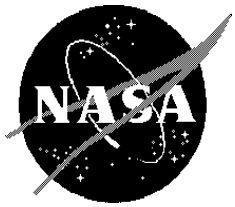
Program/Project Management Series

Work Breakdown Structure Reference Guide



National Aeronautics and

Table of Contents

Chapter 3: WBS Use

About This Reference Guide

The work breakdown structure (WBS) is an effective tool in managing NASA programs and projects. It assists both NASA and contractors in fulfilling management responsibilities. In accordance with NASA Handbook 7120.5, *Management of Major System Programs and Projects*, a WBS is mandatory for major system acquisitions and major projects, and will be used for other projects when practical. A WBS is required when performance measurement is applied to a contract.

The purpose of this WBS reference guide is to support the completion of program and project objectives within budget and schedule constraints. This reference guide can be used for various work efforts including research, development, construction, test and evaluation, and operations. The products of these work efforts may be hardware, software, data, or service elements (alone or in combination).

A glossary (Appendix A) and an acronym listing (Appendix B) have been included at the end of this reference guide.

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Chapter 1:
WBS Basic Information

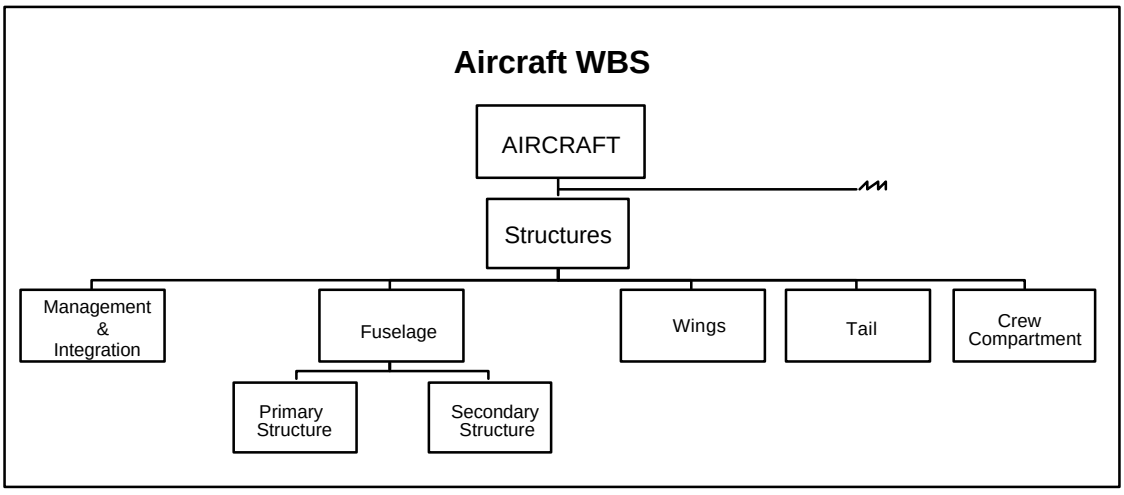
This chapter provides general work breakdown structure information including definition, types, guidelines and development process.

Definition

Each NASA program has a set of goals which are developed from NASA mission needs. These program goals are expanded into specific project objectives. The function of management is to plan and direct project activities to achieve the program goals.

The purpose of a work breakdown structure (WBS) is to divide the program/project into manageable pieces of work to facilitate planning and control of cost, schedule and technical content. A WBS is written early in program/project development. It identifies the total work to be performed and divides the work into manageable elements, with increasing levels of detail.

The following example displays a portion of a WBS for a commercial aircraft project.



A WBS is developed by first identifying the system or project end item to be structured, and then successively subdividing it into increasingly detailed and manageable subsidiary work products or elements. Most of these elements are the direct result of work (e.g., assemblies, subassemblies, and components), while others are simply the aggregation of selected products into logical sets (e.g., buildings and utilities) for management control purposes. In either case, the subsidiary work product has its own set of goals and objectives which must be met in order for the project objectives to be met. Detailed tasks which must be performed to satisfy the subsidiary work product goals and objectives are

then identified and defined for each work product or element on which work will be performed.

Completion of an element is both measurable and verifiable by persons (i.e., quality assurance persons) who are independent of those responsible for the element's completion. Because WBS element/product completion can be verified, a WBS provides a solid basis for technical, schedule and cost plans and status. No other structure (e.g., code of account, functional organization, budget and reporting, cost element) satisfactorily provides an equally solid basis for incremental project performance assessment.

WBS Types

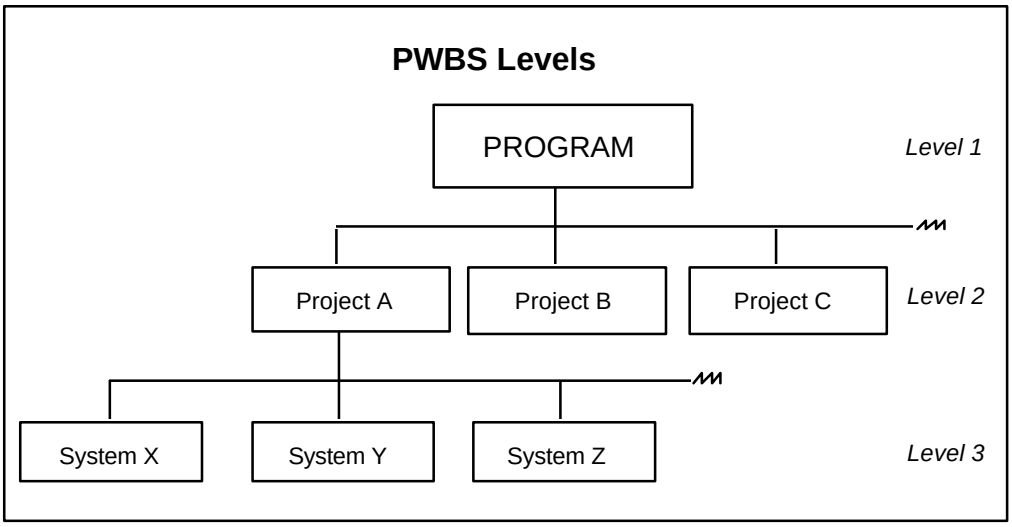
NASA uses two types of WBS: program/project WBS, and contract WBS. Following is a description of each.

Program/Project WBS

The program/project WBS (PWBS) is the structure that encompasses the entire program or project. It usually consists of three levels of products/elements with associated work definitions. The three upper levels of the PWBS are defined below.

- Level 1 is the entire program/project.
- Level 2 elements are the major product segments or subsections.
- Level 3 contains definable components, or subsets, of the level 2 elements.

This PWBS breakdown is fairly standard throughout NASA (see chart below). It is possible, however, for software and management elements to appear at system and subsystem levels.

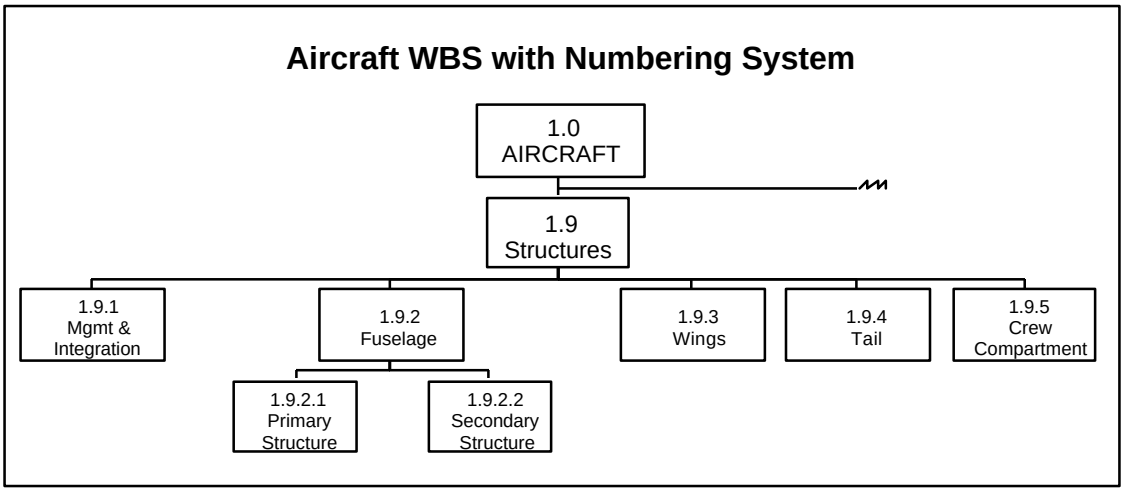


There are numerous terms used to define succeeding levels of the PWBS below the subsystem level. Some examples are equipment, assembly, subassembly, component, and part. The choice of which to use is made by project management.

A properly structured PWBS will readily allow complete aggregation of cost, schedule and performance data from lower elements up to the program level. WBS elements should be identified by title and by a numbering system that performs the following functions:

- Identifies the level of the WBS element.
- Identifies the higher-level element into which the element will be integrated.
- Identifies the cost account number (if any) of the element.

The following portion of a WBS for a commercial aircraft system includes an example of a PWBS numbering system.



Normally, NASA will control only to the top three levels of the PWBS. The lower levels are controlled by contractors. Complete numbering system standardization and uniformity may not be possible since contractor coding systems vary from contractor to contractor. When possible, contractors should follow the PWBS numbering system in use.

The PWBS is used as a starting point for individual contractors to develop their contract work breakdown structures (CWBS). If numbering system conversion is not possible without substantial cost, a coding interface conversion system will have to be applied down to the CWBS control levels or, as a minimum, at the top level of the CWBS.

PWBS examples can be found in Appendix C.

