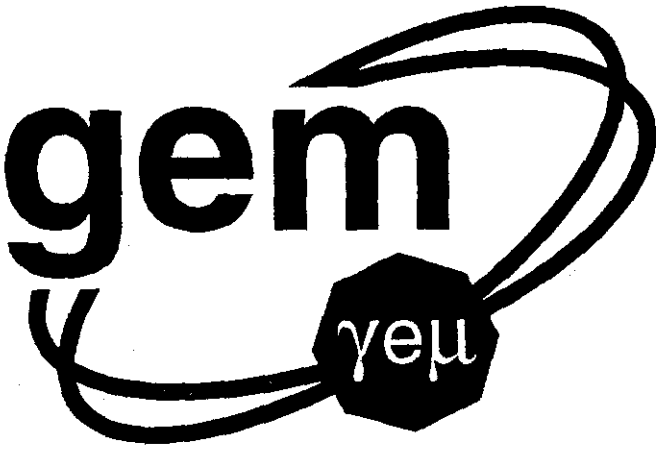
GEM TN-91-17
Rev. H



GEM Cost Estimating Plan

GEM Project Department

April 26, 1993

Abstract:

This document describes the format and procedures to be used to develop the GEM cost estimate for the Letter of Intent. This is intended to be the document which instructs the GEM "subsystem engineers" in their responsibilities for the LOI cost estimate. The Work Breakdown Structure (WBS) is defined as the highest levels and guidelines are given for completing it at lower levels by subsystem. Then the matrix to be used for accumulating the cost estimate is explained in detail. Labor rates and the procedure for setting contingencies are then described. Finally, the overall (short!) schedule for the cost estimate effort is given.

GEM
Cost Estimating Plan
Revision H
April 26, 1993

GEM Project Department

Table of Contents

1.0 Scope 3
2.0 Objectives 3
3.0 Basis 4
4.0 Work Breakdown Structure 5
5.0 Costing Methodology 10
6.0 Labor Rates 15
7.0 Productivity 19
8.0 Material Costs 20
9.0 Risk Analysis/Contingency 22
10.0 Escalation 23
11.0 Responsibilities 24

List of Charts and Tables

Table 1. Cost Matrix Components 11
Chart 1. Cost Type Distribution Objective 14
Table 2. National Laboratories Average Rates 17
Table 3. Industry National Average Rates 17
Table 4. SSC Employees Average Rates 18
Table 5. Job/Shop in Dallas Area 18
Table 6. Contractor Installation Average Rates 19
Table 7. Risk Factor 23
Table 8. Risk Percentage 23

1.0 Scope

The GEM collaboration will produce a comprehensive and detailed cost estimate for the development and construction of a large, high p_T detector at the SSC site. This cost estimating plan (CEP) defines the guidelines and methodology that will be used during the entire cost estimating process. Since GEM is truly an international collaboration of many participants spanning a broad spectrum of resources from numerous universities and laboratories around the world, clear guidance is required from the beginning to assure that the final product is complete and consistent. All participants should perform their work in full compliance with this CEP. Any changes required shall be amended to this plan only after approval from the GEM project management.

2.0 Objectives

2.1 Total GEM Project Cost - A primary objective is to develop a comprehensive estimate of the total GEM project cost. This includes costs for the necessary research and development activities as well as for the engineering, design, analysis, procurement, fabrication, assembly, installation, start-up and management of the construction project itself. Commissioning and system testing costs for GEM **subsystems** are part of GEM Project costs. Project costs shall be accumulated starting from the beginning of the project, defined to be the beginning of fiscal year 1991, i.e.. October 1, 1990, to the completion of the project, defined to be the commencement of experimental activities. All costs will be tabulated into a single computer database. The subsystem databases will be generated by each subsystem cost estimator but coordinated into a master database by the cost estimating manager.

2.2 Detailed Backup Information - During the cost estimating process it is desired to develop the detailed backup information that will justify all estimates and provide confidence to reviewing organizations that the costs are reasonable. Vendor quotations, engineering calculations, drawings, similarities to other systems and other pertinent data will be collected and organized into individual subsystem "basis-of-estimate" books. In addition, basic subsystem configuration will be defined along with a list of critical assumptions made during the estimating process. These books will be generated according to the guidelines established in this plan and be available for review.

2.3 Contingency - Projects of the size, complexity and challenge of the GEM Detector will have some uncertainty and cost risk. Estimates are being made prior to final design and include projections of expected development and engineering tasks. Thus, "contingency" will be generated to account for these uncertainties. The subsystem estimators will perform standardized risk analyses

to develop a consistent justification for all contingency costs which are included in the total system cost. These analyses will be performed according to the guidelines established in this CEP.

2.4 Cost Tracking Baseline - The costs of the GEM Detector will be monitored and must be controlled over the life of the project. This plan will guide the development of a database that can provide the basis for this task. The hierarchy used in the CEP establishes costs in a format that can be translated to a formalized planning system. That system can be implemented to track the actual incurred cost against the projected cost estimates. It is thus vital that the guidelines established by this CEP be strictly followed so that subsequent project monitoring activities may be facilitated.

3.0 Basis

3.1 Detailed Bottom-Up Estimate - The basis for the cost estimate developed according to this CEP will be a detailed bottom-up estimate for each subsystem. These estimates shall be based on FY93 dollars. Escalation factors will be applied at the top level by the cost estimating manager using the temporal cost distributions defined by the subsystem estimators.

