GEM IN-92-19

Detector Cost Review Report

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July 2, 1992

Abstract:

The Final Report for the Cost Review on the GEM Detector held on June 23-24, 1992.

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Memorandum

To Fred Gilman
From: Robert A. Richardson RAR
Subject: GEM Detector Cost Review Report
Date: July 2, 1992

Attached is a copy of the Final Report for the Cost Review on the GEM detector held on June 23-24, 1992.

CC Barry Barish
Martin Breidenbach
Charles Collins
Tom Elioff
Mike Harris
Hans Jostlein Fermilab
Ted Kozman
Harvey Lynch
Vera Luth
Mike Marx
Robert McCarthy SUNY Stonybrook
Tom Prosapio
Gary Sanders
Bill Willis

GEM Detector Cost Review
June 23-24, 1992

Introduction:
A cost review was conducted on the GEM detector on the dates indicated above by a panel consisting of the following people.

Robert A. Richardson - SSCL - chairman
Martin Breidenbach - SLAC
Charles Collins - SSCL
Tom Elioff - SSCL
Hans Jostlein - Fermilab
Ted Kozman - SSCL
Harvey Lynch - SSCL
Robert McCarthy, SUNY Stonybrok
Tom Prosapio - SSCL

GEM cost review panel charge:

The GEM cost review panel was given the following charge:
• To examine the methods and justification for the cost estimation for each subsystem of the GEM Detector including:
- subsystem R & D
- design and engineering
- procurement and fabrication
- assembly and installation
- Management

• To examine the risk analysis and contingency
• To examine the schedule

• To prepare a summary of the evaluation and list of concerns in written form for presentation to the SSC Laboratory.

Executive Summary:
This document represents a brief summary prepared by the GEM Cost Review Panel. A more quantitative report was not possible, given one and one half days that were scheduled for the review.

• The committee concurred that the Collaboration was making the effort to design the GEM detector to the indicated target goal of $500 million.
• was not $400 million dollar nor was it a $600 million. The cost is somewhere between these two figures.
• There were many items that were found to be costed quite conservatively (High) and others that were costed less conservatively or omitted.
• The Liquid Argon Calorimeter cost/pound was approximately two times the cost of the SDC, D0 or SLD Liquid Argon Calorimeter.
• The Muon system assembly and alignment cost were considered very low and partially incomplete.
• The Superconducting Magnet costs was credible and some 39% of the items costed were results of vendor quotes.
• Several areas need additional attention by the collaboration.

I Project Management, Contingency and EDIA

• The allocations do not appear to be consistent. Some items appear to have a much higher contingency than required when compared to a critical high technology item like the magnet. It is not customary to assign contingency on R&D activities.

• In general, the EDIA estimates look high in comparison to other highly technical projects and in view of the additional funds for R&D, Conceptual Design, and Project Management. If there are unknowns or uncertainties, there should perhaps be additional contingency on the EDIA and Project Management with a corresponding reduction on the overall EDIA costs. The relatively high EDIA costs may be due to the use of higher labor rate categories. The GEM collaboration are examining these issues themselves through an outside consulting firm US Cost/SAIC that has been contracted to do an independent examination of the costs for the entire detector.

• In view of the above EDIA costs and the fact that labor accounts for 37% of the overall procurement and fabrication, it would be useful to know what percentage of the labor costs were attributed to each of the five labor rate categories. The rates for a particular task vary by a factor of two between these categories.

• The M&S costs need to be uniformly applied. As we understand it, the M&S costs cited apply only to the EDIA. In the present model, the engineers apply M&S at the rate of the area where they presently think the work is going to be done or what they are familiar with. A standard national laboratory rate and a standard industrial rate should be calculated and applied uniformly.

• The report should differentiate labor represented by SSCL staff or contract labor personnel. If laboratory personnel are required, this could significantly affect SSCL plans for manpower and management.

• Because of Davis/Bacon requirements, the difference between various types of installation and assembly labor should be distinguished. Davis/Bacon requirements may only apply to some of the crafts.