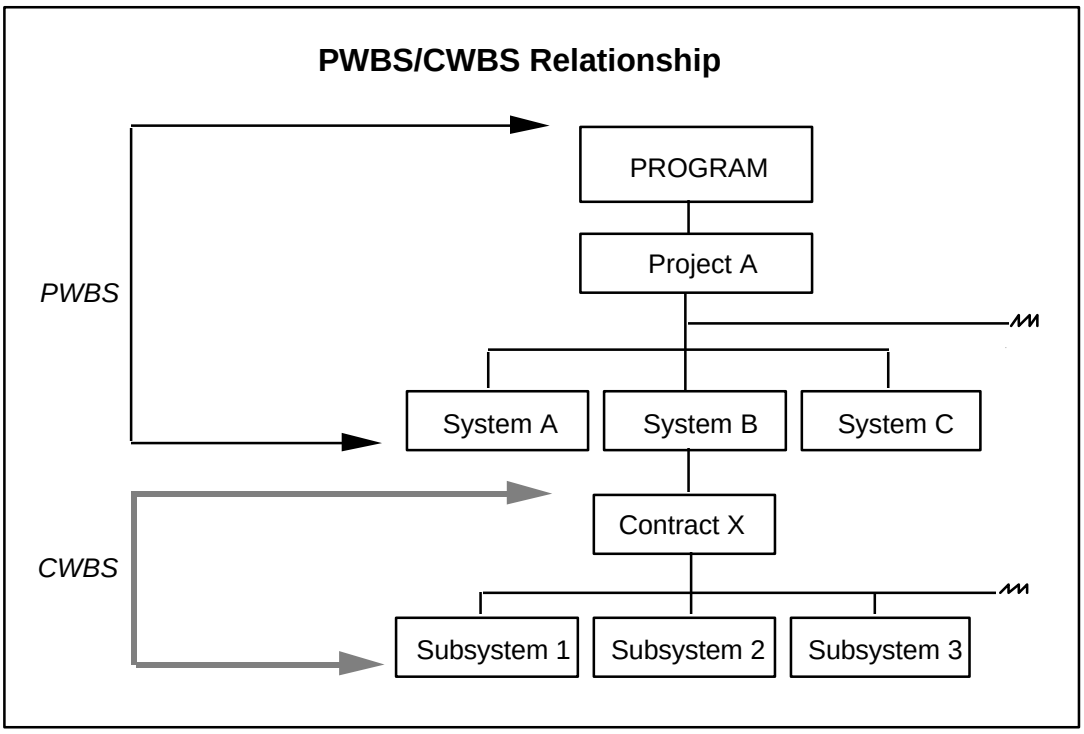
Contract WBS

The contract work breakdown structure (CWBS) is the complete WBS for a specific contract. It is developed by the contractor in accordance with the contract statement of work (SOW). It includes the PWBS elements for the products which are to be furnished by the contractor. The contractor extends these elements and defines the lower-level

products. The contract reporting requirements will indicate the CWBS levels or elements for which contract status is to be reported to NASA.

A CWBS provides a consistent and visible framework that facilitates uniform planning, assignment of responsibilities, and status reporting.

The following chart shows the relationship of the PWBS and CWBS.



Following is a typical contract clause used for incorporating the CWBS into a contract. You should work with the contracts or procurement organization to develop the desired contractual language for such a clause.

> *A Contract Work Breakdown Structure has been negotiated between NASA and the Contractor. The top levels of the Contract Work Breakdown Structure are formally incorporated into the contract as set forth in Exhibit xx attached. The elements shown in this exhibit may not be changed except by contractual action. Lower tier elements which are not shown in this exhibit may be changed by the contractor as appropriate, provided that notification of such changes is provided to the NASA Contracting Officer.*

CWBS examples are found in Appendix D.

Guidelines

A WBS is prepared for each NASA program/project and covers in-house and contractor efforts. There is no single "best way" to prepare a PWBS or a CWBS. Following are some general guidelines to help you when creating a WBS.

- The PWBS is prepared as early as project definition will permit.
- A preliminary PWBS is developed in Phase A to define the top levels of a PWBS for the entire project (system) life cycle. Normally, this life cycle PWBS will be in two parts: one part for the acquisition cycle of the system being acquired (Phases A through D), and one part for the operations and support phase (Phase E).
- The PWBS is to be compatible with the NASA Agency Wide Coding Structure defined in NASA Financial Management Manual (FMM) 9100.
- A final PWBS is prepared by compiling the elements of the CWBS(s) with the preliminary PWBS.
- As design concepts change, the PWBS is further refined and changed to reflect new systems and subsystem approaches.
- When a project is authorized by a program commitment agreement (PCA), the PWBS becomes formalized as the project outline, and all changes to it should be formally approved by the program office.
- The preliminary CWBS, written by NASA project personnel, is developed through no more than the three highest levels of the proposed contract.
- The preliminary CWBS is developed from the basic elements of the PWBS and expanded for use in the request for proposal (RFP), preparation of proposals, and the evaluation and selection process.
- Normally, only the top three levels of the CWBS will be specified by NASA in an RFP. The CWBS is considered a preliminary CWBS until it is finalized as a result of negotiation and incorporated formally into the contract.
- When high risk items are located at low CWBS levels, these items can be identified against the higher-level PWBS or CWBS element of which the high risk item is a part. It is not necessary or desirable to extend the CWBS below the top three levels in order to identify the high risk item.

Summary

As previously discussed, a work breakdown structure defines all work to be performed for project completion. It is a product-oriented structure, not an organizational structure. To develop and maintain a WBS, you must have a clear understanding of the project's objectives and the end item(s) or end product(s) of the work to be performed. The WBS elements should represent identifiable work products (e.g., hardware, software, data or related service products).

Because of its product orientation, a WBS provides the framework to plan, track and assess the project's technical, schedule and cost performance.

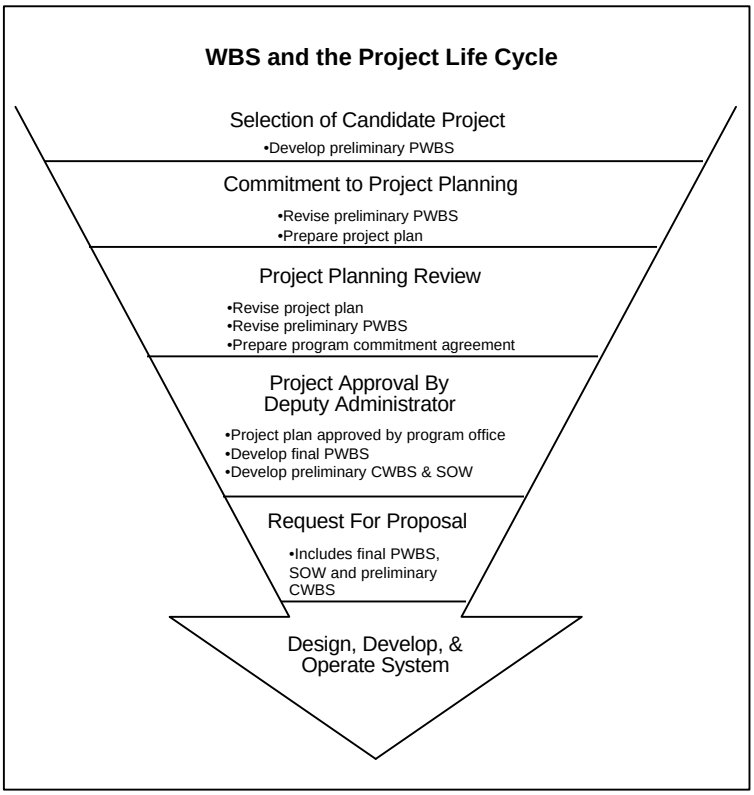
Chapter 2:
WBS Development and Maintenance

This chapter discusses the following topics: WBS and the project life cycle, WBS activities, development considerations, development techniques and common development errors.

WBS and the Project Life Cycle

A preliminary WBS is established as soon as program management believes the project has reached a stage of definition where it is feasible. It is used to assist in the preparation of the program commitment agreement (PCA) and the project plan. The preliminary project development process is an iterative process. During its early phases the preliminary WBS may be revised as necessary. Once the project is established in sufficient depth, procurements may be planned by using selected PWBS elements to develop preliminary CWBSs. Preliminary CWBSs are incorporated into the RFPs, subsequent proposals, and eventually finalized in the executed contract(s) based on negotiations.

The chart below summarizes the WBS development process.



For more information about work breakdown structures and the project life cycle, see Appendix E, the WBS section of the NASA Handbook 7120.5, *Management of Major System Programs and Projects.*

WBS Activities

The NASA project office is responsible for developing and maintaining the PWBS, and for negotiating and approving each CWBS.

The PWBS is developed early in the conceptual stages of the project. Initially, the PWBS may be based on one that was developed for a similar project. The PWBS evolves from an iterative analysis of: the project objectives, the functional design criteria, project scope, technical performance requirements, proposed methods of performance, as well as drawings, process flow charts, and other technical documentation.

Final approval of the PWBS is achieved through approval of the project plan. Once approved, the PWBS should not be revised except through the formal approval process at major transitional points in the acquisition process.

The NASA project office incorporates the PWBS into each request for proposal (RFP) by selecting the PWBS elements for the work products that will be required by each contract. Each RFP includes the same PWBS prepared by the NASA project manager. The PWBS should include the initial WBS dictionary, which is a narrative description (or definition) of each element appearing on the work breakdown structure. The RFP instructs potential contractors to extend the selected CWBS elements appropriately.

Once NASA issues the requests for proposals, the contractor extends the selected CWBS elements appropriately to create a proposed CWBS to be submitted with the proposal. If the solicitation requires a CWBS dictionary, the proposal should use the specified forms.

Contractors may suggest changes to the selected CWBS elements when a change is needed to meet an essential requirement of the RFP or to enhance the effectiveness of the CWBS in satisfying the project objective. In proposing a CWBS, a contractor may determine that the CWBS contained in the RFP would force some unusual requirements on existing contractor management control systems. The contractor may, therefore, suggest modifying the CWBS to facilitate the contractor's approach to management.

As part of the proposal evaluation, NASA performs a technical evaluation of the CWBS submitted by each proposer.

NASA selects the winning contractor and negotiates the contract. The contractor may have proposed alternate approaches to better accomplish the contract objectives. If NASA accepts and negotiates alternatives that impact the proposed CWBS, revisions to the CWBS will also have to be negotiated.

Following NASA approval of the negotiated contract, including the CWBS, NASA awards the contract.

NASA then reviews the PWBS for the impact of any approved CWBS changes. Any time changes are proposed for the PWBS, NASA should give careful consideration before approving them.

The contractor maintains the CWBS, including change traceability. Only NASA-approved changes may be incorporated in accordance with the contract terms.

The following table summarizes the WBS activities and identifies the responsible party for each activity.

WBS Activity	Responsible Party	
	NASA	Contractor
Prepare PWBS		
Select PWBS elements for CWBS and include in RFP		
Extend CWBS and submit in proposal		
Conduct technical evaluation of the contractor-proposed CWBS		
Select contractor		
Negotiate contract (including changes to CWBS, if any)		
Approve CWBS and award contract		
Review PWBS for impact of approved CWBS changes		
Maintain PWBS		
Maintain CWBS		

Development Considerations

These items should be considered when developing a PWBS or CWBS:

- compatibility of PWBS and CWBS
- compatibility with internal organization structure and management systems
- correlation with other requirements
- number of levels
- all inclusiveness
- change control

Following is a brief discussion of each consideration. Checklists to aid in the development process are found in the next section, Development Techniques.

Compatibility of PWBS and CWBS

Each CWBS must be an extension of the PWBS elements selected by NASA, and must be structured and coded so that technical, schedule and cost information may be readily summarized into the PWBS. In turn, the PWBS must accommodate management needs of the winning contractors to the maximum practical extent.