3.2 Cost Estimate Development Approach - Cost estimates will be developed using a relational database (See Section 5.0), that will be based on a system-wide Work Breakdown Structure (WBS). The WBS hierarchy to be used will delineate all subsystems and divide each of those subsystems into multiple lower levels. Cost items will define the labor and material required in each of five functional activities for each WBS element. The functional activities will be identified by the following coding scheme:

ENG	-	Engineering/Design
I&A	-	Inspection/Administration
M&S	-	Materials & Supplies
P/F	-	Procurement/Fabrication
INSTAL	-	Installation
ASSBLY	-	Assembly

3.3 Basis-of-Estimate Books - In addition to developing detailed cost items each estimator shall develop his/her own basis-of-estimate book. This document shall contain supporting information which substantiates each cost data item. The detailed cost estimate reports for the lowest level of each WBS branch will include memos further describing critical assumptions or reference to vendor quotations, engineering calculations, etc. Hence, to the extent possible narrative information will be integrated into detailed cost estimate report. All other supporting material, including vendor quotations, engineering calculations, graphs, figures, etc. will be organized in basis-of-estimate books. This

information will be used during both internal and external reviews of the subsystem costs.

4.0 Work Breakdown Structure

The WBS is a hierarchy of elements which identifies all components of a subsystem and their parent/child relationships. Costs for all subsystems and activities will be accumulated in a single WBS list. Cost estimators will develop the subsystem WBS hierarchies where it has not already been defined. These will be collected and collated into the GEM Detector WBS.

4.1 GEM Top Level Hierarchy - The guideline WBS hierarchy has been established. The numbering scheme is consistent with the structure file listing used by SSCL for the entire project. The top level elements are listed below:

522.50	GEM Detector	level 0
522.5010	Tracker	level 1
522.5020	Calorimeter	level 1
522.5030	Muon	level 1
522.5040	Magnet	level 1
522.5050	Electronics	level 1
522.5060	Computing	level 1
522.5070	Interface Systems	level 1
522.5080	N/A	level 1
522.5090	Project Mgmt	level 1

The first five digits are common to all GEM subelements. Therefore, for reasons of simplicity they will not be explicitly utilized in the lower levels of the GEM WBS.

Instead the subsystem estimators will use the following level 1 nomenclature:

10	Tracker	level 1
20	Calorimeter	level 1
30	Muon	level 1
40	Magnet	level 1
50	Electronics	level 1
60	Computing	level 1
70	Interface Systems	level 1
80	N/A	level 1
90	Project Mgmt	level 1

4.1.1 Lower Level WBS - The WBS has been discussed and agreed to by each subsystem group. Any changes to this WBS must be documented and justified. These changes will be made following GEM change control procedures.

4.1.2 WBS Dictionary - The cost estimate for each WBS element is based on a scope of work for that given element. A WBS Dictionary is essential to define the scope of work for each element. A realistic cost estimate can not be developed without a WBS Dictionary.

4.2 GEM Detector Subsystems Construction Costs

4.2.1 Central Tracker (10) - Construction costs for the central tracker shall include the inner and outer tracker, structures, alignment system, cooling systems, assembly, test and installation equipment, and other ancillary support equipment. Electronic channel costs for the inner tracker shall and outer tracker channels shall not be included in this subsystem. The electronic subsystem shall cover these costs.

4.2.2 Calorimeter (20) - The calorimeter element shall identify costs for the liquid krypton/argon calorimeter, the scintillating hadron calorimeter, and the forward calorimeter options. Costs shall include detector components, structures, cooling systems, cryogenics, assembly, test and installation equipment, and sensing electronics. Electronic channel costs shall be covered in the electronic systems WBS element. Channel costs begin with the preamplifier located in the detector and this interface is further defined in the WBS dictionary. Assembly facilities at SSC not provided by SSC shall also be included.

4.2.3 Muon (30) - Costs shall include the chambers, support structure, central and end cap assemblies, gas supply system, cooling system, assembly, test and installation equipment. Electronic channel costs, which begin with the

preamplifier located in the detector, are included in the electronic subsystems and are defined in detail in the WBS dictionary.

4.2.4 Magnet (40) - The magnet subsystem shall include all costs for the coil assemblies, end poles, structures, vacuum system, thermal control, cryogenics, power systems, sense and control electronics up to the slow control workstations, and assembly, test and installation equipment.

4.2.5 Electronics (50) - The electronic subsystem shall include trigger and data acquisition as well as electronic channel costs for all of the detectors. The triggering system includes all electronics for the level 1 and level 2 triggers for the muon, calorimeters, central tracker and all global triggering systems. This includes all optical links, racks, circuit boards, crates and ancillary electronic equipment. Channel design varies from subsystem to subsystem but in general includes cabling, optical fiber links, high and low voltage power supplies, integrated circuits, PC boards, preamplifiers, racks, and crates with power and controllers. Costs included in this subsystem generally begin with the preamplifier located after the sensing electronics and ends at the fiber termination in the Operations Center.

4.2.6 Computing (60) - The computers and control subsystem shall provide "slow" control for total detector operation, Level 3 filter computational capability and an on-line computer network with local data storage. Slow control equipment includes computer workstations, DAQ crates located at the subsystems and connecting links (sensors and actuators are costed under each detector subsystem), TV network, UPS, system software and computer support equipment. Level 3 filter costs are dominated by the array of central processing units required but also include workstations, file server, racks/cabinets, software and networking equipment. Off-line computational capability and long-term tape storage are assumed to be costed by SSCL. Also, all TV cameras, recorders, switching equipment and communication systems shall be included.