• Develop unit costing information as much as possible for comparisons with SSC and other projects. This serves also as a good management check on the overall costs. This will probably be required in subsequent reviews.

• Control, management and tracking of foreign and US collaborations may require more manpower than shown in project management. A lower level estimate of the project management labor may help determine this. This may increase in the EDIA cost.

II Magnet Panel

The review panel concluded that the cost estimate for the magnets done in a credible fashion. The Magnet engineering design is well developed and this affects the reliability of the cost estimate. Thirty nine percent of the items costed were based on vendor estimates. The procurement and fabrication labor estimates are reasonable for the vacuum vessel that is foreseen. The estimate for the cryogenic system is low, compared to the cryogenic Helium refrigerator at the ASST and MTL. The refrigerator (based on SSC N15 experience) is underestimated (it could be low by as much as 70%-80%) and the cost to the cryogenics system could result in an additional 20% to 30% of the stated cost. Some money could be saved by coupling this procurement with that of the SSC main ring refrigerators.

Concerning the magnet design, we note the following: The number of persons that follow the subcontractors seems high (this adds to the EDIA cost). The safety or engineering margin on the magnet or superconductor appear exceedingly high.

The alignment system for the magnet halves and central membrane needs additional engineering effort and is not included in the cost.

III Muon System

The muon system is a major component of the GEM detector, representing nearly a quarter of the detector cost. Much work has been done in defining technical requirements and identifying technical solutions to meet those requirements. The large open magnet provides the opportunity for excellent muon momentum resolution in a space well shielded from hadrons. The challenge is to develop detectors of sufficient intrinsic resolution and to invent ways to place them accurately, and to monitor their placement over time. The stated accuracies so far have not been attempted or achieved for structures of comparable size. The accuracy requirements have a direct connection to the cost of the detector. The resolution increases as the square of the trade length and the magnet cost goes up approximately with the 3/2 power of the resolution.

Summary of Comments on Muon System Costs

The panel lists the following concerns:

- the time to produce Muon PDT tubes and the LSDT's is probably underestimated.
- based on the experience with the D0 muon PDT's the time allotted for installation, cabling, and testing is underestimated.

- there is not enough engineering and installation effort for identified alignment systems. Many alignment issues have not yet been addressed.

Detailed Comments

The comments below refer to the "Muon Subsystem Cost Matrix" book, GEM IN-92-13, Rev. aa, dated June 16, 1992. We will refer to this as the "Muon Book", for short. The "Muon book " has no page numbers, approximate page numbers are noted.

1. Page 7: The muon support trusses are assigned a technical risk of 8. Though they are beyond the state of the art and deserve a rating of 15.
2. Page 30: Element 03.1.1.1.1.1 "Central Installation; ON-site ; Test" cites only 3 PY's . It is not clear what is covered, but it can't be much. See further comments below regarding testing.
3. Page 32: Element 3.1.1.1.1.2 Installation of sectors and integration has 1.33 PY's for a tech for the 32 trusses. The following element , 3.1.1.1.1.3 for electrical integration, has 0.33 PY's. These numbers appear to be very optimistic considering the fact that the parts have to be moved in and installed in various orientations, way above ground, and positioned to very high accuracy. Issues such as optical alignment verification and electric tests appear not to be included.
4. Page 79: Element 3.1.1.2.1.2 "Central region sector assembly; On-site test" has 0.83 PY's for a technician. The experience at D0 was less favorable. It took approx. 3 people 3 weeks to "commission" a PDT chamber (the equivalent of 1/9 of a sector). This was in part due to the fact that the electronics was completed, but not mature when commissioning started. Also, the R&D went on during assembly, and about 3 major revisions of the electronics were introduced over a 2 year period. GEM may behave in a more organized and professional way, and avoid some of these pitfalls, but the number of chambers are comparable, and the time pressures appear to be just as stringent.