Compatibility with Internal Organization Structure and Management Systems

The WBS is a tool used by both NASA and contractor management. Management objectives and needs play a dominant role in the development of a WBS. Both NASA and contractor management have flexibility in developing a WBS to accommodate their objectives and needs, including their organization and management and reporting systems. Management plans to perform the work, produce the work products, and verify that they were correctly produced, as well as the manner in which contract support work efforts are organized, managed and reported should be reflected in the WBS.

For in-house work, NASA management should follow the same basic procedure. The project manager should provide flexibility for the performing organizations to structure the lower WBS tiers for compatibility with their needs.

Correlation with Other Requirements

Each proposer's submittal should be based on the WBS contained in the RFP. However, both NASA and the proposed contractors should give attention to the correlation of the CWBS with other requirements of the contract and the project. Simply stated, when developing the WBS, do not lose sight of the project's (or contract's) overall goals.

Number of Levels

The hierarchical structure of a WBS is an important consideration. Following is a brief discussion of PWBS levels and CWBS levels (including cost accounts).

PWBS Levels

Normally, the PWBS contains only the top three levels. When necessary, lower-level elements may be included to clearly communicate all project requirements, or if there is a significant degree of technical risk associated with some lower-level elements. The PWBS may also end at the second level for those elements in which NASA wishes to give the contractor flexibility to provide further definition. If detailed levels are stipulated below the third level of a project, the contractor's normal method of operation may be hampered or excessive reporting requirements may result. Through the negotiation, these impacts may be discussed and minimized or alleviated. The RFP should instruct contractors to

extend the selected CWBS elements to a level as low as necessary to provide a useful management tool.

CWBS Levels

Work is performed by organization units which are usually structured by function or type of work performed. The work is performed to satisfy technical objectives established for each product or subproduct identified as a WBS element.

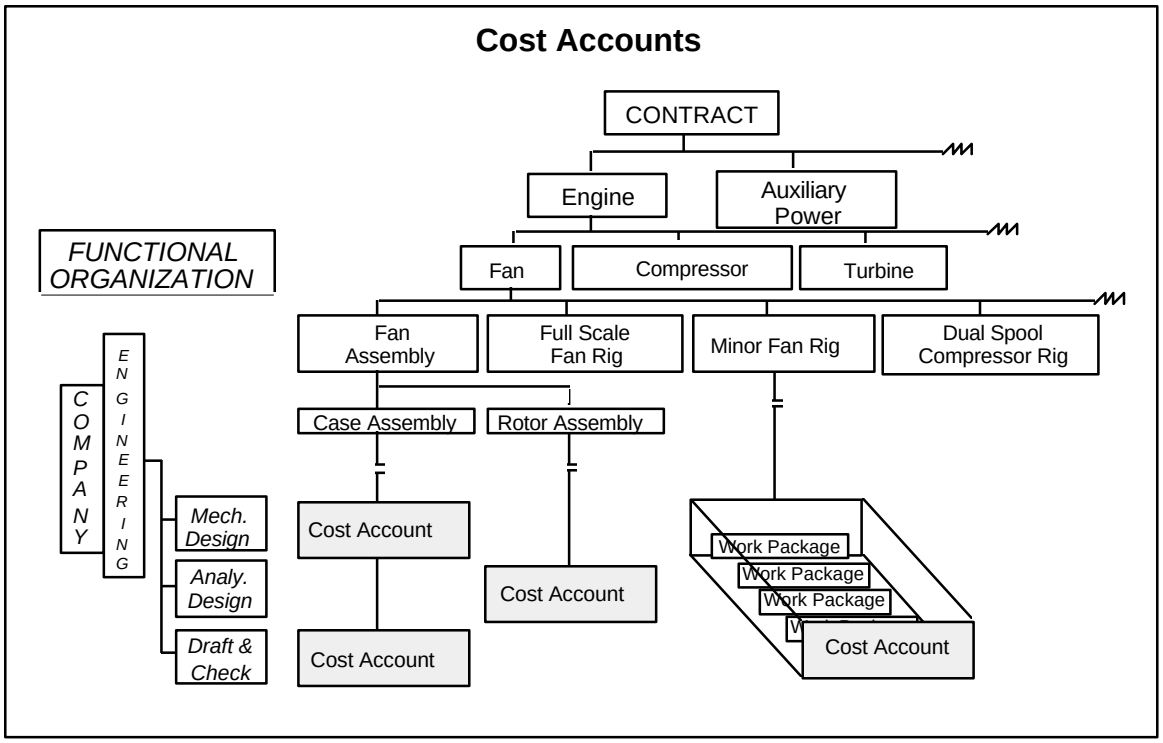
As greater breadth or depth is achieved within a CWBS, each element's technical complexity and resource requirement are reduced. The number of levels and elements in the structure is generally dependent upon the size and complexity of the total effort, the degree of technical uncertainty, organizational structures concerned, and individual contractor management's judgment of need.

Cost Accounts

As the end product is subdivided into smaller and smaller subproducts at lower and lower WBS levels, the work effort required by each element can be identified to functional organization units at a lower and lower organization level. At some level on each WBS branch, the contractor will assign management responsibility for technical, schedule, and cost performance. At this juncture of WBS element and organization unit, cost accounts are usually established, and performance is planned, measured, recorded and controlled. To do this, the technical requirements for the work and work product must be specified, the work scheduled, budgeted, and performed, and product attainment of specified technical requirements verified.

Cost accounts consist of one or more work packages. A work package is the unit of work required to complete a specific job such as a report, a design, a drawing, a piece of hardware, or a service. It is usually the lowest element shown in a WBS.

The following chart shows how cost accounts fit into the contract structure.



To provide the responsible cost account manager with technical, schedule, and cost information needed to manage the organization's work on the WBS element for which it is responsible, all management control systems must be keyed to the same WBS element and organization unit.

The WBS level at which a cost account is established is primarily a function of the size of the project and the type of product. The responsible organization level is a function of the management span of control and upper management's desire to delegate technical, schedule, and cost responsibility for WBS elements to lower management levels.

When identifying cost accounts, the contractor must be allowed to establish organization responsibilities at meaningful and appropriate levels. If this is not allowed, the contractor's existing management control systems and responsibility assignments may be adversely impacted.

The cost account brings together all aspects of the contractor's management control systems including technical definition, budgets, estimates, schedules, work assignments, accounting, progress assessment, problem identification, and corrective actions.

All Inclusiveness

A PWBS should include all work and products for a program or project, and a CWBS should include all work and products for a contract.

PWBS

The PWBS should be all inclusive and represent all products and subproducts for all potential project participants (e.g., designers, constructors, vendors, operators, project managers). The PWBS is used to specify contract work products for all of the project participants.

CWBS

The CWBS must similarly include all work to be performed under the contract. This will include the WBS elements specified by NASA.

Major subcontracts, if any, will also need to be included. In some cases, the subcontracted effort may provide for delivery of a single lower-level CWBS element, such as a vendor fabricated subassembly. In other cases, the subcontract may provide for effort covering several lower-level CWBS elements, such as design for the electronics, communications, and instrumentation systems in a new facility. In either case, the prime contractor's CWBS dictionary (and other management control systems) must be capable of uniquely distinguishing major subcontractors' responsibilities from each other and from the work retained in-house by the prime contractor. This is accomplished at the lower levels of the CWBS.

Change Control

While strong efforts should be placed on early and accurate WBS planning, WBS revisions may result from expansion or contraction of project/contract scope, and/or the movement of a project through its various stages (i.e., engineering, development, and operation). Whenever the WBS is revised, formal documentation of the revision to the previous WBS must be maintained.

PWBS Development

The WBS development process may be iterative. Changes may occur as the products of the work effort are more accurately defined or when a revised product structure (resulting from technically different requirements or a more cost effective approach to satisfy the requirements) is used. The PWBS should be revised to reflect changes resulting from contract negotiations.

The deliverable products of different project phases may differ (i.e., the products of the engineering phase may be sets of drawings, specifications and material lists, while the products of the development phase may be hardware, software, and data). However, the PWBS for each phase should reflect the end products to be produced or constructed. That is, at PWBS levels, the products of the engineering phase should be structured the same as the development phase.

Contractor-Proposed PWBS Changes

Approval of contractor-proposed changes to the PWBS must be made with great care. It is important to always be able to identify the interrelationships of each contractor's efforts to the overall project objectives.

CWBS

The CWBS is a contractual requirement and may not be changed without NASA approval. NASA should specify the CWBS elements for which NASA approval is required prior to contractor revision. Usually the NASA-controlled elements are identical to those specified for periodic contractor reporting.

Development Techniques

The following techniques will help you develop a WBS: coding of elements, preparing graphic diagrams, preparing a WBS dictionary, and using development checklists.

Coding of Elements

NASA is required by law to account for obligations and costs in a matter that is consistent with Congressional authorization and appropriation of the money. The Agency Wide Coding Structure (AWCS) is the internal means used by the Agency to account for all financial activities associated with funds appropriated by Congress. When developing a WBS, the project manager works with the financial organization to identify the account codes for the WBS elements.

Each PWBS element is assigned a PWBS element code to be used for its identification throughout the life of the project. A simple decimal or alphanumeric coding system that logically indicates the level of an element and related lower-level subordinate elements is applied. A common coding system facilitates communications among all project participants. Each CWBS coding system must be traceable to the PWBS coding system.

The table below illustrates the first four PWBS levels of a typical coding system.

PWBS Element	PWBS Level	PWBS Number	AWCS Coding
Program	1	1.0	XX
Project	2	1.1	XX-XXX
System	3	1.1.1	XX-XXX-XX
Subsystem	4	1.1.1.1	XX-XXX-XX-XX

An auxiliary coding structure may be needed to accommodate summary requirements other than technical, schedule and cost data for each element. Other summary requirements might include code of accounts (financial accounting structure), organization structure and budgeting structure.

Preparing Diagrams

WBS diagrams are routinely developed to provide a visual display. A pictorial view of the WBS aids the reader in understanding how lower-level project components support and contribute to higher-level components. This type of diagram is often called a "family tree" or "goes into tree" diagram.

Examples of WBS diagrams can be found in pages 2 and 3, and in appendices C and D.

Preparing WBS Dictionary

A WBS dictionary lists and defines the WBS elements. It is initially prepared for the PWBS by the NASA project manager, and is expanded in greater detail at lower levels by contractors as the CWBSs are developed.

The WBS dictionary briefly describes each WBS element and the resources and processes required to produce each element. This provides a link to the detailed technical documents. The dictionary may also contain an index which lists the WBS elements in indented format to show their hierarchical relationship.

