

Making the Transition from the WBS to the CWBS

Richard Sah
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Introduction

The purpose of this note is to describe some aspects of the ongoing development of a Cost and Schedule Control System for the SSC Construction Project.

Nomenclature. After examining relevant DOE publications such as DOE/CR-0014 and DOE/MA-0040, we suggest the adoption of the following nomenclature for the SSC:

WBS: The Work Breakdown Structure (WBS), as used in the CDR, was designed for convenience in cost estimating, and it is not easily broken down into activities (work orders, purchase orders, and contracts). We plan to continue using this WBS and to call it by the original name.

CWBS: The DOE guidelines define the "Project WBS", which in turn consists of the "Project Summary WBS" and a number of supporting "Contract WBS's". The organizing structure for the activities we wish to track shall henceforth be called the "Contract WBS (CWBS)".

Statement of the Problem. The definition and use of two distinct organizing structures, the WBS and the CWBS, imply that a transition must be made from one to the other. Our problem is to define a detailed procedure for making a graceful transition, while providing a mechanism for calculating and tracking all cost and schedule variances. This problem is complicated by the many-to-many mapping from the WBS to the CWBS. The description of our proposed solution emphasizes the design of several accounts, the *databases* where the account records are stored, and the associated *transaction rules* (i.e., the formal rules and procedures for adding and changing entries in these databases). Briefly, the costs will be transferred from the WBS to the CWBS at the moment when the activity becomes clearly defined (i.e., when the work order or contract is signed).

We shall use the cryogenics system as an example case to illustrate the transaction rules. The example is chosen to illustrate many types of transactions, but no attempt will be made to simulate the full ensemble of thousands of transactions which will be required to manage the construction of the cryogenics system. All costs are in FY 1986 dollars, and escalation is considered only in the last section of this memorandum.

Definitions of Accounts

Table 1 shows the six financial accounts which are needed. These accounts are defined below.

Table 1. Financial Accounts

	WBS	CWBS
Active	W1	C1
Inactive	W2	C2
Mgt Reserve	W3	C3

W1: Active WBS Account. This account contains the estimated construction cost of the SSC, without contingency, before the activities have been defined. At the start of the construction project, W1 contains the entire estimated cost of the project, namely \$2480M. Account W1 is stored in a database which contains a description of costs at the lowest WBS levels, and the *total resource requirements* for each WBS element is spelled out in terms of dollars of materials and hours of each category of labor. The W1 database contains no schedule information, because the WBS elements are not activities which can be scheduled. "W1" will also be used to denote the total dollars in account W1.

W2: Inactive WBS Account. As contracts are signed, costs are transferred from W1 to W2, while keeping the total of (W1 + W2) constant. At the start of the construction project, account W2 is empty, but by the end of the construction period, all the WBS costs have been transferred from W1 to W2. Some items of work, such as ED&I, can be defined very soon in terms of scope and milestones. These items can be transferred to W2 almost immediately after the project start.

W3: WBS Contingency or Management Reserve.

- (a) At the project start, we have
 $W1 + W3 = \$2480M + \$530M = \$3010M$
 $W2 = \$0.0$
- (b) During construction,
 $W1 + W2 + W3 = \$3010M$
- (c) At project completion,
 $W1 = \$0.0$
 $W2 + W3 = \$3010M$

C1: Active CWBS Account. This account starts out empty. As contracts and work orders are signed, the anticipated costs are put into this account. Activities in account C1 (i.e., work in progress and work completed) will be tracked in terms of percentage completion. All the CWBS databases, including C1, contain schedule information.

C2: Inactive CWBS Account, containing anticipated but not yet precisely defined activities. This account corresponds closely to account W1, and at all times we have $C2 = W1$. The C2 account, however, describes the work in terms of activities (contracts, work orders, and purchase orders), and not in terms of the WBS elements used in account W1. Since the C2 activities have not yet been defined precisely (i.e., the contracts have not been signed), the definition of C2 activities is necessarily vague. However, a rough model of these activities must be developed early on, since the model will be required for project scheduling purposes. In fact, the existing SSC summary construction schedule can be considered to be a preliminary version of the C2 account. At the project start, $C2 = \$2480M$. As activities become defined, they are transferred from C2 to C1.

C3: CWBS Management Reserve.

- (a) At the project start,
 $C1 = \$0.0$
 $C2 + C3 = \$2480M + \$530M = \$3010M$
- (b) During the construction period,
 $C1 + C2 + C3 = \$3010M$
- (c) We hope to have some remaining management reserve at the project completion, in which case we shall have
 $C2 = \$0.0$
 $C1 + C3 = \$3010M$, where $C3 > \$0.0$

Transaction Rules

This section describes the formal transaction rules (similar to those which are used for double-entry bookkeeping), which govern the use of the SSC accounts. For clarity, we use a helium refrigerator purchase contract as an illustrative example.

