WBS Dictionary/Cost Estimate Documentation

US CMS Calorimeter

Regional Trigger System

WBS 3.1.2

1. INTRODUCTION

1.1 The CMS Calorimeter Trigger System

The CMS trigger and data acquisition system is designed to operate at the nominal LHC design luminosity of 10^{34} cm^{-2} s^{-1}, where an average of 20 inelastic events occur at the beam crossing frequency of 40 MHz. This input rate of 10^9 interactions every second must be reduced by a factor of at least 10^7 to 100 Hz, the maximum rate that can be archived by the on-line computer farm. CMS has chosen to reduce this rate in two steps. The first level stores all data for approximately 3 μs, after which no more than a 100 kHz rate of the stored events is forwarded to the second level. During the 3 μs of the level 1 trigger processing time, trigger decisions must be made to discard a large fraction of the data while retaining the small portion coming from interactions of interest. The calorimeter trigger system plays a crucial role in the trigger system providing triggers based upon the energy profiles left in the CMS calorimeter by electrons, photons, jets and non-interacting particles in the interesting events. It also provides additional information for the muon trigger system for isolation and minimum ionization signal identification.

1.1.1 Requirements

The CMS calorimeter trigger system should be capable of selecting events with electrons, photons, jets and large missing transverse energy with high efficiency and good geometric acceptance. At high luminosity, 10^{34} cm^{-2} s^{-1}, the single electron/photon trigger is required to be fully efficient in the pseudo-rapidity range $|\eta|<2.5$ for a threshold of $E_t>40$ GeV. For the di-electron/di-photon trigger the threshold should be $E_t>20$ GeV for each particle in the same η-range. Single and multiple jet triggers are also required, having a well known efficiency in order to allow reconstruction of the jet spectrum. Finally, a missing transverse energy trigger with a threshold of 150 GeV is also required. At low luminosity, 10^{33} cm^{-2} s^{-1}, in addition to the above requirements, the system is required to trigger on single and double electrons in the pseudo-rapidity range $|\eta|<1.6$ with transverse momenta above 10 and 5 GeV respectively, with an efficiency greater than 50%. The system is also required to select hadronic tau-jets in the pseudo-rapidity range $|\eta|<2$ with jet $E_t>40$ GeV with an efficiency above 50%. The total calorimeter trigger rate should not exceed approximately 15 kHz at all luminosities. The trigger E_t cutoffs should be sufficiently low such that full efficiency is realized at the specified physics thresholds while keeping the background rates within the requirements of the data acquisition system. All triggers should also run at prescaled level with lower thresholds.

1.1.2 Input Data

For most of the CMS ECAL, a 6 × 6 array of PbWO4 crystals is mapped into trigger towers. In the rest of the ECAL there is somewhat lower granularity of crystals within a trigger tower. There is a 1:1 correspondence between the HCAL and ECAL trigger towers. The trigger tower size is equivalent to the HCAL physical towers, .087 × .087 in $\eta \times \phi$. The ϕ size remains constant in $\Delta\phi$ and the η size remains constant in $\Delta\eta$ out to an η of 2.1, beyond which the η size doubles. There are 3888 total ECAL and 3888 total HCAL trigger towers from η = -2.6 to η = 2.6 (54 × 72 $\eta-\phi$ divisions).

For each trigger tower the front-end electronics sums the constituent ECAL crystal energies or HCAL longitudinal segments and converts it to transverse energy in a compressed 8-bit non-linear scale using a programmable lookup table. In addition, the energy profile within the trigger tower is used to set a bit to indicate fine-grain identification of electro-magnetic deposit in ECAL or muon identification bit in HCAL. The fine-grain EM isolation bit is set if the maximum energy found in a pair of strips of six crystals represents a large fraction of the total energy found in the 36 crystals in the trigger tower (See Figure 1).