Each element definition should include the following:

- System design description number - a coded link to quantitative technical engineering definition of process performance and product completion.
- Cost content - for resource identification.
- Technical content - a brief quantitative description of form, interface, and function.
- Work statement - identifies the process to accomplish the work.

A WBS dictionary should be revised to reflect changes and should be maintained in a current status throughout the life of the project.

Using Checklists

Checklists are a useful tool to ensure proper WBS development. Following are three separate checklists: PWBS development, contractor-proposed PWBS changes, and CWBS development.

PWBS Checklist

The PWBS checklist helps ensure that all major factors have been considered during development.

1. Has the PWBS subdivided the end product into discrete and logical product-oriented elements? (A project is usually subdivided into one or more hardware, software, data and/or service product elements at level 2.)

2. If there are any elements below level 3, are they of exceptional risk?

3. Are the proposed PWBS elements complete, compatible, and continuous?

4. Does the PWBS provide for further logical subdivision of all project products requiring the application of resources?

5. Do the PWBS elements correlate with the following:

   - project specification tree
   - NASA system engineering requirements
   - functional design criteria
   - technical scope of work
   - manufacturing, engineering and construction engineering requirements
   - configuration management requirements
   - NASA internal reporting level elements

Contractor-Proposed PWBS Changes Checklist

The following key issues should be considered before approving contractor-proposed changes to the PWBS.

1. Can the revised PWBS still provide a meaningful structure for relating the objectives of the various systems and subsystems to each other and to the total project?

2. Does the revised PWBS still define the deliverables and products which NASA is buying?

3. Does the revised PWBS still provide a meaningful structure for measuring and controlling the technical, schedule and cost performance of the deliverable?

4. If the proposed PWBS change is disapproved, what is the impact on the contractor's management capabilities?

5. If the proposed PWBS change is approved, what is the impact on other contractors' CWBSs?

CWBS Checklist

It is important to consider the following when evaluating a proposed CWBS.

1. Is the CWBS code structure compatible with the PWBS? Is summarization of data into the PWBS (by automation or other techniques) possible?

2. Is the proposed CWBS compatible with the contractor's organization and management system?

3. Do the CWBS elements correlate with the contract:

   - specification tree
   - line items
   - end items
   - data items
   - work statement tasks
   - configuration management requirements
   - reporting levels

4. Has the contractor defined distinct and logical product-oriented CWBS elements down to the level where such definitions are meaningful and necessary for management purposes?

5. Do the CWBS elements encompass all the products of all the work NASA has contracted?

6. Do the CWBS elements encompass all the products of all the work to be performed under subcontract?

7. Is level of effort work minimized by eliminating high-level functional WBS elements? (For example, design engineering is a function which should be planned, budgeted and costed in work packages assigned to unique product elements.)

8. Have modifications or changes involving new product elements been appropriately integrated?

Common Development Errors

Three common WBS development errors are: using a WBS from an unsuitable prior project, including non-product elements, and including functional elements.

Unsuitable Old WBS Error

If the WBS from a prior project will be used as a basis for WBS development of a new project or contract, be careful not to perpetuate any mistakes or undesirable features of the earlier WBS. Discuss the adequacy of the previous WBS with the manager of that project.

Non-Product Elements Error

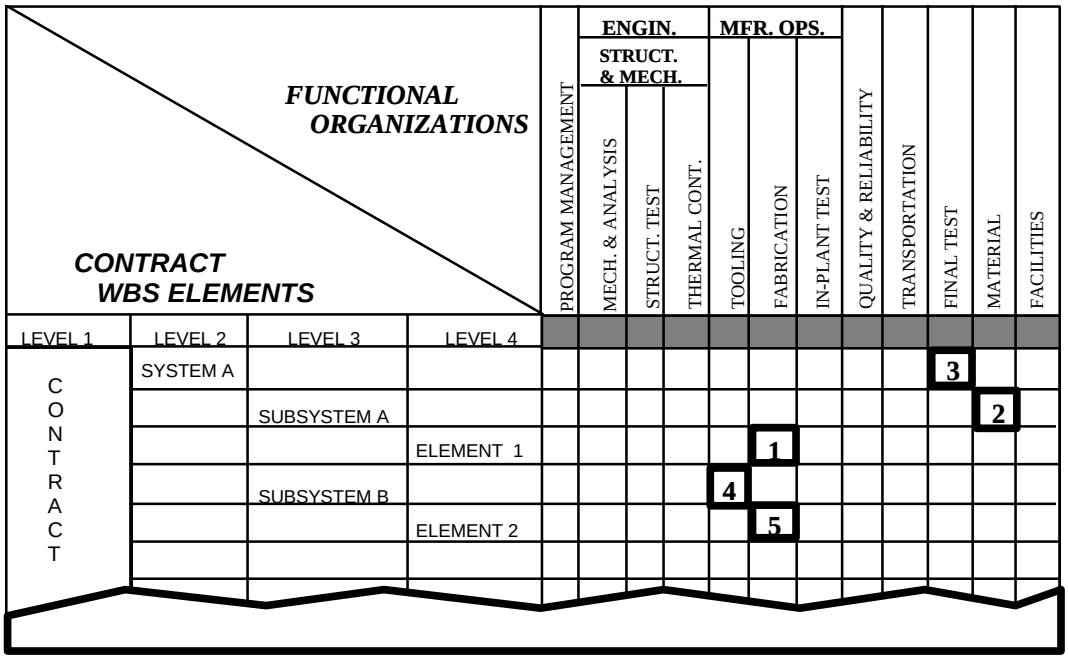
WBS elements are product-oriented. Design, mechanical engineering, concrete, piping labor and direct cost are not products. Design is an engineering function; mechanical engineering and pipe fitting are skills; concrete is a material resource; and direct cost is an accounting classification. None are appropriate as WBS elements. Project phases (e.g., construction) and type of funds (e.g., plant and capital equipment) are also inappropriate elements of a WBS. Rework, retesting and refurbishing should be treated as work for the appropriate CWBS element, not as separate elements.

Functional Elements Error

There is a natural tendency for contractors and individual managers to ask, "Where am I in that WBS?" They feel more comfortable if they see specific elements which reflect their functional areas of responsibility. When NASA project management is functionally organized in terms of design, construction and operation, the tendency may be for NASA to approve a functionally-oriented PWBS.

The following chart is an example of how the WBS elements and the functional organizations interface. For example, the fabrication manager is responsible for the manufacture of Element 1 (see box 1), and the material manager is responsible for the material for Subsystem A (see box 2). The manager of final testing is responsible for the final test of System A (see box 3). The tooling manager is responsible for all tooling for Subsystem B (see box 4), and the fabrication manager is responsible the manufacture of Element 2 (see box 5).

Interface Between WBS Elements and Functional Organizations

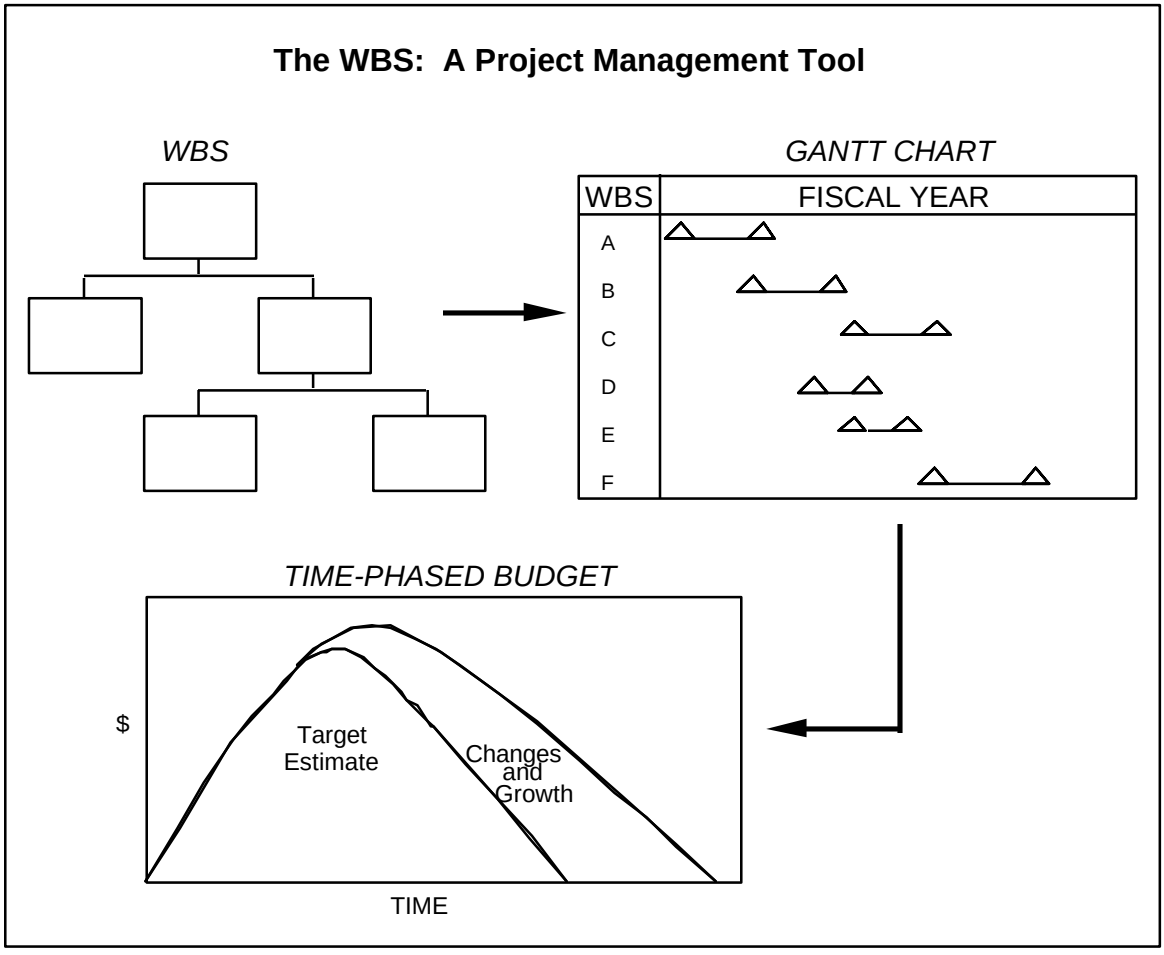


Both contractor and NASA managers are shown in the organization structure, but are not shown in the WBS structure because the WBS is product-oriented.

Chapter 3:
WBS Use

Introduction

The WBS is a project management tool (see chart below). It provides a framework for specifying the technical aspects of the project by defining the project in terms of hierarchically-related, product-oriented elements and the work processes required for each element's completion. Each element of the WBS provides logical summary points for assessing technical accomplishments, and for measuring cost and schedule performance.