Cryogenics System. In this section, the cryogenics system (CRYO) is taken to include the HEB cryogenics system and the collider cryogenics system.

CRYO Total (CDR cost estimate)	\$134.7M
(WBS .1.1.4.2) HEB, cryogenics	13.6
(WBS .1.2.2) cryogenics, refrig [collider]	121.1

Purchase Contract. We assume here that the first helium refrigerator purchase contract will be for six refrigerators: one for the HEB and five of the ten required for the collider. The relevant WBS elements, as defined in the CDR, are identified below. Note that only half of each control system is included in the refrigerator purchase contract; the remaining costs are associated with equipment located in the tunnel.

HEB Refrigerator	\$8.9M
(WBS .1.1.4.2.1) HEB, cryo, purchased refrig system	4.5
(WBS .1.1.4.2.2) HEB, cryo, refrig-comp other	2.3
(WBS .1.1.4.2.6) HEB, cryo, refrigerator control [50%]	1.1
(WBS .1.1.4.2.8.3) HEB, cryo, connection to m ring	0.3
(WBS .1.1.4.2.8.4) HEB, cryo, energy storage system	0.7
Ten Refrigerators for the Collider	\$75.6M
(WBS .1.2.2.1) refrig, compressor purchased package	45.0
(WBS .1.2.2.2) refrigerator station - other	25.7
(WBS .1.2.2.6) cryo sys instrumentation and control [50%]	4.9

Refrigerator contract 1 (RC1) is assumed to cover six refrigerators:

RC1 (CDR cost estimate)	\$46.7M
HEB refrig	8.9
5 collider refrig	37.8

Transactions. This section consists of a step-by-step description of the state of the SSC accounts throughout the construction period, when various types of transactions occur. Three types of variances (V1, V2, and V3) are calculated.

- (1) **Project Start.** Account W1 contains the CDR cost estimate in WBS format; account C2 has the same total but is given in CWBS format.

W1 = 2480.3	C1 = 0.0
[CRYO = 134.7]	
W2 = 0.0	C2 = 2480.3
	[RC1 = 46.7]
W3 = 530.0	C3 = 530.0
WBS = 3010.3	CWBS = 3010.3

- (2) WBS Variance (V1). The HEB refrigerator cost estimate is increased by \$0.2M. The notation "dX" is defined to mean an increment of account X. $dW1 = 0.2$; $dW3 = -0.2$; $dC2 = 0.2$; $dC3 = -0.2$; note that $W1 + W2 - W1(\text{initial}) = V1$.

$W1 = 2480.5$ [CRYO = 134.9] $W2 = 0.0$ $W3 = 529.8$ $WBS = 3010.3$ $V1 = 0.2$	$C1 = 0.0$ $C2 = 2480.5$ [RC1 = 46.9] $C3 = 529.8$ $CWBS = 3010.3$
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- (3) As progress is made on the SSC construction project, \$140.0M of contracts, mostly for conventional facilities, are signed. No variances are noted. $dW1 = -140.0$; $dW2 = 140.0$; $dC1 = 140.0$; $dC2 = -140.0$.

$W1 = 2340.5$ [CRYO = 134.9] $W2 = 140.0$ $W3 = 529.8$ $WBS = 3010.3$ $V1 = 0.2$	$C1 = 140.0$ $C2 = 2340.5$ [RC1 = 46.9] $C3 = 529.8$ $CWBS = 3010.3$
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- (4) Activity Variance (V2). The contract RC1 is signed for \$49.9M, and the activity corresponding to RC1 is now precisely defined. The variance is $\$49.9M - \$46.9M = \$3.0M$ and must be covered by management reserve. At this time, an entry is made into the *Activity Definition File* to record the details of the WBS elements which correspond to the newly signed contract. The bid experience for contract RC1 may lead us to re-examine the cost estimate for the five remaining helium refrigerators. If a revision to the cost estimate were required, a corresponding change must be made to variance V1. $dW1 = -46.9$; $d(\text{CRYO}) = -46.9$; $dW2 = 46.9$; $dC1 = 49.9$; $dC2 = -46.9$; $dC3 = -3.0$; $dV2 = 3.0$.