4.2.7 Interface Systems (70) - Interface systems are facilities, installation equipment and non-standard utilities that are not provided by SSCL. They are not subsystem specific and are used by the collaboration as a whole. Items that are required for a single subsystem are listed under that subsystem WBS element. The central membrane which supports the tracker and calorimeter, the forward calorimeter support structure and the steel interface structure between the magnet vacuum vessel and the SSC provided concrete foundation is also a part of this WBS element. Examples of interface systems are compressed air systems, cryogenics infrastructure, scaffolding, multipurpose installation fixturing, transport systems, non-conventional cooling, detector emergency power, and detector safety systems. The Central Detector Support, magnetic shielding, and global modeling effort are also included in this WBS.

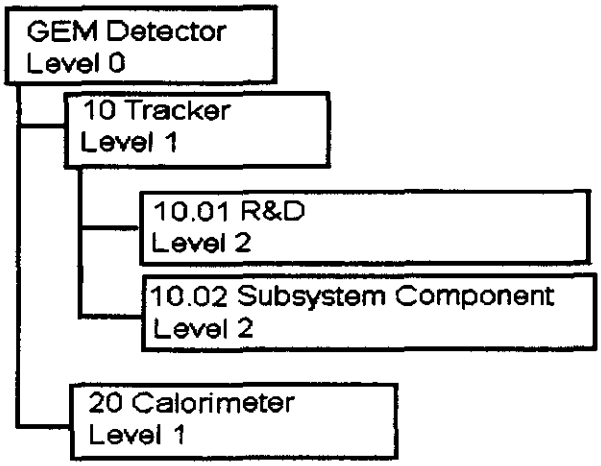
4.2.8 Project Management (90) - Project management encompasses all administrative and management efforts required to direct the GEM project through completion. This includes management personnel and technical staff, system engineering, resource management, safety, and QA personnel, ancillary support contracts, travel, and supplies and expenses. Global analyses that assess technical issues of multiple subsystems shall also be included in this WBS element. Costs that are required to manage the detector project as a whole are included here. Subsystem management costs are defined at the subsystem level.

4.3 WBS Level 2 and Below

4.3.1 Level 2 - Levels at 2 and below have been defined and agreed to by each subsystem estimator and the GEM Project Department, as required. In general most subsystems should be listed down to level 5 or 6 to provide sufficient detail for a meaningful estimate.

4.3.2 Subdividing Level 2's - Each level 2 element shall be subdivided into its logical subsystem components. The next to last subelement at this level shall be subsystem project management and the last is conceptual/preliminary Design. This is illustrated below.

xx.01 R&D
xx.02 Subsystem component 1
xx.03 Subsystem component 2
.
.
xx.n Subsystem component n
xx.n+1 Integration and Final Assembly
xx.n+2 Subsystem project management
xx.n+3 Conceptual/Preliminary Design



4.3.3 Project Management - Subsystem project management includes manpower for planning and control, Group or Division administrative personnel including supervisors and clerical support. ES&H and QA planning and controls, meetings, travel, reviews, developing plans and controls for detector subsystems and facility interfaces are also included. Procurement costs must identify office supplies, engineering service equipment and operating charges.

4.3.4 Interface Systems and Project Management - Interface Systems and Project Management will not be subdivided into the previously listed level 4 subsystems since they are global efforts that are common to all subsystems. Instead they are subdivided as follows:

70 Interface systems	level 1
70.01 Central Detector Support	level 2
70.02 Beam Pipe	level 2
70.03 Detector Access Equipment	level 2
70.04 Detector Safety Systems	level 2
70.05 Utility Services	level 2
70.06 Cranes	level 2
70.07 Auxiliary Equipment	level 2
70.08 Gas Services	level 2
70.09 Survey Alignment Systems	level 2
70.10 Magnetic Shielding Systems	level 2
70.11 Test Beam / Calibration Hall	level 2
70.12 Detector Cable/Plumbing Routing	level 2

90 Project Management	level 1
90.01 Project Mgmt, Planning/Controls	level 2
90.02 Engineering & Integration	level 2
90.03 Environment, Safety & Health/QA	level 2
90.04 Administration	level 2

5.0 Costing Methodology

5.1 Relational Cost Database (SUCCESS) - SUCCESS is the cost estimating program that will be used to collect all information for the GEM cost estimate. SUCCESS is a relational database application that operates in Microsoft Windows (Version 3.0 or greater). Each subsystem will be compiled into a single SUCCESS project for preparation of all subsystem cost reports. These reports will include, but are not limited to, the following:

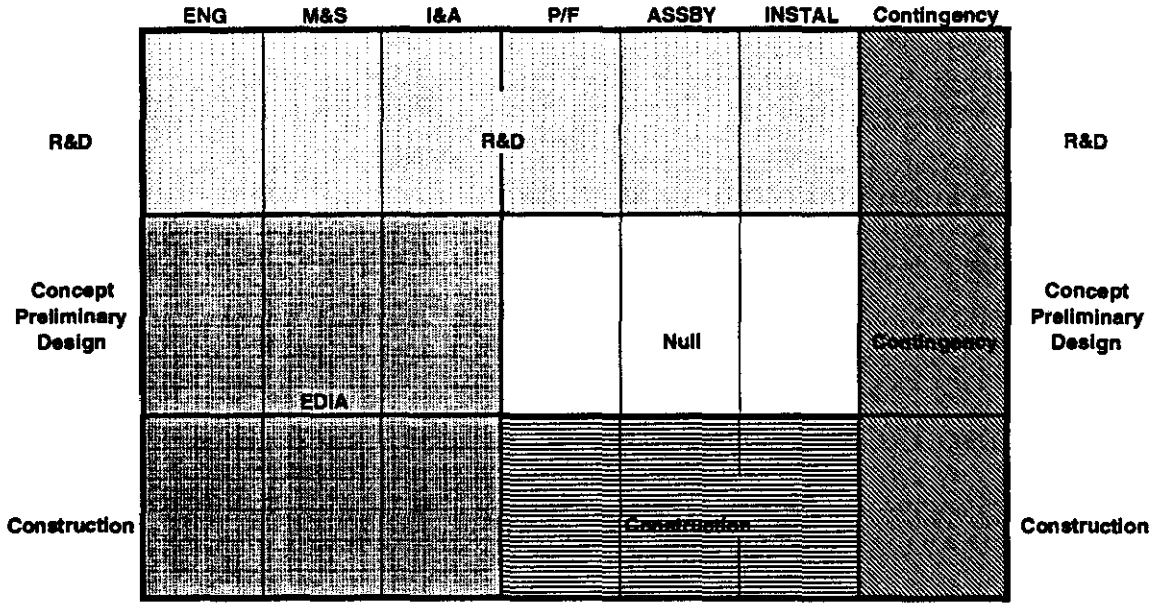
- WBS Cost Summary Report
- Industrial Prime Contractor Report (if applicable)
- Team Composition/Utilization Report (if applicable)
- Labor Craft Utilization Report
- Detailed Cost Estimate Report

SUCCESS will then be used to link all subsystem projects for GEM system-wide data analysis such as tables and graphs for:

- Cost Matrix Components (See Table 1)
- Labor Distributions (for EDIA, and Touch Labor)
- Material Cost Distribution by Subsystem
- Labor Rate Analysis
- Cost Distribution by Subsystem
  - Total
  - R&D
  - EDIA
  - Contingency

5.2 Collection of Cost Information - Previously prepared spreadsheet cost estimates will be converted into the SUCCESS format. SUCCESS reports will be forwarded to each subsystem leader once the data conversion process is complete. **Revisions** or edits to these estimates may be done directly on the reports and then submitted to the GEM Project Planning & Controls Group for updating the SUCCESS project files. The Supporting Data Tables (SDT's), discussed later in the CEP, will also be prepared from previous spreadsheets or an electronic spreadsheet copy (EXCEL Format) of the WBS may be forwarded, upon request, as a starting point. The SDT's should be part of the cost basis books. **New** cost estimates may done by using the attached input forms. Cost Basis books shall include any other supportive information that will not be included in the SUCCESS reports.

Table 1. Cost Matrix Components



$$\text{R\&D \%} = \frac{\text{R\&D}}{\text{Construction}}$$

$$\text{EDIA \%} = \frac{\text{EDIA}}{\text{Construction}}$$

$$\text{Contingency \%} = \frac{\text{Contingency}}{\text{Construction + EDIA}}$$

5.3 Cost Estimate Report Book - The cost estimate report book for TDR submission will consist of the SUCCESS generated reports, supporting data tables (SDT), and basis-of-estimate information. The SDT's shall be generated using EXCEL (Version 3.0 or greater) spreadsheets that are vertically synchronized with the WBS elements. The SDT's will contain (at a minimum) pertinent estimate information that is defined later in the CEP.

5.3.1 Basic Cost Information - The SUCCESS database contains the basic cost information for each WBS element. Material and labor costs are identified in each of 5 main functional categories: engineering/design, inspection/administration, procurement/fabrication, assembly, and installation as described in section 3.2. Costs are estimated in FY93 dollars. Roll-ups of total costs from subelements to higher level elements are performed internally within the SUCCESS framework. Labor rates, material estimating strategies, and contingency methodology are defined in subsequent sections. Attached are cost input forms with instructions and examples.

5.3.1.1 Functional Activities

5.3.1.1.1 Engineering/Design (ENG) - Engineering/Design includes labor for all engineering design, engineering analysis, reliability analysis, design layout, and detailing and checking of fabrication drawings. Documentation for performance and fabrication specifications, safety analysis reports, design reviews, assembly procedures and testing or system checkout procedures are also included in this work category.

5.3.1.1.2 Materials and Supplies (M&S) - Material and supply costs cover all procurements required to support the EDIA activity in general. Material costs for travel, supplies and expenses, office and engineering service equipment and operating charges for that equipment are included.

5.3.1.1.3 Inspection/Administration (I&A) -
Inspection/Administration collects all labor costs to administer fabrication and procurement contracts, scheduling of production, production inspection, pre and post assembly inspection of individual components of the detector subsystem. Also included is engineering administration labor associated with supervising both on-site and off-site assembly, installation and system checkout. Quality assurance planning, inspection, oversight, and documentation costs are also accumulated in this category. In addition, this functional category collects all costs associated with administering the project at either the subsystem or detector level. This includes project management, scheduling, planning, costing, and activities associated with implementing ES&H requirements.

5.3.1.1.4 Procurement/Fabrication(P/F) - Procurement/fabrication includes procured costs for detector component material, fabrication, tooling, and equipment, necessary to construct the GEM detector and supporting facilities. Purchased labor contracts to perform tasks associated with engineering, installation, or assembly are not included in this category but rather in the specific category that they are associated with.