This chapter discusses using the work breakdown structure for:

- technical management
- work identification and assignment

- schedule management
- cost management
- performance measurement

Technical Management

The WBS provides the framework for defining the technical objectives, establishing a specification tree, defining configuration items, providing integrated logistic support (ILS), and preparing and executing a test and evaluation plan for a project.

Specification Tree

A specification tree, developed by system engineering, structures the performance parameters for the system or systems being developed. It subdivides the system(s) into its functional constituent elements and identifies the performance objectives of the system(s) and its elements. The performance characteristics are explicitly identified and quantified. The completed specification tree represents a hierarchy of performance requirements for each element of the system for which design responsibility is assigned. Because specifications may not be written for each WBS element, the specification tree may not map the WBS completely.

Administrative tasks associated with system engineering and development of the specification tree are normally treated as a support services WBS element.

Configuration Management

Configuration management is the process of managing the technical configuration of elements being developed. In establishing the requirement for project configuration management, NASA designates which contract deliverables are subject to configuration management controls.

A contract deliverable designated for configuration management is called a configuration item. Configuration management involves defining the baseline configuration for the configuration items, controlling the changes to that baseline, accounting for all approved changes, and verifying that all changes have occurred. The WBS is the framework for designating the configuration items on a project. Thus, the WBS needs to be extended sufficiently to clearly define all elements subject to configuration management.

Configuration management tasks are normally associated with a support services WBS element.

Integrated Logistic Support

Integrated logistic support (ILS) includes all support necessary to assure the effective and economical support of a project, system, or equipment for the project's life cycle. ILS efforts include:

- spare and repair parts inventories, warehousing, and control
- preventive and scheduled facilities and equipment maintenance
- reliability and maintainability data
- transportation and handling systems
- test equipment
- training
- related publications

ILS efforts require detailed definitions of the systems or components being supported down to the individual spare part or individual component receiving preventive maintenance. The WBS provides a hierarchical basis for such detailed definition.

ILS tasks are usually associated with a support services WBS element. For example, planning and analysis tasks may be performed under system engineering.

Test and Evaluation

Many projects require a formal test and evaluation plan to ensure the procured systems satisfy the project's objectives as defined by the project technical baselines. Test plans may be developed for individual WBS elements. The effort associated with conducting and evaluating those tests may become part of the work defined for the appropriate WBS element.

Since tests may involve entire systems, parts of systems or individual components, they may not be uniquely identifiable to a single WBS element, but may span two or more of the elements going into one higher-level WBS element. Such integrated test work may be planned in conjunction with other work on the higher-level element that incorporates the elements being tested. Another alternative would be to establish a lower-level "test and evaluation" element for planning and controlling all tests.

Work Identification and Assignment

People performing work are organized to facilitate effective management, whether the organization is designed along project, functional, or matrix lines. To assign specific work responsibility to a specific organization, the WBS and organizational structure should be integrated with each other (i.e., functional responsibility is established for managing

specified work to produce defined products). This integration can occur at any level of the WBS, but certainly occurs at the top project level and whichever level responsibility has been assigned to manage the work. Other natural points of integration may occur as a result of how the scheduling, budgeting, work authorization, estimating and cost management systems interface with each other, with the WBS and with the organization.

Schedule Management

This section discusses using the WBS to help plan, revise and status schedules.

Plans

The WBS provides a framework for detailed work schedule information based on technically verifiable product completion. A network of events (e.g., start, complete) and activities (e.g., design, develop and operate) must take place. There is a logic to the relationship of the activities needed to produce and complete the WBS products. Resources (e.g., labor skill, dollars, and materials) and responsible organizations (e.g., mechanical engineering department, fabrication department, subcontractor) can then be identified for each of the activities.

The number and type of schedules are dictated by the scope and complexity of the work and the needs of management for schedule visibility. Schedule levels and management levels need not coincide with WBS levels. There is no requirement for separate schedules for each WBS level.

Although scheduling methodologies may vary, it is important that schedule events require completion of a tangible product in accordance with predefined specifications, and that completion is verified by test or inspection by persons other than those responsible for performance of the activities leading to completion of the product.

Revisions

When work is underway, the impact of schedule changes may be readily assessed if a network of events is used. This is because each WBS element's completion date is integrated with the schedule for completion of other elements and the schedule for all supporting activities. In other words, all elements going into a higher-level element must be completed before the higher-level element itself can be completed and, in some cases, before work on the higher-level element can even begin.

Status

Product-oriented schedules allow NASA to monitor the schedule baseline for the project's products to ensure that the project objectives are completed on time. NASA may require contractors to file the following reports which help to monitor schedule progress and to manage the project:

- Periodic Milestone Schedule Status Reports - to provide schedule status information in terms of duration.

- Cost Performance Report - to assess schedule performance in terms of earned value.
- Status Report - to provide a narrative description of the schedule.

Cost Management

The WBS assists management in measuring cost. By breaking the total product into successively smaller entities, management can verify that all work identified to the WBS (and hence charged to the effort) actually contributes to the project objectives. Using WBS elements to plan the work serves as the basis for estimating and scheduling resource requirements.

Cost Estimating

Using the WBS to help with cost estimating facilitates project and contract management. The WBS provides a systematic approach to cost estimating that helps ensure that relevant costs are not omitted. An estimate based on WBS elements helps NASA to plan, coordinate, and control the various project activities that NASA and the contractors are conducting. The WBS also provides a common framework for tracking the evolution of estimates (e.g., conceptual estimates, preliminary design estimates, and detailed design estimates). The WBS can also provide a framework for life cycle cost analysis.

As periodic project cost estimates are developed, each succeeding estimate is made in an attempt to forecast more accurately the project's total cost. Basically, the estimates may be organized in two ways: by WBS element or by code of accounts. Both support NASA's on-going efforts in preparing budgets and evaluating contractor performance.

Budgeting

In general, funds management involves periodic comparison of actual costs with time-phased budgets, analysis of variances, and follow-up corrective action (as required). When WBS elements and the supporting work are scheduled, a solid base for time-phased budgets is ready-made. Assignment of planned resource cost estimates to scheduled activities and summarization of each WBS element by time period results in a time-phased project/contract budget, which becomes the performance measurement baseline.

Accounting

Following is a brief discussion of analysis and control, and historical database development.

Analysis and Control

If budgets are based on WBS elements, and time phased with scheduled accomplishment, the accounting process must similarly be able to cost WBS elements over time (i.e., costed transactions must be coded in such a way that they can be identified to the WBS element

which incurred the transaction cost, and to the time period when the transaction occurred).

An accounting process or system which can accommodate the WBS has several advantages. The accounting system can be programmed to accept or reject charges to relatively small increments of work with the planned time schedule for the work; this helps minimize unauthorized charges. Also, the accounting and financial organizations can better ensure that they have gotten what they paid for since a product is accepted as complete only when a third party (e.g., inspector, quality control, next responsible manager) agrees that it meets the specified objectives. As a result, periodic accounting and financial variance analyses become more meaningful. Also, project performance measurement, with its dependence on cost and schedule variance analysis, is then possible.

Historical Database Development

When cost information is accounted by WBS element, it can be used in cost estimations for pricing and negotiating contract changes and for follow-on procurements. Over time, NASA will accumulate a growing cost database of similar WBS elements from different projects. Such historical cost data can be used in conjunction with learning curves, regression and other techniques to estimate the cost requirements for similar elements of new projects. Subsequent cost data collected by NASA can be compared to the original estimates to establish their validity, identify trends, and reestimate future project needs.

Contractors will similarly benefit from use of such databases. Contractors are expected to periodically provide a current estimate of future costs and the total estimated cost for each reporting element. They are also expected to complete a detailed bottoms-up estimate periodically. The WBS provides the framework for summarizing detailed costs. Since contractors tend to provide similar products on similar projects, the cost history that is accumulated can assist them in bidding future contracts and in budgeting new work.

Performance Measurement

Proper use of the WBS for technical, schedule, and cost management accomplishes the performance measurement objectives of defining work and related resources, ensuring that all work is included, and ensuring there is no duplication of effort.

In addition, the WBS is used to accumulate performance data and associated variances. This permits the contractor to evaluate progress in terms of contract performance. There is no need for separate contract performance assessments to be made at levels above the cost account because the WBS facilitates the summarization of data for successively higher levels of management. Significant variances will usually appear at summary WBS levels. Using the WBS, variances can then be traced to their sources.

Summary

The WBS is a tool that helps management measure technical and schedule performance as well as cost. By dividing the total product into successively smaller entities, management can ensure that all required products are identified in terms of technical performance goals. Management can also verify that all work identified to the WBS, and then charged to the project, actually contributes to the project objectives. The planning of work based on WBS elements serves as the basis for estimating and scheduling resource requirements. Subsequently, the assignment of performance budgets to scheduled segments of contract work produces a time-phased plan against which actual performance can be compared. When performance deviates from the plan, appropriate corrective action can be taken. Identification of potential cost and schedule impacts of proposed technical changes is simplified when this integrated approach to work planning is used.

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Appendix A:
Glossary

Budget Line Item (BLI)	A major classification of NASA programs; a subdivision of a Congressional appropriation.
Configuration Item (CI)	An aggregation of hardware/computer programs or any of its discrete portions, which satisfies an end-use function and is designated by NASA for configuration.
Contract Work Breakdown Structure (CWBS)	A work breakdown structure of the products or services to be furnished under contract. It is comprised of selected PWBS elements specified in the contractual document and the contractor's lower level extensions of those elements.
Cost Account	A management control point at which actual costs can be accumulated and compared to budgeted cost for work performed. A cost account is a natural control point for cost/schedule planning and control, since it represents the work assigned to one responsible organizational element on the contract work breakdown structure.
Data Item	An individual data element ; an item of information (UPN, fund source, object class, etc.) which identifies a specific characteristic of a transaction.
End Item	A final combination of end products components, parts, or materials which is ready for its intended use; an item of software or documentation that is deliverable to a user or customer.
High Risk Item	An item which involves technological, manufacturing or other state-of-the-art advances or considerations, and program/project management designates as requiring special attention. It is critical from the standpoint of achieving program objectives, reliability, maintainability, safety, quality assurance or other such factors.