1.1.3 Algorithms

The electron/photon trigger is based on the recognition of a large and isolated energy deposit in the electromagnetic calorimeter by asking for a small hadronic energy deposit in the HCAL in the cluster region. There are different thresholds for inclusive electrons/photons, dileptons, and for very high E_t electrons. The isolation cuts are relaxed and finally eliminated for triggers with increasing E_t thresholds. As shown in Figure 1, the basic 3x3 sliding window electron algorithm implemented in the hardware design involves multiple cuts on the longitudinal and transverse isolation of the ECAL energy deposit. The first cut involves a favorable comparison of the hit tower HCAL to ECAL energy ratio, i.e. $H/E < 0.05$. The second cut involves requiring fine-grain EM ID described above. These two cuts alone are used at low luminosity to provide a "non-isolated" electron trigger. A third cut requires a favorable H vs. E comparison in all eight nearest neighbors. A fourth cut requires transverse isolation of the electron/photon energy deposit by considering all four 5- tower corners of the 3x3 window and requiring that at least one of them is below a programmable cutoff $\Sigma_5 E < 2$ GeV. The act of checking all four 5-tower corners ensures that the candidates depositing energy in any corner of the central tower do not self-veto due to leakage energy.

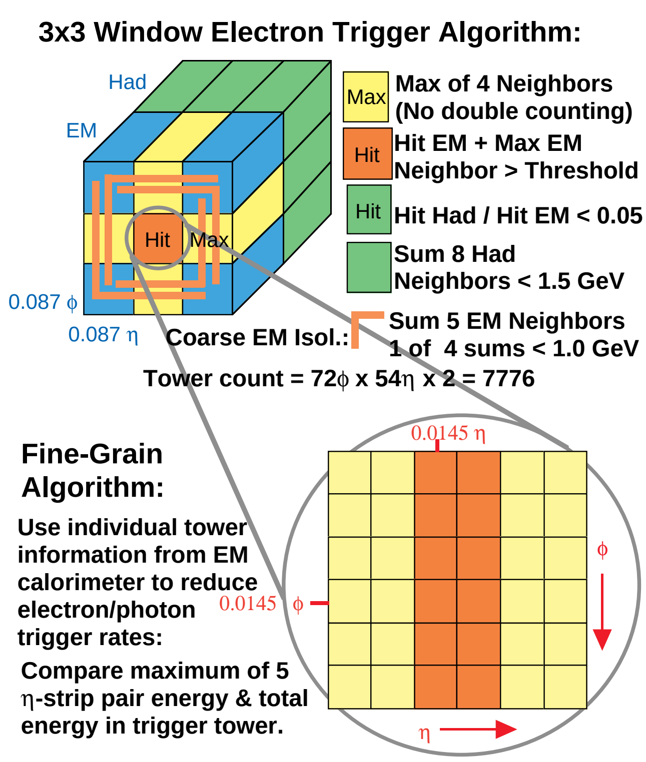

Figure 1. Level 1 Electron Trigger Algorithm.

The jet triggers are based on sums of ECAL and HCAL transverse energy in non-overlapping 4x4 trigger tower (0.35 η x 0.35 ϕ) regions. The jet trigger region sums have a 10-bit dynamic range covering energies up to about 1000 GeV. The jet trigger region sums are sorted based on their transverse energy to obtain top ranking jets. Tests of single, double, triple and quadruple jet region sums against progressively lower programmable thresholds, possibly in combination with electron and muon candidates, enables making level-1 trigger decision.

Neutrino identification consists of calculating the event missing E_t vector and testing it against a threshold. The calorimeter trigger calculates both sums of E_t and missing E_t. The transverse energy vector components are calculated from each 10-bit jet trigger region by multiplying with entries in corresponding lookup tables with angular coordinates. The sum of the scalar E_t and the vector components over the entire detector span made using digital summing networks provides sum E_t and the missing E_t. When pre-scaled by factors of 1000 or more the unbiased sum Et trigger enables checking other trigger efficiencies and measuring the E_t spectrum.

