LIGO II

COST ESTIMATING PLAN (CEP)

May 19, 2000

LIGO-M990310-04-M

LIGO II Cost Estimating Plan

1.0 Scope

This Cost Estimating Plan (CEP) defines the guidelines and methodology that will be used to prepare and update the LIGO II cost estimate. This guidance is provided to assure that the final product is complete, consistent, and well documented. The cost estimate will be assembled and maintained in a LIGO II Cost Book.

2.0 Objectives

The primary objective is to develop a comprehensive estimate of the total LIGO II project cost. This includes the costs for engineering, design, analysis, procurement, fabrication, assembly, installation, commissioning, and management of the detector upgrade. It also includes any associated research and development costs required beyond that funded by the NSF under the Advanced R&D Program (PHY-9801058).

The cost estimates will be prepared by technical experts who are experienced in the fields of specialization required to accomplish the LIGO II upgrade. Vendor quotations, engineering calculations, drawings, and other pertinent data including similarities to LIGO I, which are used to support the cost estimate, will be collected and organized into a Basis-of-Estimate (BOE). A copy of the BOE will be provided to Project Controls and maintained in the Cost Book with the cost estimate. The Cost Book will be organized according to the LIGO II Work Breakdown Structure (WBS). This Cost Book and BOE will furnish LIGO II management as well as reviewing organizations with the data required to substantiate all estimates. The documentation will include the basic configuration information and list all critical assumptions used during the estimating process. The BOE will be prepared according to the guidelines established in this plan.

Large, complex, and challenging projects entail uncertainty and cost risk. A contingency to cover anticipated costs resulting from this uncertainty will be developed using standardized risk analyses as established in this CEP. Contingencies will be developed at the same level of the WBS used to prepare cost estimates.

LIGO II costs will be monitored and controlled over the life of the project. The cost estimate will be used to establish budgets in a formal project management control system. The control system will compare actual costs with the budgets established for the work accomplished. Thus, it is vital that the guidelines established by this CEP be strictly followed to facilitate subsequent project monitoring activities.

3.0 Basis-of-Estimate (BOE)

The cost estimate developed according to this CEP shall be a detailed bottom-up estimate performed at the lowest reasonable or “activity” level. These estimates will be based on current (2000) year dollars. A Work Breakdown Structure (WBS) will be used to sum estimates to

intermediate and upper levels. Escalation will be applied at the top level to adjust costs to the anticipated Funding Year basis.

Cost estimates shall be entered into a relational database (see Section 5.0) indexed to the project WBS. The WBS hierarchy will delineate all subsystems and divide those subsystems into successively lower levels. For each lowest level of the WBS specific design, fabrication, procurement, assembly, quality, test, installation, commissioning, integration, and management activities will be defined. Within each activity, items to be estimated include direct funded staff labor, contract labor, equipment, travel (foreign and domestic), materials and supplies, consultants, computer costs, publication costs, and subcontracts (subawards).

The cost estimator shall provide supporting information in the form of a BOE for each activity. The Basis-of-Estimate (BOE) shall contain supporting information substantiating each cost data item including vendor quotations, engineering calculations, graphs, figures, etc. This information shall be provided with the cost estimate to be included in the Cost Book. More detailed backup may be retained by each WBS estimator in his/her own copy of the Cost Book. This information will be used during internal and external reviews of the LIGO II cost estimates.

Narrative information including memos describing critical assumptions or referencing other documentation shall also be integrated into the Cost Book and be used during internal and external reviews of the LIGO II cost estimates.

4.0 Work Breakdown Structure

The Work Breakdown Structure (WBS) is a product-oriented hierarchy that identifies all elements of the LIGO II Project and their parent/child relationships. Cost estimators, working with LIGO II Project Management, will develop the subsystem WBS hierarchies. These will be collected and defined in a Work Breakdown Structure Dictionary. The scope of work for each WBS element will be delineated in the dictionary. Each lowest-level WBS element shall be further subdivided into specific research and development, design, procurement, fabrication, assembly, test, quality assurance, installation, and commissioning activities or tasks. The cost estimate for each activity shall be based on the scope of work defined for the WBS element.

5.0 Costing Methodology

Each WBS estimator shall provide data for each activity. This data will be entered into a Microsoft Access database established by Project Management for the purpose. The estimator may provide this data either by completing input forms and submitting them to Project Management or by entry directly onto a Web-based form. The costs associated with each cost element shall be distributed by year and be categorized by labor category, equipment, travel, materials and supplies, consultants, publications/documentation costs, and subcontracts. This information will enable Microsoft Access to generate reports summarizing the cost estimate at various WBS levels and to prepare the summary budgets required for proposals submitted to the NSF.