Program	A related series of undertakings which continue over a period of time (normally years), and which are designed to accomplish broad scientific or technical goals or increase knowledge in an area of space science or engineering. Programs are typically planned and executed as a series of individual projects or as a group of projects to provide a major system capability.
Project	A defined, time-limited activity with clearly established objectives and boundary conditions executed to gain knowledge, create a capability, or provide a service as part of an overall development program. A project typically encompasses design, development, fabrication, test, and as applicable, operation of advanced hardware and software, including data collection, distribution, and analysis and reporting of results.
Project Plan	A detailed plan which, when formally approved, sets forth the agreement between a program associate administrator and the involved field installation directors, and defines the guidelines and constraints under which the project will be executed.
Program/Project Work Breakdown Structure (PWBS)	A work breakdown structure which describes the total program and/or project in conformity with the Agency Wide Coding Structure contained in NASA Financial Management Manual 9100.
Request for Proposal (RFP)	A solicitation used in negotiated acquisition to communicate government requirements to prospective contractors and solicit proposals.
Statement of Work (SOW)	The technical statement of contractual requirements the contractor must satisfy to complete the contract.

Specification Tree	A graphic portrayal arranged to illustrate interrelationships or hardware and/or software performance/design requirements specifications; normally, this portrayal is in the form of a "family tree" subdivision of the specifications with each lower level specification applicable to a hardware/software item which is part of a higher level item.
Subsystem	A functional entity within a system. The name for the next level of breakdown under a system.
System	One of the principal functioning entities comprising the project hardware within a project or flight mission. Ordinarily, a system is the first major subdivision of project work.
Unique Project Number (UPN)	Identifies funds for a major project or program within a budget line item. There may be numerous contracts linked to a single UPN. Work under a single UPN may be spread across more than one directorate and across more than one NASA center.
Work Breakdown Structure (WBS)	A family tree subdivision of effort to achieve an end objective. The WBS is developed by starting with the end objective required and successively subdividing it into manageable components in terms of size and complexity. It should be product or task oriented and should include all the effort necessary to achieve the end objective.
WBS Dictionary	A narrative description (or definition) of each element appearing on the work breakdown structure including, recurring and non-recurring work to be performed, hardware or software to be developed and delivered, services to be furnished, products or data required for each element, and any other significant data.
WBS Element	Any block or unique entry in a work breakdown structure regardless of level.

WBS Levels	The arrangement or configuration of a work breakdown structure which establishes an indenture of projects to programs, systems to projects, subsystems to systems, etc.
Work Package	The unit of work required to complete a specific job such as a report, a design, a drawing, a piece of hardware, or a service which is within the responsibility of one operating unit in the performing organization. Usually the lowest element shown in a work breakdown structure.

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Appendix B:
Acronym Listing

ART	Advanced Research and Technology
AWCS	Agency Wide Coding Structure
BLI	Budget Line Item
CWBS	Contract Work Breakdown Structure
DDT&E	Design, Development, Test and Evaluation
FMM	Financial Management Manual
GSE	Ground Support Equipment
HST	Hubble Space Telescope
ILS	Integrated Logistic Support
MSFC	Marshall Space Flight Center
NASA	National Aeronautics and Space Administration
NHB	NASA Handbook
NMI	NASA Management Instruction
PCA	Program Commitment Agreement
PMS	Performance Measurement System
PrISMS	Program Information Systems Mission Service
PWBS	Program/Project Work Breakdown Structure
R&T	Research and Technology
RFP	Request for Proposal
SE&I	Systems Engineering and Integration
SOW	Statement of Work
SSM	Support Systems Module
STME	Space Transportation Main Engine
UPN	Unique Project Number
WBS	Work Breakdown Structure

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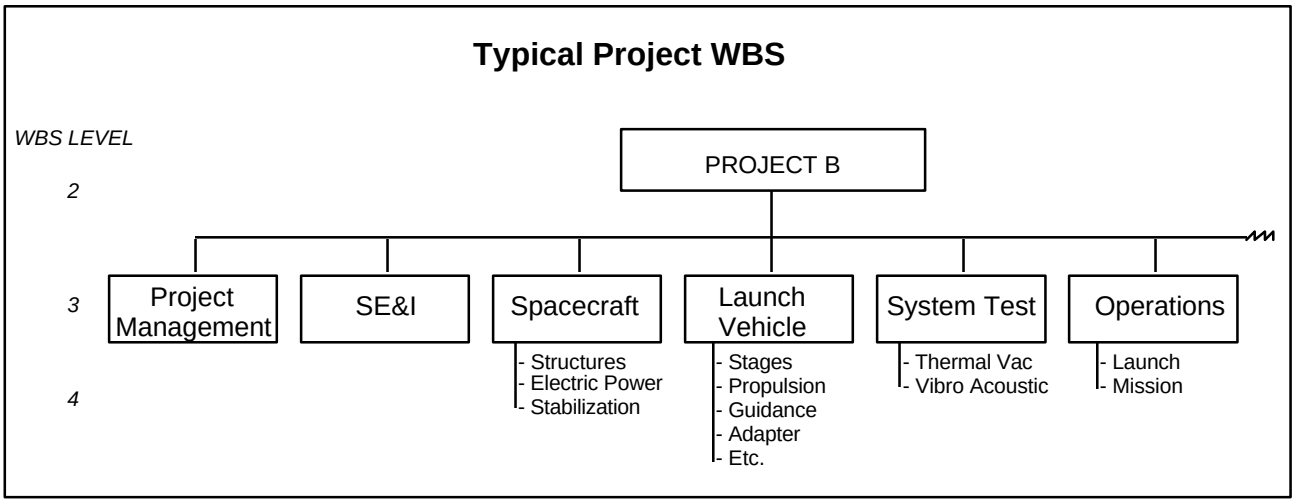
Appendix C:
PWBS Examples

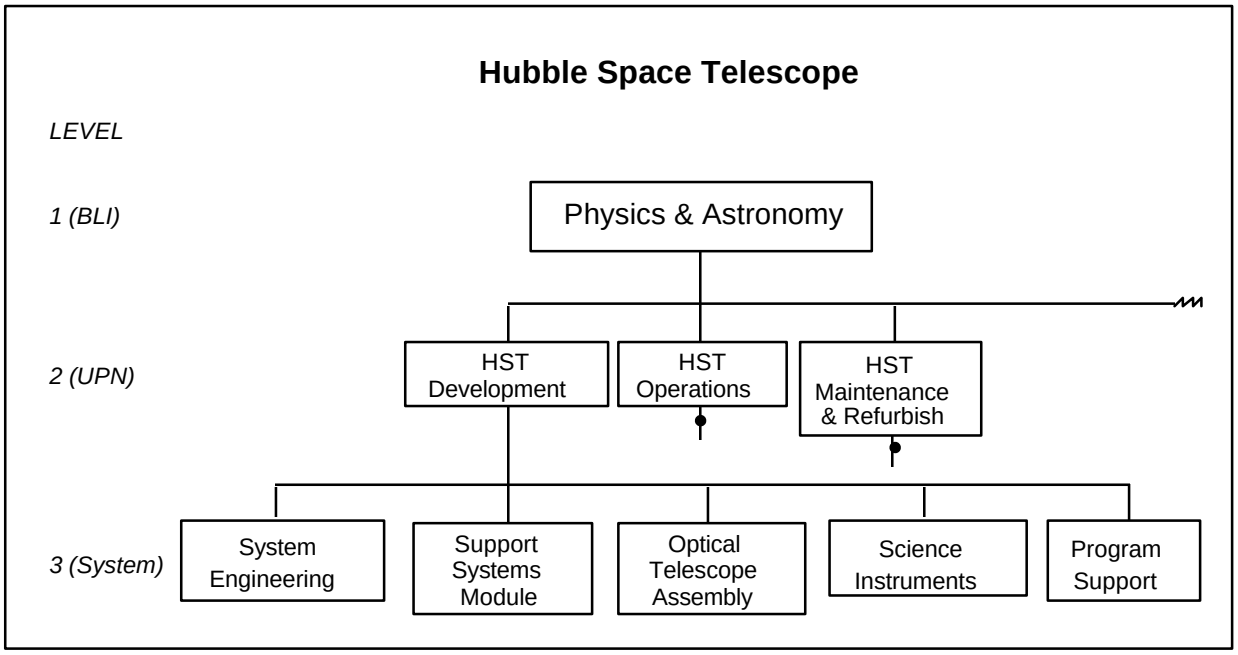
Following is a typical project WBS which follows the conventional format (i.e., project at level 2, systems at level 3, subsystems at level 4).



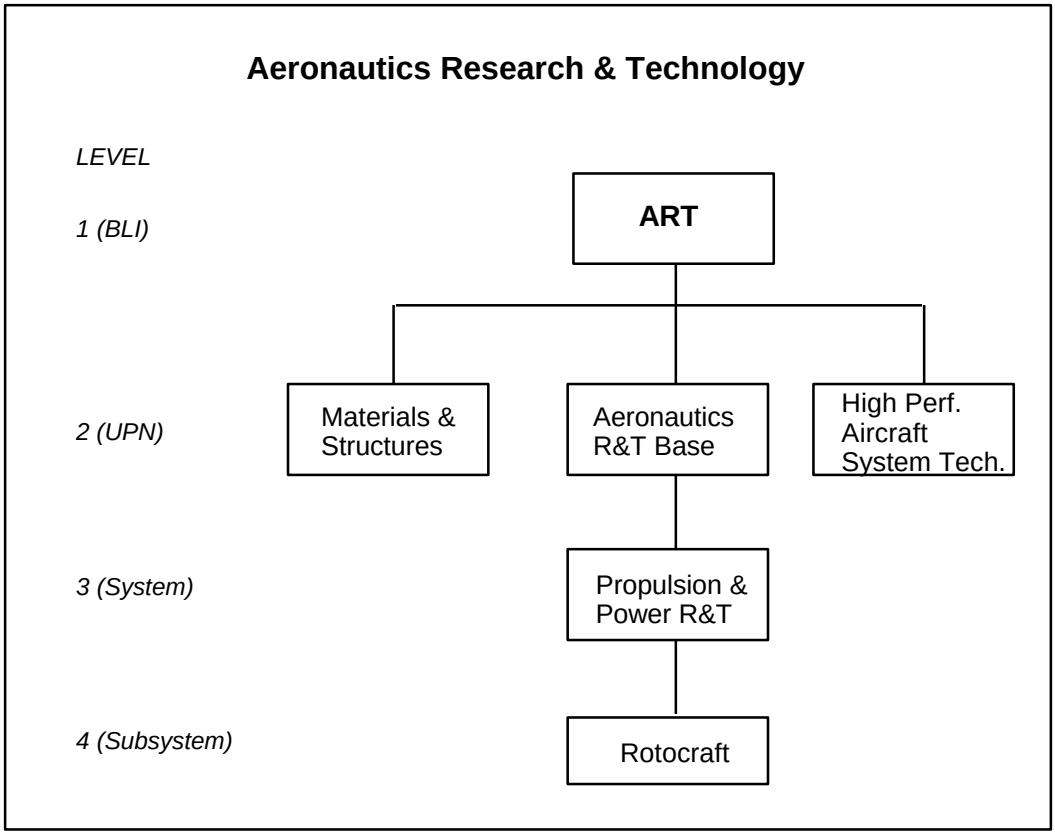
Following is the actual WBS for the Hubble Space Telescope (HST) Project. It is part of the Physics and Astronomy Program.