5. Page 81: Element 3.1.1.2.1.3 The same comment applies. Perhaps it will be fruitful to ask SLD, CDF (new muon chambers) and D0 for comparison, keeping in mind the greater size and more stringent performance requirements at GEM.
6. Page 129: Element 3.1.1.2.3.1.2 "PDT's offsite tests"
The tests include laser, tension/clamping and leak testing. The allotted time (engineer, tech etc,.) are allotted 4 months. This comes to 20.9 sec per tube, and seems ambitious.
7. Page 131: Element 3.1.1.2.3.1.3 The time to produce PDT tubes was estimated in the Muon Book, page 151, as 441 hours per 128 tube-chamber. This is 3.41 hours per tube. The assumptions leading to this estimate appear sound. Using this time effort in WBS 03.1.1.2.3.1, we arrive at 194 PY's, compared to the quoted 22.5 PY's.
8. Page 160: Element 3.2.1.2.3.1.3. This should not be taken as a decisive factor in favor of LSDT's, however; the production time used for LSDT's (141 sec. per tube) is based on Tommy Lyons's machine to make plastic Iarocci tubes. These tubes were far less demanding in accuracy than the LSDT's considered here. Their construction differs in that the wire supports are on sliding bridges. More study will be needed to firm up the cost to produce these LSDT's.
9. Page 223: Element 3.1.1.2.5.1.3 "Support structure design". Engineering time (given as 5 PY's) appears short, considering the required accuracy and size and complexity of the structure. The much simpler muon chamber mounting system at D0 took over two PY's.
10. Page 238: Element 3.1.1.2.6.1.1.5 "Central region, local alignment PDT". The effort allowed here appears to be very optimistic (total 0.5 PY's). A more detailed analysis and design of the local alignment system will be needed. It appears that there is no allowance for the needed optical precision alignment of all chamber survey monuments. This can only be done by interferometry to the required level of accuracy (@50 k$ for the equipment). It will also require a surveyor and a cherry picker operator for the duration (9 chambers at 1 day/chamber, perhaps). In addition, the optical system must be installed, calibrated, and tested.
There is also no allowance for alignment software, which can easily take several PY's. The alignment plan is far from complete in assuring knowledge of the placement of all critical detectors during and magnet operation. Much design work needs to be done before costs can be identified. The less demanding L3 system used 10 to 20 PY's.

IV Liquid Argon Calorimeter

Preliminary designs were presented for the barrel, end cap, and forward liquid argon calorimeters. With the few exceptions pointed out below, the experimenters seem to have included all considerations required to build a successful calorimeter, so that we believe the quoted cost is not an underestimate. On the contrary, rough comparisons to existing calorimeters (SLD and DØ) indicate that the GEM cost estimate may be high by as much as a factor of 2. We suggest that a comparison with these existing calorimeters should be provided.

The GEM cryogenic system design appeared to be in a rudimentary stage. We suggest that the designers should study the experience gained by SLD and DØ. In particular, the quality control plans for aluminum welding seemed weak. The additional cost necessary to improve these controls could be balanced by simplifications in the cryogenic system.

Cable routing and cabling for the Liquid Argon Forward Calorimeter is not well defined and should be worked out. The assembly of the calorimeters does not account for unforeseen problems and mistakes and the time allotted may be extremely short. The costs should be increased for this and the contingency lowered by a similar amount.

The forward calorimeter design requires the drilling of many holes in metal plates for use in a "spaghetti" style calorimeter. Thorough cleaning of metal shavings from these holes will be required.

V Central Tracker

The level of technical development that has been reached on both the Silicon Microstrip detector and the Interpolating Pad Chambers (IPC) of the GEM Detector is quite advanced. This allowed a rather detailed cost estimate to be performed.

The GEM IPC tracker has about the same number of channels as compared to the SDC Outer Tracker, but it is physically smaller and requires less expensive electronics. The cost of $21.1M for the GEM IPC tracker appears to be in line when compared to the $39.6M estimated cost of the SDC Outer Tracker.

The designers of this system are to be commended on the mechanical design approach. It appears that the tracker will not be overly difficult to assemble, repair, and maintain.