5.1 Relational Cost Database (Microsoft Access)

A Microsoft Access database has been established to collect and report the LIGO II cost estimate and supporting information. The reports that Microsoft Access will generate include:

- the WBS Dictionary,
- WBS Summary Reports,
- rollup reports for parent level WBS elements, and
- detail reports for lowest level WBS elements.

The Microsoft Access cost estimate database will also be integrated with:

- the planning system used to establish and track schedules (Primavera 3.0), and
- the performance measurement systems used to track cost and schedule status during execution of the LIGO II program.

5.2 Collection of Cost Information

Data may be submitted by cost estimators using hardcopy forms provided by Project Management. We have also developed on-line Web-based forms for entering data directly into the Microsoft Access database.

The Web-based Cost Book Tool is an application that was developed using data from the project schedule to facilitate the collection of cost data and integrate with the project schedule. The application provides all project team members access through the intranet and the internet. It is an estimating application that collects and reports detailed cost information for all the activities required to execute LIGO II and generates the Cost Book submittal. The WBS element definitions are also entered via the Cost Book Tool.

As a user creates an estimate, called an activity sheet, the user is simultaneously creating an activity for the project schedule. Conversely, the process can work the other direction as well. In some cases the user will produce a work plan prior to creating the estimate. The work plan then is used to generate estimate activity sheets for entry of detailed cost estimates.

The Cost Book Tool is constructed around the data dictionaries contained within the Primavera Project Planner (P3) software. This provides the basis for integration with the schedule. These data dictionaries are:

- the WBS Dictionary,
- the Activity ID Dictionary,
- the Resource Dictionary,
- the Cost Code Dictionary, and
- the Cost Group Dictionary.

By integrating the systems at this level, the development of the Cost Book simultaneously creates a cost and resource loaded project schedule. Having a cost and resource loaded project schedule allows the management team to perform cash flow analysis, resource leveling analysis,

earned value analysis, and meet all reporting requirements.

Detailed procedural information regarding the use of the Web-based Cost Book Tool will be found in LIGO-M000162-00-P, The LIGO II Cost Book Tool User's Procedure.

MS Access reports will be returned to the cost estimator for verification of the accuracy of the database.

The estimator shall also provide copies of supporting information for inclusion in the Cost Book as the Basis-of-Estimate (BOE).

5.3 Confidence of Cost Estimate

Each item in the cost estimate shall be tagged with a confidence descriptor which characterizes the uncertainty associated with the estimate. The categories established for the project in decreasing order of confidence include:

- LIGO I costs or other historical data (HD),
- catalog prices (CP),
- vendor quotations (VQ), or
- engineering estimates (EE).

5.4 Cost Book

All detailed and summary reports as well as the supporting BOE will be collected and maintained in the LIGO II Cost Book. Copies of the LIGO II Cost Book will be provided to the cost estimators, project management, and cost reviewers.

5.5 5.5 Cost Book to Schedule Integration

All cost estimate data is collected at the activity level to facilitate the integration of the estimate with the schedule. As cost estimate data is entered into the Cost Book Tool [See "Relational Cost Database (Microsoft Access)" on page 3], an activity for the schedule is also created. The one-to-one relationship between the cost estimate and the schedule will assist the project team and reviewers to evaluate the proposal. Integration will also allow the project team to assess resource usage and determine by discipline what resources are needed to effectively execute the plan.

6.0 Labor Pricing

Material, labor, and subcontract costs will be based directly on information provided by the cost estimator. However, the estimator will provide labor estimates in hours which will be priced according to average LIGO I direct salary experience for the labor resource identified. Indirect costs and Benefits will be computed and reported by Microsoft Access based on rates established for the purpose by the Caltech Office of Sponsored Research.

6.1 Direct Labor Rates

Average LIGO I labor rates for each labor category will be used when available for pricing direct labor. The labor categories available for estimating include:

- A Key Personnel/Faculty
- B1 Post Doctoral
- B2 Senior Scientists
- B2 Scientists
- B2 Senior Engineers
- B2 Engineers
- B2 Technicians
- B2 Other (Subcontract Management, etc.)
- B3 Graduate Students
- B4 Undergraduate Students
- B5 Clerical/Administrative
- B6 Other

The rates used to price labor hours will be adjusted to include paid leave such as sick leave, vacations, holidays, etc. There are a total of 2080 hours paid during a normal full year. However, paid leave hours reduce the productive year for estimating purposes to 1800 hours. **Hourly labor rates are adjusted so that 1800 hours estimated will be priced at a full year of salary.**

The rates used do not include Benefits or Indirect Costs. Benefits and Indirect Costs are added by the reporting system.