Note that HST Development (a WBS level 2 element) is not the typical designation for a unique project. The WBS was structured this way because Congress appropriated funds for the unique project, "Development Phase".

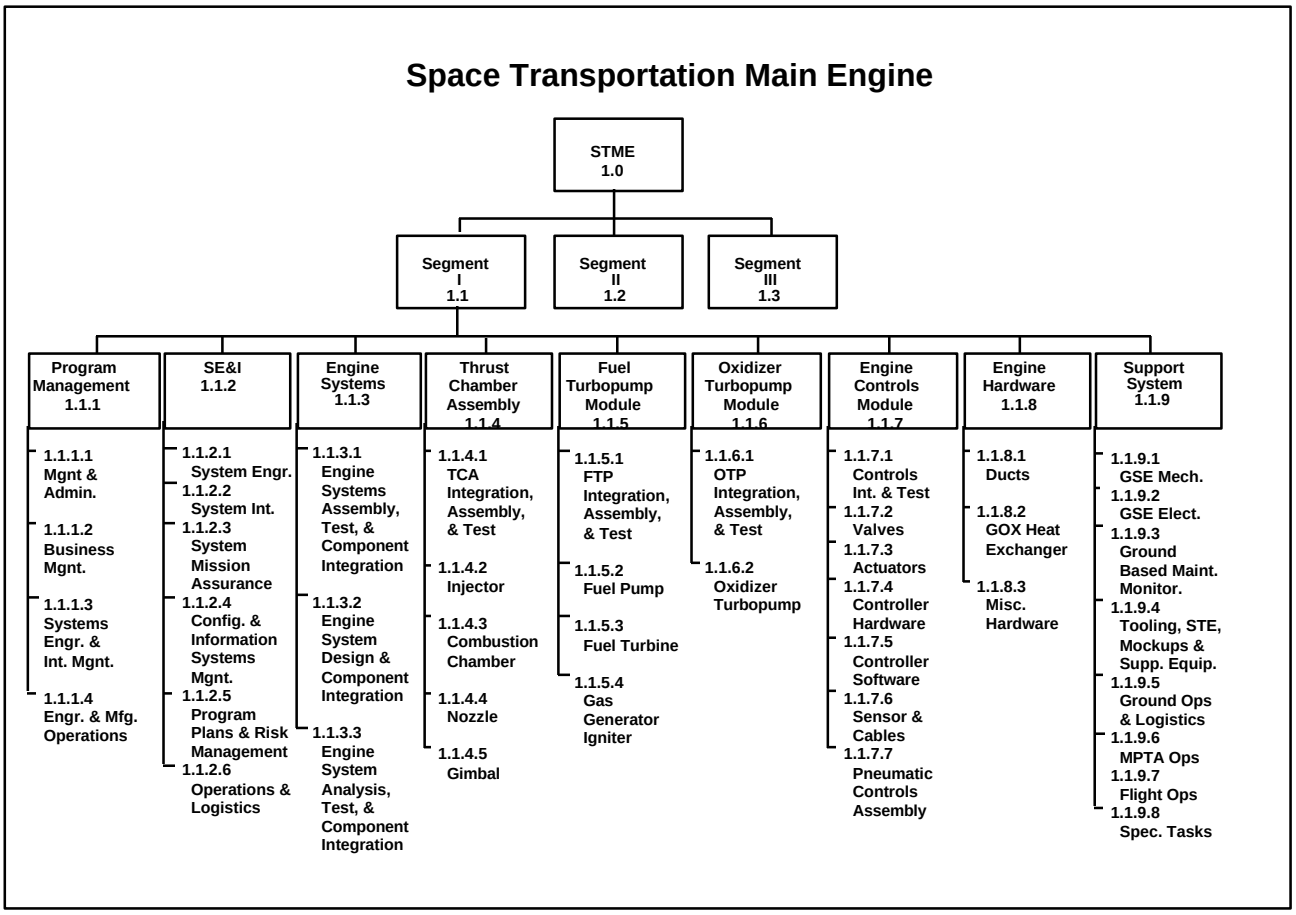
This is a good example of how the Congressional budget appropriation process drives the WBS format. You must be aware of such influences on the development of the WBS and make the necessary adjustments.



The following PWBS is for Aeronautics Research and Technology (ART). It is different from the typical program WBS because its format was driven by Congressional budget appropriations. Note that the budget line item is at level 1, and the unique projects are at level 2.



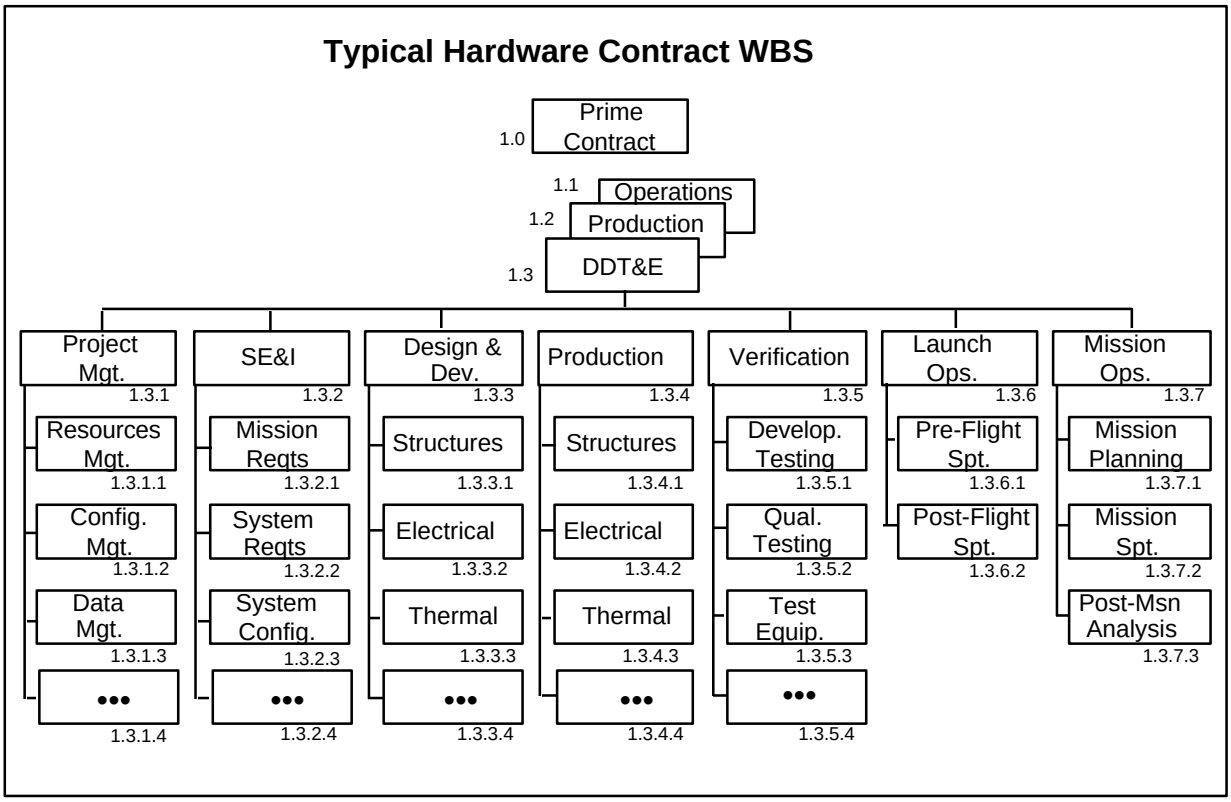
Below is the actual PWBS developed for the Space Transportation Main Engine (STME) for the National Launch System. It was developed to level 4 because there are three segments at level 2. Note the numerical identification for each element.



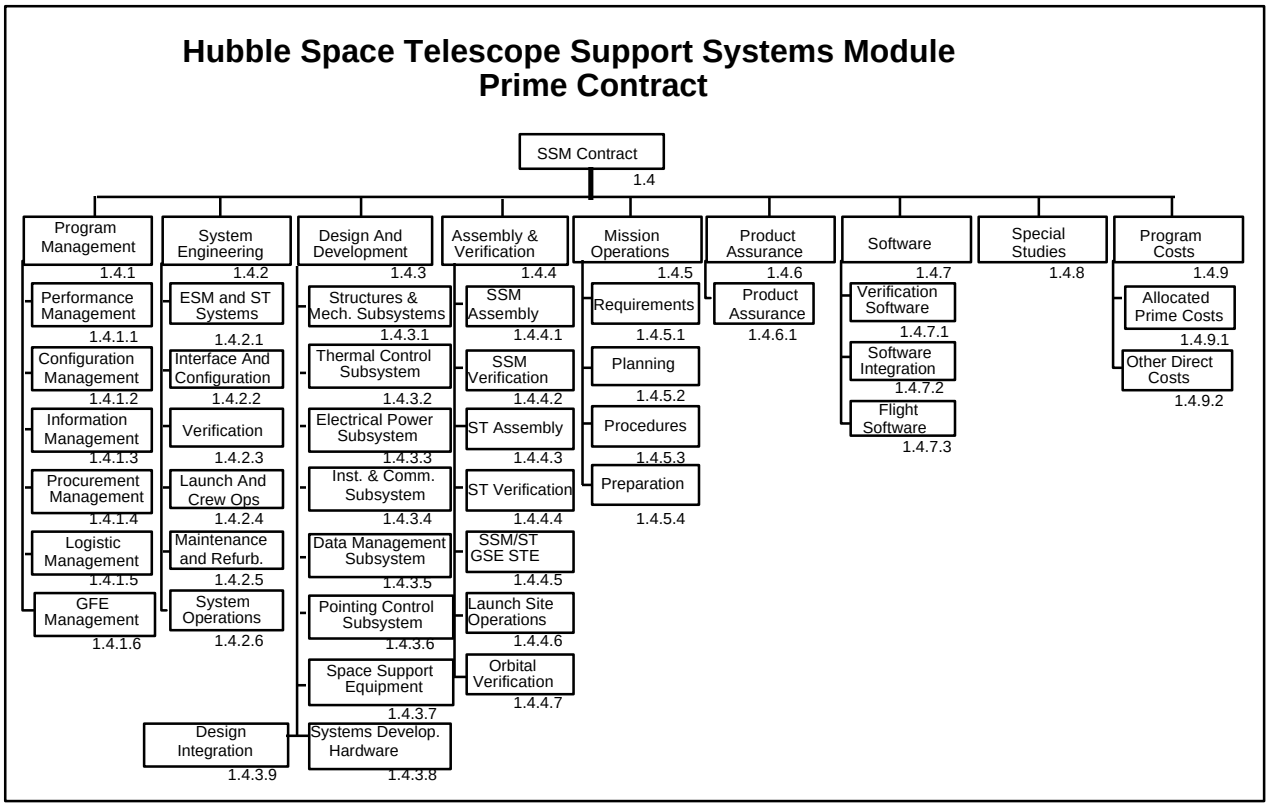
Appendix D:
CWBS Examples

Following is a typical hardware contract work breakdown structure. This example is for the Shuttle Program.

