A Simple Guide for Constructing a Work Breakdown Structure (WBS)

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One of the standard project management tools is the Work Breakdown Structure (WBS). The WBS has been described as "a critical tool for organizing work, building realistic schedules and cost estimates, and reporting/ tracking/ controlling" [1]. The main purpose of creating a WBS is to provide a common approach and framework for cost estimates among all subsystems and to produce a comprehensive, accurate, and defensible cost estimate.

An accepted definition of WBS is "an exhaustive, hierarchical (from general to specific) tree structure of deliverables and tasks that need to be performed to complete a project" [2].

The steps of the WBS and cost estimate development, described in the following sections, are:

1. Develop a list of all components and tasks, organized by subsystem, that constitute the work to complete the project. Each component and task is a WBS element.
2. Estimate the cost of the components and activities which comprise the lowest level of the WBS, and complete the basis of estimate document for such activities.
3. Complete the WBS dictionary and cost basis for each WBS element.

Guidelines for WBS Development

1. WBS Elements and Activities - Deliverables

Generally the first three levels, but sometimes more levels, of the WBS elements are deliverables and for the most part are described as nouns. One should think of a deliverable as simply a tangible product, or component, e.g., mirror, camera, or phototube.

Descending levels provide an increasingly detailed definition of the top element. The number of levels depends on the scope and complexity of the individual project and the degree of control it warrants. The activities, such as engineering design procurement, appear at the lowest level of the WBS. Activities are the steps needed to produce the deliverable. For example, if the deliverable is "mirror segments," then the activities might be "design," "procure materials," "fabricate," and "test."

2. Non-deliverables

The only high level WBS elements which are not deliverables are subsystem assembly, installation, system integration and test, and project management.

a) Subsystem Assembly: the activity of putting together all subsystem components; i.e., assembling a number of related deliverables into a subsystem ready for installation

b) Installation: the act of putting the subsystems together at the detector site.

c) System Integration & Tests: the activities of assembling all of the related subsystems into a working system. System tests, or commissioning, are those tests performed after the assembly activities.

d) Project management: the activities of planning, estimating, organizing, directing, controlling, and reporting needed to manage the project.

3. WBS Numbers

WBS elements are numbered in the classical dotted decimal format. The first level of the WBS corresponds to the Pierre Auger Project major systems; the second level to the major components.

4. WBS Columns

The WBS elements are arranged in numerical order in a spreadsheet. Each row corresponds to a single WBS element. Each observatory site (North and South) is assumed to consist of a number of stations. The WBS is structured so that one may easily determine the cost per station. The columns of the table are defined in Table 1.

Table 1. WBS column names and descriptions

Column name	*Description*
WBS	The WBS number, e.g., 1.2.2.4
Activity	A brief description of the deliverable or activity
Quant	The quantity required per station. Defined only for lowest WBS level; blank for higher (summary) levels
Base unit	Units of Quant column. Typically “each” for deliverables, “hours” for labor
Trade code	Applies to activities. See Labor Categories discussion below for the codes to be used.
Est. code	Estimate code. See Contingency Assignment table below for the appropriate codes.
Cont. %	Contingency percentage for the estimate code, using the Contingency Assignment table.
Wastage	Expressed as a fraction of the total quantity. units that will be wasted in the process of implementing the project.
Spares	Expressed as a fraction of the total quantity. This is an estimate of the number of spare units that may be needed for the duration of the project.
Cost / Unit	The cost in dollars for the Base Unit.
Mat’ls / Station	The total cost in dollars for the deliverable for one station. This is a calculated quantity: Quant * (Cost/Unit) * (1 + Wastage + Spares)
Labor / Station	The total cost in dollars for the activity for one station. Calculated quantity: Quant * (Cost/Unit)
S (or N)	The number of stations at each site.
Esc. Factor	Escalation factor. An estimate of the percentage that costs will rise during the procurement of the deliverable.
Total M&S South (or North)	The total Materials & Services (M&S) cost for the deliverable for the site, expressed in k$. Calculated quantity: (Mat’ls/Station) * S / 1000
Total Labor South (or North)	The total Labor cost for the deliverable for the site, expressed in k$. Calculated quantity: (Labor/Station) * S / 1000
Total EDIA South (or North)	The estimated cost of Engineering, Design, Inspection, and Administration (EDIA) for the deliverable for the site, expressed in k$.
Esc.	Total Escalation. Calculated quantity: (Esc. Factor) * [(Total M&S) + (Total Labor) + (Total EDIA)]
Estimated Cost (Escalated)	Calculated quantity: (Total M&S) + (Total Labor) + (Total EDIA) + (Esc.)
Total Cont. South (or North)	Total contingency. Calculated quantity: (Estimated Cost Escalated) * Cont %
Total Project South (North) w/ Contingency	Sum of previous 2 columns. This is the total amount of money which needs to be provided for this WBS element.