The estimator shall provide hour estimates for all labor resources. Full-time-equivalent (FTE) estimates should be converted to 1800 hour years. In other words 1.0 FTE is equivalent to one person working full time with normal holidays, vacations, and sick time. No paid overtime is assumed.

6.2 Contract Labor

Contract Labor rates will be based on historical cost data from LIGO I. No Benefits or Overhead will be applied.

7.0 Risk Analysis, Contingency

Contingency established for the LIGO II Project shall be based on a standardized risk analysis as described below. The cost estimator is responsible for providing risk factors for each activity. The estimator is responsible for assuring that each and every component has appropriate and defensible contingency applied.

7.1 Risk Analysis

A risk analysis is used to calculate contingency. The method is based on estimator evaluation of the technical, cost, and schedule risk for every activity. Technical, cost, and schedule risk factors

are input fields on the forms used to enter data into the database. Standard ranges for these parameters are 1 to 15 for technical and cost risk and 2 to 8 for schedule risk.

7.2 Risk Assessment Methodology

Risk Factors are assigned as described in Table 1 on page 7. For technical risk, the value of 1 implies “normal industry supplied off the shelf items,” and 15 is reserved for components significantly “beyond the current state-of-the-art.” For cost risk, a value of 1 is used to indicate “vendor quote or catalog price for a specific item”, and 15 is used for estimates where no data are available. Schedule risk factors range from 2 to 8.

The technical risk factor is multiplied by the risk percentage, which is categorized in Table 2 on page 7. The applied risk percentage depends on two factors. The first is whether the risk is associated with technical, cost, or schedule concerns. The second is whether these concerns relate to design, manufacturing, materials cost, or labor rate uncertainties. Acceptable values in the range of 1 percent to 4 percent are defined in Table 2 on page 7. These percentages are multiplied by the corresponding risk factor to determine the contingency to be applied. The resulting percentages are added together to establish the total contingency for the activity. The minimum contingency percentage using this approach is five percent and the maximum is 98 percent.

There may be special cases where the parameter limitations defined above are not appropriate. Some high-risk elements may deserve contingencies greater than 98 percent. In these cases, at the discretion of the estimator and Project Management, higher values may be used. Justification must be provided in the supporting documentation.

Risk analyses shall be performed at the activity level. Results of this analysis will be summed to compute the contingency that will be reported at each level of the WBS.

While contingencies will be estimated at the same level as the bottom-up cost estimate, during execution of the project contingency will be held at the top level by the Project Manager and allocated as needed to address problems and items or activities that have been overlooked during the estimating process. A formal change control process will be used to allocate contingency to specific activities.

8.0 Escalation

The LIGO II estimate is based on year 2000 dollars. The funding will be provided and the work accomplished starting in 2002. Escalation will be computed using NSF-provided escalation rates based on the time phasing provided by the estimator. Escalation will be applied at the top level of the WBS.

Table 1: Risk Factors

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 production 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 2: Risk Percentage

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

9.0 Responsibilities

Cost estimating responsibilities are as follows:

WBS	Description	Responsibility
4.0	LIGO II Total (LIGO II)	Sanders
4.1	Facility Modifications (FAC)	Asiri, Worden
4.2	Seismic Isolation (SEI)	Asiri, Coyne
4.3	Suspensions (SUS)	Romie, Coyne
4.4	Prestabilized Laser (PSL)	Camp, Gustafson
4.5	Input Optics (IO)	Camp
4.6	Core Optics Components (COC)	Camp, Billingsley
4.7	Support Optics (SOS)	Camp
4.8	Interferometer Sensing and Controls (ISC)	Bork
4.9	Data Acquisition and Diagnostics (DAQ)	Bork, Lazzarini
4.10	Support Equipment	Asiri
4.11	LIGO II Research and Development (R&D)	NA
4.12	Data Analysis and Computing (COMP)	Lazzarini
4/13	Installation and Commissioning (INS)	Coyne
4.14	Project Management (PM)	Lindquist