The Silicon Microstrip Tracker estimated cost of $30.2 at first appears high when compared to the SDC Silicon Tracker, however, the GEM Silicon Microstrip Tracker cost estimate included electronics.

The design of the GEM Silicon Microstrip Tracker also represents a mechanical design that accommodates assembly and maintenance.

Both of the GEM tracking systems have technical issues that are to be addressed. These issues appear to be well recognized by the persons involved in the work and have been sufficiently covered by contingencies in the cost estimate.

VI Electronics

The GEM electronics systems follow the now classical architecture developed for the major SSC detectors. Signals are amplified, minimally processed, and delayed awaiting a level one trigger. Data are then further buffered awaiting a level two trigger, after which data are passed to a level three processor farm. From the information presented, the approach is similar to SDC's, and there are no technical disagreements with the architecture.

Although a significant amount of work has been done, the design is much less advanced than SDC's. Consequently, the cost estimation is primarily a parametric exercise based on LRS experience rather than a bottom up estimate. The general impression is that the parameters are realistic to conservative. However, this impression is strongly correlated with the requirement of doing the design engineering and prototyping early enough to correct errors and optimize manufacturable designs. If this is not done, there will be opportunities for cost overrun. Conversely, there may be noticeable cost savings if design confidence in the ASIC's develops early enough to increase multiplexing, increase channel count per board, etc. Tradeoffs between engineering and production costs should be carefully managed!

A significant component of the uncertainty and contingency of the estimate appears to be associated with the difficulties of developing radiation hard circuitry. The engineering strategies associated with rad hard CMOS are reasonably well developed (although vendors are limited in number), bipolar technology should be more straightforward.

The costs associated with "miscellaneous" components (power supplies, crates, racks, testing, etc) again seem realistic to conservative, in that they agree with experience derived from purchases of comparatively small quantities of similar components.

The installation and testing cost estimate, very grossly, is under $1/channel. Clearly, the tracking system channel counts dominate, and it is not obvious what is considered assembly and assembly testing versus installation and installation testing. However, if this labor is intended to include all fiber and cable installation, it may be low.

The electronics room is located some 850 ns (round trip) from the detector. There is concern regarding the radiation shielding of the electronics room in its current location, and additional costs may be incurred in more shielding and/or longer cables and level one pipelines.

VII Computing and Controls

The level three, on-line computing and slow control hardware costs seem plausible. The software engineering labor of 70 man-years to produce a core system seems optimistic.

Obviously, most detector collaborations prefer to design and manage all aspects of the software and controls for the detector by themselves. However, there may be an interesting possibility for cost savings if SSCL were to coordinate the sharing of some items. Some electronics and core software are possibilities.

• A collaboration between SSCL/ASD, SDC, and GEM could save some money for computer control systems. Areas where this should be considered include global positioning, slow machine controls, computing, and certain areas of electronics.

VIII Scintillating Fiber and BaF2 Calorimeters

Scintillating Fiber Calorimeter

In general, the budget is done logically, and it is easy to read. It is hard to judge its completeness without a great deal more time than has been available. No obvious major problems were evident.

There is an inconsistency on the price of scintillating fiber. In the handout 6.0 it is stated that fiber costs $0.22/m, but under WBS .1.4 the fiber is listed at $0.76/m. The latter figure is used for the total cost of $3.6M for fiber. The quote for the Hamamatsu 2490 tube could not be found.

It is not clear what is meant by "Systems Integration". The budget calls for 2 MY of effort over a period of 7 years. Interpreted narrowly, this may be adequate. If this means the way in which the calorimeter goes together as well as how it relates to the rest for the GEM detector, such as looking after mechanical interferences and electronic cooperation, the estimate of 2 MY may be quite low.

Barium Fluoride

In general, it was hard to find the basis for the numbers used apart from the BaF2 crystals, it is hard to gauge the accuracy of the budget estimates. For example, is the "local electronics" cost of $50/channel based on L3 experience?

The test plans are unclear. It is stated that only a fraction of the crystals would be independently tested, but it is not stated what fraction. How does this testing differ from other testing done on every crystal?