5.3.1.1.5 Assembly (ASSBLY) - Assembly includes labor and material necessary to assemble the purchased and fabricated components into subassemblies. These activities may occur at both off-site and above ground SSC facilities. Tasks also include alignment, checkout and test necessary to verify that assembled components satisfy subsystem requirements. Fixturing, handling equipment and test equipment are included in this category. Supervision and inspection of the activities performed in this category are specified in EDIA.

5.3.1.1.6 Installation (INSTAL) - Installation covers all activities performed by the GEM collaboration in the experiment hall. This includes transporting the equipment to the down hole location, rigging, erection, downhole assembly, alignment, integration, test, checkout and startup of the entire GEM detector.

Costs in this category begin to accrue when the physical equipment enters the experiment hall and ends after the initial startup of the detector prior to commencement of experimental activities. All equipment necessary to perform these functions must be included.

5.3.1.1.7 Contingency - Contingency for the GEM detector cost estimate shall be based on a standardized risk analysis. Each estimator shall perform the risk analysis identified in Section 9.0 and enter the associated contingency in an SDT and for application within the SUCCESS project. Depending upon the particular subsystem being analyzed contingency may be applied at the lowest WBS level or at a higher subassembly level. It is the responsibility of the estimator to make this determination. In any case, the estimators are responsible for assuring that each and every component has appropriate and defensible contingency applied.

5.3.2 Supporting Data Table - The SDT's, which may be divided into one or more matrices, provide important supporting data to the cost estimates. Estimators are required to provide input to these tables and submit it to the GEM Project Planning & Controls Group for additional processing into the SUCCESS framework. The information contained in the SDT is essential for interpreting the cost estimates, reviewing them and temporally distributing the costs to permit accurate cost projections to the end of the project. *Please note: The SDT information is only applied to WBS elements. All cost items internal to a given WBS element will be applied the SDT information.*

5.3.2.1 Quantity (QTY) and Units of Measure (UM) - The QTY and UM parameters identify the basic cost unit that was used to determine the cost and the total number of the units that was assumed. Typical values used for units are tons, meters^2, channels, system, assembly, and fibers. For any given WBS element almost anything can be used but the more descriptive it is the more helpful it will be to a reviewer.

5.3.2.2 Estimate Types - Each WBS element shall be tagged with a cost basis descriptor which characterizes the type of estimate that was used. Acceptable data entries are as follows:

1) Bottom-up (BU)
2) Specific analogy (SA)
3) Parametric study (PS)
4) Review and update (RU)
5) Trend analysis (TA)
6) Expert opinion (EO)

Definition of these categories can be found in DOE 4700.1, Project Management System.

It is important that a concerted effort be made to maximize as many WBS elements with BU detail as illustrated below.

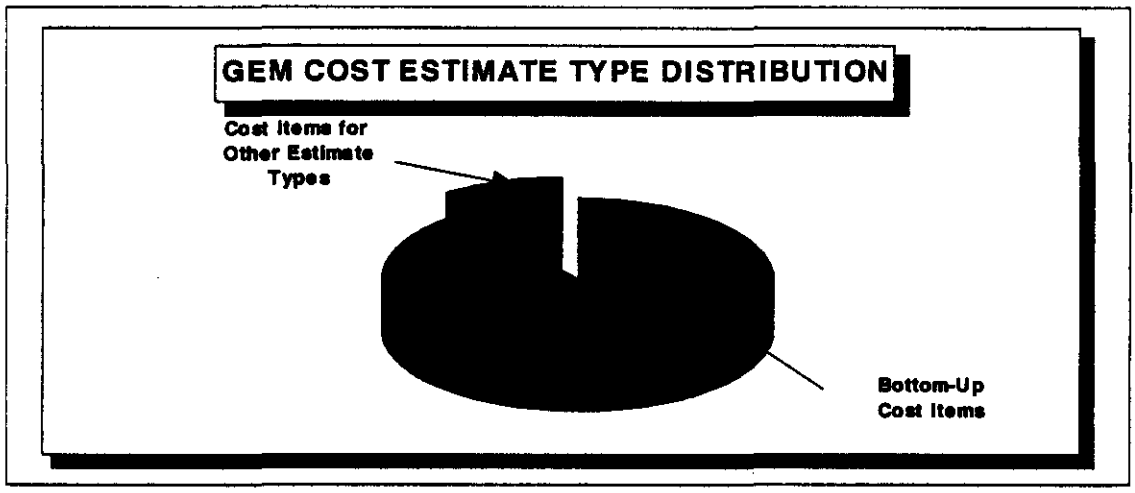


Chart 1. Cost Type Distribution Objective

5.3.2.3 Risk Factors - The risk analysis described in Section 9.0 is used to calculate contingency. In the three columns provided in the SDT, technical, cost and schedule risk factors are input. Standard ranges for these parameters are 1 to 15 for technical and cost risk, 2 to 8 for schedule risk. In some cases the standardized risk parameters may not be appropriate. Higher values may be used as described in Section 9.

5.3.2.4 Risk Percentage - The applied risk percentages are dependent on two factors. The first is whether the risk is associated with technical, cost or schedule concerns. The second is whether these concerns involve design, manufacturing, material cost or labor rate uncertainties. Acceptable values which range from 1% to 4% are defined in Section 9. These percentages are

multiplied by the corresponding risk factor to determine the total contingency which should be applied.