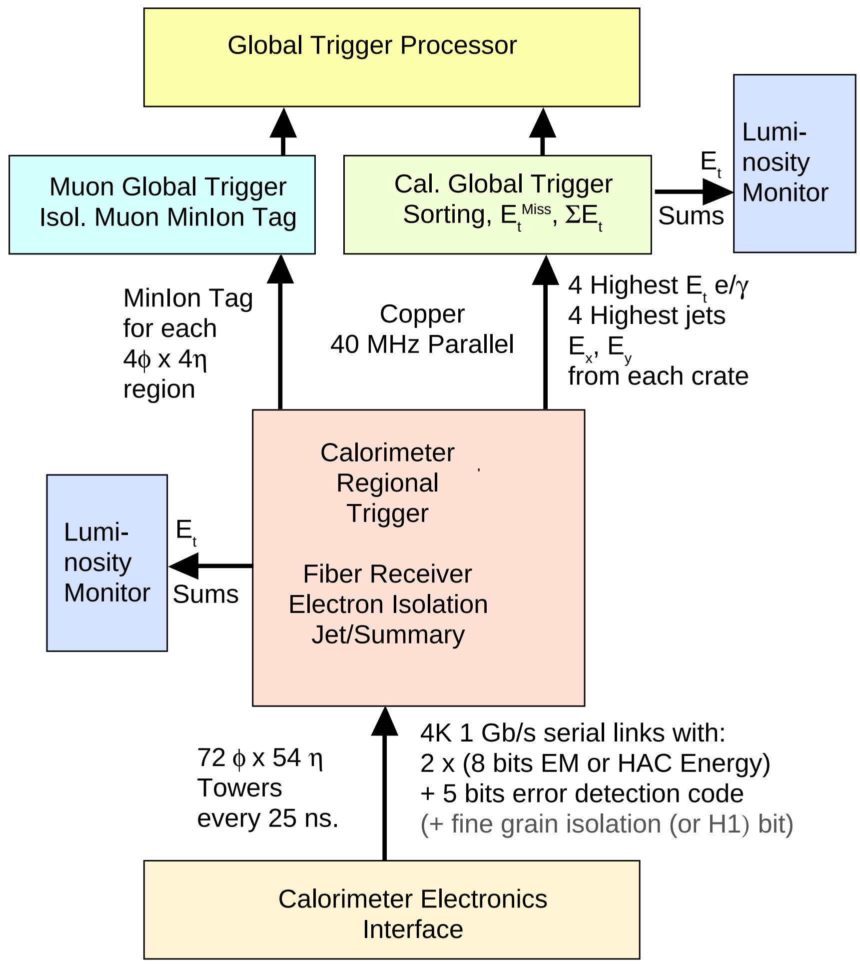

Figure 2. Overview of Level 1 Calorimeter Trigger.

2. SYSTEM OVERVIEW

2.1 Design Criteria:

The main design criteria for the system are:

The design is implemented using off the shelf technology where possible.
ASIC's are used only where fully justified.

The design emphasizes flexibility and programmability:
Digital logic built around memory lookup tables.
All trigger cutoffs are programmable.

The design minimizes hardware on the detector:
Reduce power, space, and cooling requirements
Maximize access
Reduces coupling between trigger and detector geometry

Boards and crates:
Designed using realistic power consumption, circuit density and cooling considerations.
I/O connections, fiber optics, backplane traffic and timing, DAQ and clock and control interfaces can be implemented with present day technology

Fiber optics and copper cables:
Designed to minimize the interconnects between crates.
Gbaud optical fibers carry trigger primitives from detector to the crates in barracks.
Could be produced with currently available hardware.

Full Trigger system carries sufficient information for diagnostics, efficiency studies, and understanding trigger behavior.