The description of the electronics has some gaps and inconsistencies. The text discusses photopentodes, but the detailed listing talks about phototriods.

IX Assembly, Installation and Maintenance

A statement was made that the design of the detector considered a three month period to open the magnet to perform maintenance tasks on subsystems. This seems an unusually long period to gain access to the interior of the detector. It's generally felt that the GEM position will change on this was encouraged by outside forces such as the Accelerator Division. The reconfiguration of the detector to cut the access time to the interior will increase the complexity and increase costs.

GEM should make an engineering effort to identify the cost to provide access to the tracker on a time scale much faster than the 3 month as currently designed. Once the cost of this effort is identified, management can weigh it against the benefits in likely reduced downtime, and the potential savings in ultra-redundancy.

It didn't seem that there was enough cost consideration given to "heavy lift" installation equipment. An example of this is the muon system installation. There was a vehicle discussed and shown which would be used to install the loaded muon space trusses. Consideration for design and fabrication of this vehicle could not be found. The rigging and installation costs for all the subsystems needs to be reviewed in more detail after plans have been developed.

GEM Cost Review Panel
List of Documents

1.	GEM Cost Estimating Plan	GEM TN-91-17
2.	Cost Estimate Review: Overview, Methodology Estimate Summary	Gem IN-92-14
3.	GEM Letter of Intent	SSCL-SR-1184 GEM TN-92-49
4.	GEM Baseline 1	GEM TN-92-76
5.	GEM Magnet Subsytems Post LOI Conceptual Design Cost Estimate	GEM IN-91-1 REV F
6.	Liquid Argon Calorimeter Cost	GEM IN-92-3
7.	Scintillating Fiber Hadron Calorimeter Design Cost Review	GEM IN-92-5
8.	Barium Fluoride Electromangetic Calorimeter	GEM IN-92-6
9.	Tile Hadron Calorimeter Design	GEM IN-92-7
10.	Liquid Krypton Parallel Plate	GEM IN-92-8
11.	Muon Subsystem Cost Matrix	GEM IN-92-12
12.	Magnet Technical Design Report	GEM TN-92-116
13.	GEM Central Tracker: A Progress Report	GEM TN-92-63

Presentation Handouts

GEM Muon System Cost Review
Design of Cost-Effective Manufacturing Systems
Production Improvement Behavior
GEM Muon Subsystem Cost Matrix, Revision 11
GEM Detector Forward Calorimeter Cost Book
GEM Liquid Argon Calorimeter, Baseline 1 Configuration
GEM Liquid Argon Calorimeter (LAC) Cost Presentation
GEM Silicon Tracker Electronics Cost Estimate
GEM Electronics Cost Estimate
Central Tracker Cost Review
GEM Detector Scintillating Fiber Hadron Calorimeter

GEM Cost Review

SSC Laboratory

Agenda

Tuesday	June 23	Upstairs Conference Room	Building 4
8:30	Executive Session	Lüth	
9:00	Overview Baseline Description Methodology Independent Cost Analysis Summary of Cost Estimate Future Work Plan	Sanders	
10:00	Magnet Cost Estimate	Pedrotti/Deis	
11:00	Break		
11:15	Muon System	Baker/Gustavson/Nimblett	
12:15	Liquid Argon Forward Calorimeter	Rennich/Chae	
12:30	Lunch		
13:30	Liquid Argon Calorimeters	Mason/Coulon	
14:30	Central Tracker	Baltay/Barber/Musser	
15:15	Break		
15:30	Electronics	Marlow	
16:30	Scintillator Fiber Hadron Calorimeter alternate	Rennich	
17:00	Barium Fluoride EM Calorimeter alternate	Rennich	
17:30	Computing and Controls	Cornell	
17:45	Interface Systems Project Management Future and Wrapup	Sanders	
18:15	Adjourn		

Wednesday	June 24	Directorate #2	Building 4
9:00	Committee Executive Session with option for questions to be directed to GEM		
3:00	Summary Report		