5.3.2.5 Contingency Total - This parameter is the sum of the products of the individual risk factors and corresponding risk percentages.

5.3.2.6 Durations - Durations must be assigned to permit appropriate scheduling of all WBS elements and subsequent application of escalation factors to the base cost estimates. The durations shall be assessed for each of the applicable functional categories; i.e., engineering/design, inspection/administration, procurement/fabrication, assembly and installation. In general this information shall be provided down to the lowest WBS elements. However, in some cases, lower level activities may be so detailed that identifying specific timelines for them becomes unreasonable or adds no further meaningful information. In these cases the subsystem estimators may decide to limit data entries to higher WBS levels. GEM Project Management shall make the final determination.

6.0 Labor Rates

6.1 Labor Rates - Estimators shall use their best discretion in selecting the labor categories and rates that should be used for their subsystem cost estimates. In making their decision, the estimators should determine where the work shall be performed and use the most accurate information available regarding the labor rates for that particular institution. Detailed backup information shall be provided in the cost book supporting any labor classification used. Rates used shall be fully burdened with all associated costs.

6.1.1 Labor Rate Plan - In some cases the subsystem estimators will either know (or establish as a basis) specifically the location where many of the engineering, design development, quality assurance, etc. types of efforts will be performed.

In the remaining cases, exact sources of labor will not be known, thus they will have to be assessed using average rates. Average rates for various categories have been defined in the section below for selective use as required. Tables 2 through 6 below list the fully burdened rates for FY93.

In all cases when an appropriate labor category is not predefined a new craft may be appended to the list of labor resources. However, each new resource should be supported with detailed backup information. An SDT shall be

prepared listing these labor categories with the minimum associated information.

Craft Name/Description
Base Annual Salary[1] (k$/Yr)
Payroll Burdens[2] (%)
General Overheads[3] (%)

[1] Base Annual Salary is defined as the average payroll compensation for FY 1993.

[2] Payroll Burdens are expressed as a percentage of Base Annual Salary. These burdens will typically include payroll taxes for FICA, unemployment insurance, workers compensation, etc. The aggregate percentage for the payroll burdens will suffice for estimating purposes. Also, this percentage in most cases will be a constant for all labor classifications at a given institution.

[3] General Overheads are expressed as a percentage of Base Annual Salary. These overheads will typically include cost allocations for vacation pay, sick leave pay, holiday pay, facilities, engineering support burdens, laboratory general expense, laboratory directed R&D, etceteras. The aggregate percentage for the general overheads will suffice for estimating purposes. Also, this percentage in most cases will be a constant for all labor classifications at a given institution.

For instance, if it is known that an effort will be performed at a specific location, then a new craft should be developed and supported with the aforementioned backup information relative to the specific location.

The cost estimating approach may then be streamlined by using crafts, for items of work requiring only one craft, as a means of assessing labor costs in a relational fashion. For other items of work which require a group of crafts, then a team (crew) should be established for this purpose. The team would consist of one or more labor crafts, each with a designated usage or mix. Only predefined and/or new crafts supported with detail information should be used as member(s) of the team. The teams developed for the estimate must be defined in detail. In most cases, only a few teams will have to be developed. Subsequently, systematic application of the crafts or teams will: 1.) streamline the detailed estimate development; 2.) simplify the process of creating a relational database estimate (using SUCCESS); 3.) expedite the normalization process for labor rates to be used throughout all GEM Detector subsystems by the GEM Project Planning & Controls Group.

6.1.1.1 National Laboratories Average Rates - It is anticipated that the US National Laboratories will participate in many of the GEM subsystems. The

following rates are average rates that may be used for work performed for any of these institutions. These rates include general overhead, support, payroll burden and general laboratory taxes. These rates [based on 1772 Full-Time-Equivalent (FTE) hour per year for hourly rates] should be used for the first iteration of the estimating process. While cost estimates are being prepared a concurrent effort will be conducted to assess the most accurate average rates to use for effort to be done by prospective institutions, contractors, etc.

Table 2. National Laboratories Average Rates

CRAFT CODE	CLASSIFICATION	FY 93 STUDY ANNUAL LOADED RATE ($/YR)	FY 93 BASE FTE $/HR	FY 93 LOADED FTE $/HR
NATIONAL LABORATORY				
NL01	MANAGER	$226,650	**$50.96**	$127.91
NL02	SECRETARY	$69,650	**$15.66**	$39.31
NL03	ENGINEER/PHYSICIST	$159,480	**$35.86**	$90.00
NL04	DESIGNER/COORDINATOR	$132,780	**$29.85**	$74.92
NL05	SENIOR TECHNICIAN	$125,920	**$28.31**	$71.06
NL06	JUNIOR TECHNICIAN	$94,880	**$21.33**	$53.54
NL07	CRAFT	$104,790	**$23.56**	$59.14

6.1.1.2 Industry National Average Rates - National average rates [based on 1900 Full-Time-Equivalent(FTE) hour per year for hourly rates] may be used for cases where the source of labor is completely unknown. These labor classifications would be used for industry based effort.