$W1 = 2293.6$ [CRYO = 88.0] $W2 = 186.9$ $W3 = 529.8$ $WBS = 3010.3$ $V1 = 0.2$ $V2 = 3.0$	$C1 = 189.9$ $C2 = 2293.6$ $C3 = 526.8$ $CWBS = 3010.3$
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- (5) CWBS Variance (V3). After contract RC1 has been signed, all budgeting, scheduling, and planning for this work is done in terms of the activity (the contract) in account C1. As mentioned earlier, a major project management task will be to track the C1 activities in terms of percentage completion. Soon after contract RC1 is signed, the vendor notices that some highly desirable safety valves had been overlooked in the original specifications. The contract is modified by \$0.1M to cover the changes. $dC1 = 0.1$; $dC3 = -0.1$; $dV3 = 0.1$.

W1 = 2293.6	C1 = 190.0
W2 = 186.9	C2 = 2293.6
W3 = 529.8	C3 = 526.7
WBS = 3010.3	CWBS = 3010.3
V1 = 0.2	
V2 = 3.0	
V3 = 0.1	

- (6) The project is completed. Additional variances total \$525.0M: $dV1 = 25.0$; $dV2 = 400.0$; $dV3 = 100.0$. The remaining \$1.7M of management reserve may be used to cover possible claims. $dW1 = -2293.6$; $dW2 = 2293.6 + 25.0 = 2318.6$; $dW3 = -25.0$; $dC1 = 2293.6 + 525.0 = 2818.6$; $dC2 = -2293.6$; $dC3 = -525.0$.

W1 = 0.0	C1 = 3008.6
W2 = 2505.5	C2 = 0.0
W3 = 504.8	C3 = 1.7
WBS = 3010.3	CWBS = 3010.3
V1 = 25.2	
V2 = 403.0	
V3 = 100.1	

Databases

The W1 and W2 accounts contain information about the cost estimate; they contain no schedule information at all. As the earlier example case illustrates, sometimes only a *portion* of a WBS element is transferred from W1 to W2, when a contract is signed. It would be simplest to use separate databases for W1 and W2, in order to avoid complexities concerning duplicate WBS codes in the two accounts.

In contrast, the C1 and C2 accounts contain *activities* which must be scheduled. There is never an overlap of activities in the two files, since a contract can only be signed or unsigned. Most likely it would be convenient to use a single database for C1 and C2, and a special code would be used to indicate whether the activity were active (i.e., whether the activity belongs to account C1).

The *Activity Definition File* (ADF) is empty at the project start, and it grows slowly as the construction proceeds. As mentioned in the previous section, a CWBS element (an activity) can be defined precisely at the signing of a contract, a work order, or a purchase order. At that time, the WBS elements which are being transferred from account W1 to account W2 are recorded in the ADF, along with the code for the CWBS activity. Normally, the ADF entries are never changed after they are recorded, and this file becomes a permanent record of the precise mapping of the WBS to the CWBS. Eventually, all activities are defined, and a complete mapping of the WBS to the CWBS is created. However, it must be stressed that during the construction project, *undefined activities* (i.e., unsigned contracts) are not contained in the ADF, because no precise correspondence yet exists between the WBS elements and the CWBS activities.

Concluding Comments

This memorandum describes a proposed scheme for tracking all costs and variances throughout the SSC construction project. We suggest the use of multiple accounts containing some redundant information in order to provide complete traceability of budget changes. Some details remain to be worked out, and then work can proceed on the software which will be needed to implement this scheme.

- (1) Cost escalation due to inflation must be considered. The WBS accounts have no schedule information and cannot be escalated; all WBS costs must remain in FY 1986 dollars. CWBS costs must be calculated both in FY 1986 dollars and in then-year dollars: the costs in FY 1986 dollars are needed for comparisons with WBS cost estimates, and the costs in then-year dollars are needed for tracking actual expenses. It may be best to store CWBS costs in FY 1986 dollars and to use an escalation table to calculate, as needed, the corresponding then-year dollars.
- (2) At least for some OPEN PLAN reports, it appears necessary to enter all WBS or CWBS codes (for all activities being considered) at the same level. Some scheme must be worked out to deal with the problem that the lowest level of the WBS varies from level 5 for some systems to level 8 for other systems.
- (3) The proposed scheme for project management and control is designed to cope with detailed cost and schedule data for the entire SSC construction project. However, the project management will need to deal with summary data (at level 3 or 4, perhaps). The method for preparing summary reports at a higher and more manageable level must be worked out.
- (4) In this memorandum we have outlined a system for tracking and accumulating all variances throughout the life of the construction project, so that at any time it would be possible to trace all cost changes since the project start. However, it is probable that updated cost estimates and schedules will be considered and accepted by the funding agency during the construction period. In that case, there will presumably be a new baseline cost estimate and a new construction schedule against which all future progress must be measured. Perhaps the simplest method to deal with this redefinition of baselines is to absorb the "old" variances into the C1 account, so that we can start all over again in tracking new variances.