The remaining columns indicate the contribution to each WBS element from each of the countries in the collaboration. In addition to the country columns, there is a column for Argentina Infrastructure, representing contributions from Mendoza Province for

infrastructure costs, and also a Common Funds column. The sum of these columns equals the amount in the "Total Contrib. Project" column. Finally, the "Needed to Complete Project" Column is the difference between the required cost (Total Project w/ Contingency) and the total contributed cost.

A sample file is included as an appendix to this document. This represents the complete WBS for the optics for the FD system (WBS 1.1.1).

Guidelines for Cost Estimation

The basis for the cost estimate is a detailed bottoms-up estimate, starting with the lowest WBS elements. Each higher level of the WBS summarizes the lower levels. The supporting documentation consists of the WBS Dictionary and the Cost Book.

WBS Dictionary: This provides a link between the costs listed in the WBS spreadsheet and the justification or basis of the cost estimates. An example entry is shown in Table 2.

Table 2. WBS Dictionary structure

WBS Number	
WBS Dame	
WBS Definition	Identify included components Interface with other elements Drawing references List of key parameters Key technical issues
Basis of Estimate	A brief description of how the estimate was made.

Cost Book: In addition to developing a WBS each Task Leader should develop a cost book. This document will contain supporting information such as vendor quotes, invoices from previous procurements, and catalogue page copies, and will summarize the philosophy and parameters used to prepare the cost detailed items. This information will be used for both internal and external reviews of the system costs.

Labor Categories

Six labor categories have been identified for the completion of labor cost estimates. They are:

- P Physicist
- E Engineer
- D Designer
- T Technician
- L Labor
- C Clerical

Labor Rates

Generic labor rates may be used, unless more specific information is available. Labor costs listed in the WBS are for labor that must be purchased with Project funds. It does not include labor costs paid for by the individual Universities or Institutes. In determining which labor rates to use, the cost estimator needs to determine where the work will be performed, and to use the most accurate information available regarding the labor rates for that institution. All assumptions should be clearly stated in the cost book.

The labor rates should be fully burdened with associated costs. Typically, one converts the direct labor rate into the burdened labor rate by including fringe, overhead, vacation, sick leave, and general and administrative costs.

Often labor estimates do not include all labor associated with manufacturing a product (e.g., manufacturing support, facility maintenance, etc.) because some of this effort is included in the overhead rate for that institution. A description of what is included in overhead at a given location should be provided.

Calendar and Time Units

A standard calendar of 250 days/year, based on 8 hours/day, 5 days/week, 10 holidays/year, which equates to 2000 hours/year, will be used for all activities. The standard unit of time will be the day.

Material Costs

Material costs include the purchase of raw materials for fabrication and the procurement of components, subassemblies, and tooling from outside sources, or items estimated in such a way that only a total dollar amount can be identified. This includes detector hardware, equipment, fixtures, tooling, utilities, test and assembly equipment, computer hardware and software, raw materials, and procurement processing. Travel is considered a material cost. The cost book should indicate the basis for arriving at the materials cost estimate.

Contingency Analysis

To do a contingency analysis, first determine the base cost estimate. Then, determine the cost contingency and assign contingency percentages. The base cost estimate is the estimated cost of doing things correctly the first time, unless from past experience you are fairly certain that it will take more than once. In other words, contingency should not be included in the base cost.

Cost contingency is the amount of additional money, above and beyond the base cost, that is required to ensure the project's success. This money is to be used only for omissions and the unexpected difficulties that may arise. Contingency is held entirely by Pierre Auger Project management and not by individual subsystem managers. Contingency costs are explicitly part of the total cost estimate. Use the percentages listed in Table 3.

Table 3. Contingency Assignments

Estimate Code	*Source of Estimate*	*% Contingency*
A	Actual – for deliverables already purchased	0%
VQ	Vendor Quote	10%
VI	Vendor Information	20%
EE	Engineering Estimate	30%
PE	Physicist Estimate	≥ 50%

References:

[1] U.S. Dept. of Energy, Office of Management, Budget, and Evaluation, “Work Breakdown Structure,” Rev E, June 2003.

[2] Wikipedia contributors, "Work breakdown structure," Wikipedia, The Free Encyclopedia, http://en.wikipedia.org/w/index.php?title=Work_breakdown_structure&oldid=37667601 (accessed March 28, 2006).