designated to ensure the complete compliance of all Environmental rules and regulations as well as Safety & Health rules and regulations during all phases of the facility construction.

L2.7 Training
Development of training material and deliverable training services, devices, accessories, aids, equipment, and parts used to facilitate instruction through which personnel will learn to conduct process and procedures associated with assigned operations, and or the use of personal protective equipment, safety and health equipment.

L2.8 Security
The business and administrative planning, organizing, directing, coordinating, controlling, approval actions and execution designated to ensure a secure site during all phases of the facility construction. This includes security of site workers, property and information.

L3 Support Equipment & Facilities
Procurement, lease or rental of equipment and facilities that supports the facility construction effort.

L3.1 Support Equipment
Procurement, lease or rental of equipment that supports the facility construction effort.

L3.1.1 Material handling equipment (e.g., cranes)
Procurement, lease or rental of equipment related to the movement, storage, control and protection of materials, goods and products throughout the process of facility construction. Includes storage and handling equipment, engineered systems, cranes, industrial trucks, and bulk material handling.

L3.1.2 Transfer equipment (e.g., fork trucks/trains/etc.)

Procurement, lease or rental of equipment related to the transfer of materials, goods and products to another site. Includes fork trucks, trains, trailers, etc.

L3.1.3 Excavation equipment
Procurement, lease or rental of heavy equipment used for excavation at the facility construction site. Includes excavators, diggers, steam/power shovels, bulldozers, etc.

L3.2 Support Facilities
Procurement, lease, rental, assembly and/or construction of facilities that support the main facility construction effort.

L3.2.1 Temporary Facilities/Trailers
Temporary structures used in support of the facility construction.

L3.2.2 Assembly/Maintenance Facilities
Assembly and maintenance structures used in support of the facilities mission. This includes vehicle maintenance facilities, manufacturing plants, factories, etc.

L3.2.3 Storage Facilities
Storage facilities used in support of the facilities mission. This includes warehouses, etc.

L3.2.4 Restroom Facilities
Restroom facilities used in support of people working in or around the facility.

L3.2.5 Support Treatment/Processing/Other Facility
This element includes the new facility construction effort for 'n' facilities. Includes any new facility construction specific design and engineering, testing, and project management.

L4 System Test & Evaluation
Tests and evaluations to obtain data on the performance of facility systems or contamination of remediation areas.

L4.1 Simulation (Cold Test)
Includes efforts to assess the system's effectiveness, reliability, maintainability, etc. in a controlled, simulated environment without subjecting the system to live power or radioactive, toxic, or hazardous substances. Includes all detailed planning, support, data reduction, reports and all hardware/software items consumed in the conduct of the testing.

L4.2 Integration Test
Includes efforts to assess, measure, and verify system and subsystem interfaces. Includes all detailed planning, support, data reduction, reports and all hardware/software items consumed in the conduct of the testing.

L4.3 Operational Test (Hot Test)
Includes efforts to assess and certify the system for operational use in a controlled, but non-simulated environment by subjecting the system to live power or radioactive, toxic, or hazardous substances.

Includes all detailed planning, support, data reduction, reports and all hardware/software items consumed in the conduct of the testing.

L4.4 Test & Measurement Equipment
Includes the procurement, rental, or lease of all test & measurement equipment not specific to any specific test. Examples include calibration instruments, electronic meters, oscilloscopes, probes, digital multimeters, etc.

L4.5 Sampling and Monitoring
Includes efforts to assess and certify contamination levels and types. Includes investigations, characterization, treatability tests, destructive sampling, borings, compliance monitoring, and sample analysis. Includes planning, support, reports, data management, and sample management. It also includes the procurement, rental, or lease of all sampling & measurement equipment not specific to any specific sample. Examples include calibration instruments, electronic meters, spectroscopes, chromatographs, radiation detectors, etc.

L4.6 Commissioning and Operations Start-up
Cost incurred as a result of achieving, verifying, and documenting that the performance of the facility or system and its various components meet the design intent and the functional and operational needs of the intend owners, users, and occupants. It includes the cost incurred as a capital asset project transitions from construction to operations and maintenance during CD-4. These costs are attributable to activities such as the development of operations and maintenance manuals, generation of as-built drawings, identification of operations budget, and the procurement of any materials required for initial operations. Commissioning of capital asset projects for nuclear or chemical process facilities requires the determination by the DOE project office if hot commissioning (i.e., introduction of radioactive material) is a condition of CD-4. Operational readiness review/readiness assessment is conducted during the project execution phase (i.e., CD-3) in preparation for CD-4; accordingly, these other project costs (OPCs) are not components of commissioning costs.

L4.7 Operations start-up
The scope associated with developing a start-up plan associated with a new facility

L5 Integration, Assembly, Test and Checkout
This element includes all effort of technical and functional activities associated with the design, development, and production of mating surfaces, structures, equipment, parts, materials, and software required to assemble the lower level equipment (hardware/software) elements into a higher level equipment (hardware/ software) as a whole and not directly part of any other individual lower level element.

Includes, for example:
- The development of engineering layouts, determination of overall design characteristics, and determination of requirements of design review
- The set-up, conduct, and review of testing assembled components or subsystems prior to installation
- The detailed production design, producibility engineering planning (PEP), and manufacturing process capability, including the process design development and demonstration effort to achieve

compatibility with engineering requirements and the ability to produce economically and consistent quality
- Inspection activities related to receiving, factory and vendor liaison
- Design maintenance effort
- Quality planning and control
- Tooling (initial production facilities, factory support equipment) including planning, design, and fabrication
- Administrative engineering
- The joining or mating and final assembly of lower level equipment elements resulting in higher level equipment elements when the effort is performed at the manufacturing facility
- Integration of software (including loading and verification of firmware)
- Conduct of production acceptance testing

Excludes, for example:
- All systems engineering/program management and system test and evaluation which are associated with the overall system

Note: When an integration, assembly, test, and checkout element is utilized at lower levels of the contract WBS, it will be summarized into the next higher level equipment (hardware/software) WBS element and should never be summarized directly into a higher level integration, assembly, test, and checkout element.

L6 Operations and Support
This element covers the cost of operating and sustaining a facility upon completion of commissioning and operations start-up.

L6.1 Manpower
This element captures the cost of operators, maintainers, and other support manpower assigned to operating units, to include both government and contractor support.

L6.2 Unit Operations
This element captures the cost of unit operating material (e.g., fuel and training material), unit support services, and unit travel. It excludes the cost of all maintenance and repair material.

L6.3 Maintenance
This element captures the cost of all maintenance (e.g. repair parts) other than maintenance manpower.

L6.4 Sustaining Support
This element captures the cost of support activities other than maintenance that can be attributed to a system and are provided by organizations other than operating units.

L6.5 Continuing Improvement
This element captures the cost of hardware and software modifications to keep the system operating and operationally current.

L6.6 Indirect Support

This element captures the cost of support activities that provide general services that cannot be directly attributed to a system. Indirect support is generally provided by centrally managed activities that support a wide range of activities.