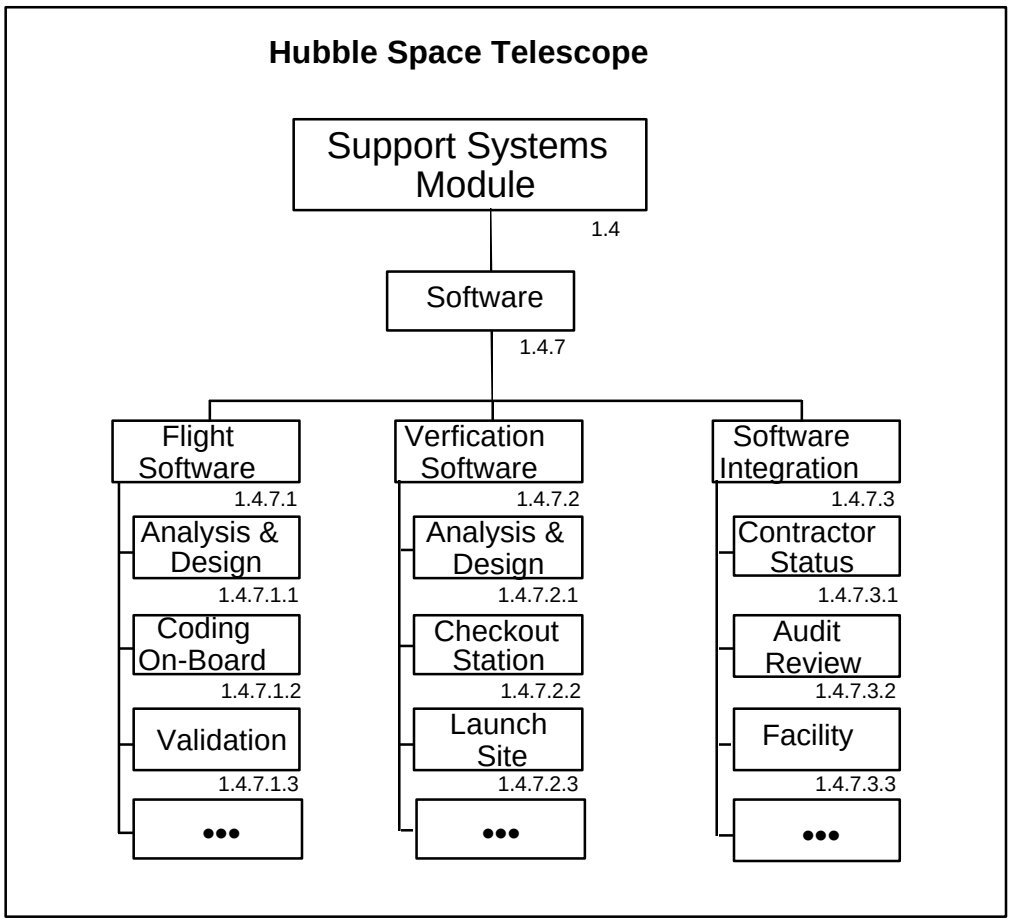
Note that DDT&E, production and operations are at level 2. Each has a separate substructure. Because these elements are at level 2, it was necessary to extend the CWBS to level 4.



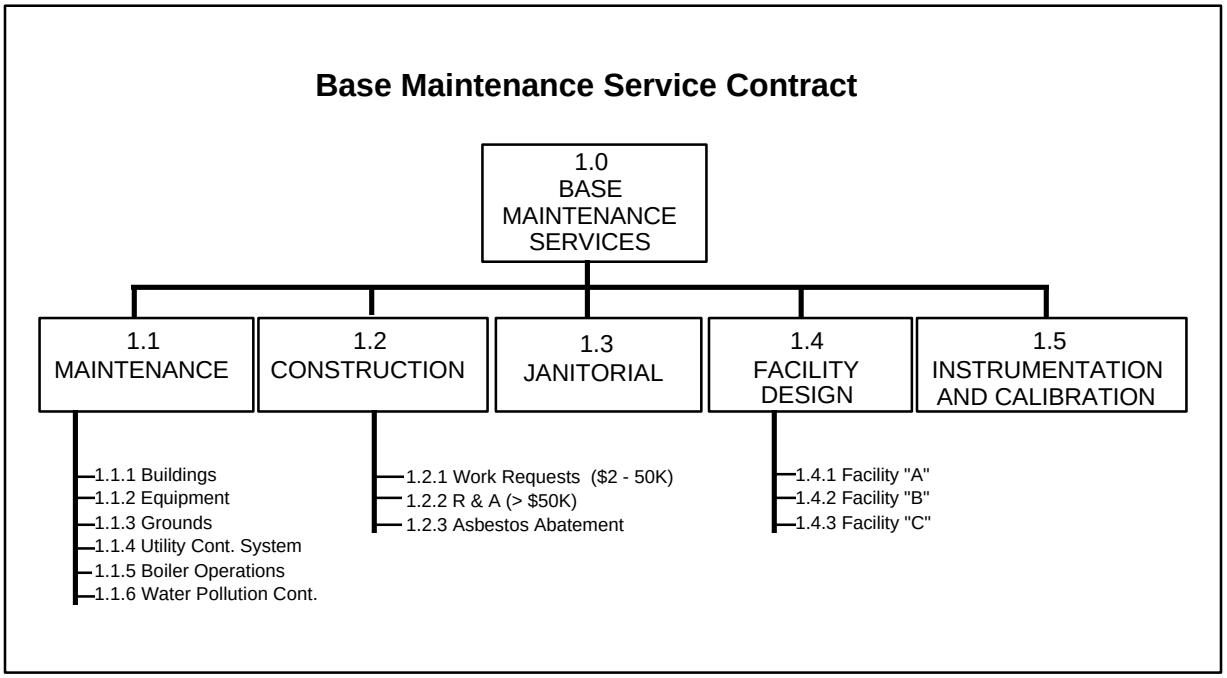
The chart below is the actual CWBS for the Hubble Space Telescope Support Systems Module Prime Contract.



Following is the actual CWBS for the Hubble Space Telescope Support Systems Module Software. Although element nomenclature is quite different, note the similarities of the software CWBS with a typical hardware CWBS.



Following is the actual CWBS for the Base Maintenance Service Contract at MSFC. Note that the basic hardware contract format is applicable to a service contract . This CWBS was developed to level 3, which is the level at which the statement of work was developed and the level at which the contractor reported to NASA.



Appendix E:
WBS Section of NHB 7120.5, *Management of Major System Programs and Projects*

WORK BREAKDOWN STRUCTURE

1. PURPOSE

These WBS policies and processes establish the essential framework for project: technical planning, scheduling, cost estimation and budgeting; defining the scope of statements of work and contracts; developing documentation products (including specifications and drawings); and program/project status reporting and assessment (including integrated cost/schedule performance measurement).

2. POLICIES

a. The WBS shall:

(1) Define all the work necessary to complete the project;

(2) Be a product-oriented, hierarchical division (tree) of deliverable items (hardware, software, information) and associated services; and

(3) Relate the elements of work to each other and to the end item (system or product).

b. A WBS shall be developed for each project and for each individual contract.

(1) A preliminary project WBS will be developed in Phase A to define the top levels of a WBS for the entire project (system) life cycle. Normally, this life cycle WBS will be in two parts--one for the acquisition cycle of the system being acquired (Phases A through D), and one for the operations and support phase (Phase E).

(2) A final project WBS will be prepared by compiling the elements of the contract WBS(s) with the preliminary project WBS.

3. PROCESSES

a. Project WBS. The project WBS should contain the project's Product Breakdown Structure (PBS), with the specified prime product(s) at the top, and the systems, segments, subsystems, etc. at successive lower levels. At the lowest level are products such as hardware items, software items and

information items (e.g., documents, databases, etc.) for which there is a cognizant engineer or manager.

(1) Branch points in the hierarchy should show how the PBS elements are to be integrated. The WBS is built from the PBS by adding, at each branch point of the PBS, any necessary service elements, such as management, systems engineering, integration and verification, and integrated logistics support.

(a) The family of specifications and drawings resulting from the progressive steps of systems engineering will conform to the WBS.

(b) Integrated logistics support will be accommodated in the appropriate WBS elements.

(c) Software will be accommodated in the appropriate WBS elements. Software will be identified with the hardware it supports. Any aggregations of WBS elements required for software management and reporting will be accomplished by summation of relatable elements of the project WBS.

(d) Overall system software to facilitate the operation and maintenance of the computer systems and associated programs (e.g., operating systems, compilers, and utilities) and applications software that interfaces with more than one equipment item will be called out at the appropriate WBS level.

(e) If several WBS elements require similar equipment or software, then a higher level WBS element can be defined to perform a block buy or a development activity (e.g., "System Support Equipment").

(2) A project WBS will be carried down to the level appropriate to the risks to be managed. The appropriate level of detail is determined by management's desire to have visibility into costs, balanced against the cost of planning and reporting.

(3) Extensions of the WBS will be consistent with a product-oriented approach, but can be tailored to the specific project.

b. Contract WBS.

(1) Contractors must have a Contract WBS (CWBS), which is appropriate to the contractor's needs to control costs. A summary CWBS, consisting of the upper levels of the full CWBS, is usually included in the project WBS to report costs to the project office.

(2) From the initial project WBS, preliminary CWBS(s) for individual contracts will be negotiated with the contractors involved. The CWBS will be extended to lower levels by the contractor in accordance with the product-oriented approach.

c. WBS Identification. WBS elements must be identified by title and by a numbering system that performs the following functions:

(1) Identifies the level of the WBS element;

(2) Identifies the higher level element into which the WBS element will be integrated;

(3) Shows the cost account number (if any) of the element.

d. WBS Dictionary. A WBS must have a companion WBS dictionary that contains each element's title, identification number, objective, description, and any dependencies (e.g., receivables) on other WBS elements. This dictionary provides a structured project description for orienting both project staff and others. It fully describes the products and/or services expected from each WBS element, and should be consistent with any contractor statement of work.

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