Table 3. Industry National Average Rates

CRAFT CODE	CLASSIFICATION	FY 93 STUDY ANNUAL LOADED RATE ($/YR)	FY 93 BASE FTE $/HR	FY 93 LOADED FTE $/HR
INDUSTRY NATIONAL AVERAGE				
NA01	EXECUTIVE MANAGEMENT	$144,900	**$47.65**	$76.26
NA02	PROF. SPECIALIST/TECH. ENGINEER	$96,300	**$31.67**	$50.68
NA03	FAC. SPT./SUPVSR/FOREMAN	$77,900	**$25.63**	$41.00
NA04	PRECISION PRODUCTION	$78,900	**$29.64**	$41.50
NA05	AVERAGE MACHINIST	$56,600	**$21.29**	$29.79

6.1.1.3 SSC Employees Average Rates - Work performed by SSC employees shall be charged at the following rates. [Based on 1772 Full-Time-Equivalent(FTE) hour per year for hourly rates]

Table 4. SSC Employees Average Rates

CRAFT CODE	CLASSIFICATION	FY 93 STUDY ANNUAL LOADED RATE ($/YR)	FY 93 BASE FTE $/HR	FY 93 LOADED FTE $/HR
SSC EMPLOYEES AVERAGE RATES				
SSC01	MANAGER	$142,362	**$55.41**	$80.34
SSC02	ENGINEER/PHYSICIST	$83,284	**$32.42**	$46.00
SSC03	ANALYST/ADMINISTRATION	$53,497	**$20.82**	$30.19
SSC04	SENIOR TECHNICIAN	$46,790	**$18.21**	$26.40
SSC05	TECHNICIAN/DRAFTSMAN	$39,569	**$15.40**	$22.33
SSC06	CLERKS	$30,709	**$11.95**	$17.33
SSC07	JUNIOR TECHNICIAN	$30,124	**$11.73**	$17.00
SSC2.5	SENIOR ADMINISTRATOR	$81,512	**$31.73**	$46.01

6.1.1.4 Job/Shop in Dallas Area - These are based on 2080 Full-Time-Equivalent(FTE) hour per year for hourly rates.

Table 5. Job/Shop in Dallas Area

CRAFT CODE	CLASSIFICATION	FY 93 STUDY ANNUAL LOADED RATE ($/YR)	FY 93 BASE FTE $/HR	FY 93 LOADED FTE $/HR
JOB SHOP IN DALLAS AREA				
JS01	ENGINEER/PHYSICIST	$92,900	**$29.97**	$44.66
JS02	SOFTWARE ENGINEER	$81,100	**$26.17**	$38.99
JS03	DRAFTSMAN	$57,800	**$18.65**	$27.79
JS04	JUNIOR TECHNICIAN	$46,100	**$14.88**	$22.17
JS05	SENIOR TECHNICIAN	$61,200	**$19.75**	$29.43
JS06	AVERAGE MACHINIST	$63,800	**$20.57**	$30.65
JS07	PRECISION MACHINIST	$75,900	**$24.50**	$36.51

6.1.1.5 Contractor Installation - For installation of equipment at the SSC site in Texas the appropriate Davis-Bacon wage rates are as follows. Rates are fully burdened and based on 1900 Full-Time-Equivalent(FTE) hour per year for hourly rates.

Table 6. Contractor Installation Average Rates

CRAFT CODE	CLASSIFICATION	FY 93 STUDY ANNUAL LOADED RATE ($/YR)	FY 93 BASE FTE $/HR	FY 93 LOADED FTE $/HR
CONTRACTOR INSTALLATION				
CI01	CRANE OPERATOR	$50,300	**$18.90**	$26.46
CI02	RIGGER	$51,000	**$19.16**	$26.82
CI03	LABORER	$28,900	**$10.85**	$15.19
CI04	MILLWRIGHT	$51,500	**$19.37**	$27.12
CI05	ELECTRICIAN	$54,800	**$20.60**	$28.84
CI07	PIPEFITTER	$54,600	**$20.54**	$28.76
CI08	CARPENTER	$42,500	**$15.98**	$22.37
CI09	PAINTER	$38,400	**$14.42**	$20.19
CI10	WELDER	$53,600	**$20.16**	$28.22

7.0 Productivity (Manpower per Unit of Measure)

7.1 Productivity - Once the subsystem estimators have established crafts, teams, and their associated rates, the next step in the estimating process for assessing cost for any given effort is to assess production. Production in essence may be defined as the total amount of manpower required to perform a given task, effort, work, etceteras. For any given item of work the Unit Productivity (work rate) is defined as the amount of manpower per Unit of Measure (UM). Labor Cost (LC) may then be expressed as follows:

LC= QTY * (Craft or Team Rate) * (Unit Productivity)

Once Unit Productivity values are established they may be used effectively and can become a powerful tool throughout the estimating process.

7.1.1 Full-Time-Equivalent (FTE) Manpower Units -
For estimating purposes the CEP has defined a set of conventions for calculating manpower requirements throughout the cost estimate development process. A FTE-Man-year is the equivalent of a salaried person ***actually*** working (and billable) for 1772 Actual-Time (AT)hours during a 12 calendar month period for National Laboratories. [For other sources of labor the AT hours year varies - See Average Rate tables above.] The Unit Productivity convention established within the SUCCESS framework for manpower is FTE rates as a baseline. Hence, all cost items should be estimated on an FTE basis. In some instances, conversions from calendar time units to FTE-Man-years will be required. For

simplicity, it is recommended that man-hours required be used during the estimating process. The GEM Project Planning & Controls Group will then convert to FTE-Man-years. To calculate Unit Productivity of a given cost item we offer the following examples:

Example 1

There are 10 drawings to be designed, each estimated to require 40 actual man-hours (MH) of effort. It is not known which National Laboratory will perform the work. Thus, craft NL03 is used. Unit Cost parameters for this item would then be:

QTY: 40 UM: Drawings Craft: NL03
Unit Productivity: 40 MH/Drawing

Example 2

Site inspection will be required for 5 calendar months by two senior technicians. Craft NL05 is used. Unit Cost parameters for this item would then be:

QTY: 5 UM: Months Craft: NL05
*Unit Productivity:(2 Persons)/Month * (173.3 MH)/person = 346.6 MH/Month*

8.0 Material Costs

8.1 Material Cost Index - Material costs shall include all hardware costs for the entire GEM project. WBS elements shall be listed to cover projected requirements for each subsystem. All costs not based on FY 1993 dollars will be escalated as appropriate from the estimate basis FY by the GEM Project Planning & Control Group. All material costs shall have backup details included in the subsystem cost books.

8.2 Material Requirements - Material costs include all procurement and fabrication for all GEM assemblies and facilities. This includes detector hardware, equipment, fixturing, tooling, utilities, test equipment, assembly equipment, computer hardware, raw material, and material processing, etc.

8.3 Facility & Utility Costs - Detector costs must also include facility and utility costs not provided by SSCL. These include, but are not limited to, gas systems, access and structures in the experimental hall and surface facilities, non-conventional cooling, power distribution exceeding the baseline, and emergency power. Safety systems costed by GEM include fire extinguishing systems, fluid spill control system, radiation monitoring systems, oxygen deficiency system, and nitrogen inerting system.

8.4 SSCL (EFD/CCD) Provided Cost Elements - SSCL (EFD/CCD) will cost the following facilities:

1) Underground detector facilities
    - Collision hall, shafts and tunnels
    - Power and electrical cabling*
    - HVAC*
    - Cooling*
        - CPW
        - CHW
        - LCW
        - ICW
2) Surface facilities
    - On-site assembly buildings
    - Shaft head houses
    - Gas mixing building
    - Utility building
    - Storage areas/hard stands
    - General purpose machine shops
    - Power and electrical cabling, routing and distribution
    - HVAC
    - Cooling*
        - CPW
        - CHW
        - LCW
        - ICW
    - Gantry Crane
    - Shaft Covers
3) Site infrastructure
    - Roads
    - Parking
    - Water, sanitary, and storm sewer
    - IR power distribution
    - Hardstands

*but not internal distribution through the detector.

9.0 Risk Analysis/Contingency

9.1 Risk Analysis - Risk analysis shall be performed for each WBS element. Results of this analysis will be related to a contingency which shall be listed for each WBS element. Risk analysis parameters shall be listed in the SDT with equivalent contingency aggregate values also calculated. Risk analysis/contingency methodology shall, in general, comply with the SSCL recommended technique.

9.2 SSCL Methodology - This method is based on estimator evaluation of technical, cost and schedule risk for every WBS element. For technical risk, the value of 1 implies "normal industrial supplied off the shelf item" and 15 is reserved for components "way beyond the current state-of-the-art." For cost risk values, 1 is used to indicate "vendor quote or catalog price for a specific item" and 15 is used for estimates where no data is available. Schedule risk factors range from 2 to 8. The technical risk factor is multiplied by a risk percentage which is categorized below The resulting percentages are added together to establish the total contingency allocation for a particular WBS element. The minimum contingency percentage under this approach is 5% and the maximum is 98%.

Table 7. Risk Factor

Risk factor	Technical	Cost	Schedule
1	Existing design and off-the-shelf hardware	Off the shelf or catalog item	not used
2	Minor modifications to an existing design	Vendor quote from established drawings	No schedule impact on any other item
3	Extensive modifications to an existing design	Vendor quote with some design sketches	not used
4	New design within established product line	In-house estimate for item within current product line	Delays completion of non-critical path subsystem item
6	New design different from established product line. Existing technology	In-house estimate for item with minimal company experience but related to existing capabilities	not used
8	New design. Requires some R&D development but does not advance the state-of-the-art	In-house estimate for item with minimal company experience and minimal in-house capability	Delays completion of critical path subsystem item
10	New design. Development of new technology which advances the state-of-the-art	Top down estimate from analogous programs	not used
15	New design way beyond the current state-of-the-art	Engineering judgment	not used

Table 8. Risk Percentage

	Condition	Risk percentage
Technical	Design or mfg concerns only	2%
	Design and mfg concerns	4%
Cost	Material cost or labor rate concern	1%
	Material and labor rate concern	2%
Schedule		1%

9.3 Good Judgment - There may be special cases where the parameter limitations defined above are inappropriate. Some high risk elements may deserve contingencies greater than 98%. In these cases, at the discretion of the estimator, higher values may be used. Justification for these cases must be provided in the estimator's subsystem cost book.

10.0 Escalation

Escalation factors will be applied to the base FY 1993 costs identified in each estimator's cost table. Factors to be used will be supplied at a later date and will be implemented into the GEM detector cost by the cost coordinator. Subsystem estimators do not need to take any action except to include activity start and end dates.

11.0 Responsibilities

Cost estimating responsibilities are as follows:

Subsystem	Responsible person
Magnet subsystem	G. Deis
Muon subsystem	D. Gustavson
Calorimeter subsystem	J. Coulon
Central tracker subsystem	T. Thompson
Electronic systems	D. Marlow
Computers and Control	K. MacFarlane
Interface systems	J. Coulon
Project management	R. Fischer