2.2 Baseline design

The calorimeter level 1 trigger system baseline design, shown in Figure 2, receives digital trigger sums via copper links from the front end electronics system in the electronics counting house. The data includes energy on an eight bit compressed non-linear scale and the fine grain ID. The data for two HCAL or ECAL trigger towers for the same crossing will be sent on a single copper serial link in eighteen total bits accompanied by five bits of error detection. One additional bit is used to set the link into either control or data modes.

The calorimeter regional crate system uses 19 calorimeter processor crates covering the full detector. Eighteen crates are dedicated to the barrel and two endcaps. These crates are filled out to an η of 2.6, with partial utilization between 2.6 and 3.0. The remaining crate covers both Very Forward Calorimeters.

Each calorimeter regional crate transmits to the calorimeter global trigger processor its sum E_t, E_x and E_y. It also sends its 4 highest-ranked electrons and 4 highest energy jets along with information about their location. The global calorimeter trigger then sums the energies and sorts the electrons and jets and forwards the top four calorimeter-wide electrons and jets, as well as the total calorimeter missing and sum E_t to the CMS global trigger.

The regional calorimeter trigger crate, shown schematically in Figure 3, has a height of 9U and a depth approximately of 700mm[1]. The front section of the crate is designed to accommodate 280mm deep cards, leaving the major portion of the volume for 400mm deep rear mounted cards.

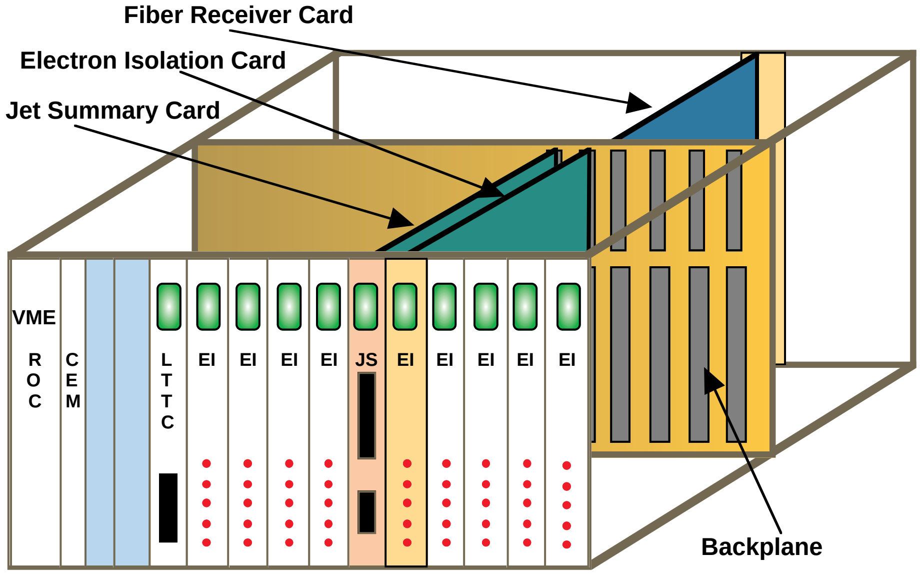

Figure 3. Schematic view of a typical Calorimeter Level 1 Regional crate.

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The majority of cards in the Calorimeter Level 1 Regional Processor Crates, encompassing three custom board designs, are dedicated to receiving and processing data from the calorimeter. There are eight rear mounted Receiver cards, eight front mounted Electron Isolation cards, and one front mounted Jet Summary card for a total of 17 cards per crate. The high density high-speed 160 MHz data flow is achieved by plugging all cards into a custom "backplane" with about 1400 point-to-point differential links in addition to full VME bus.

The Receiver card is the largest board in the crate. It is 9U by 400mm. The rear side of the card receives the calorimeter data from optical fibers, translates from fiber to copper, and converts from serial to parallel format. The front side of the card contains circuitry to synchronize the incoming data with the local clock, and check for data transmission errors. There are also lookup tables and adder blocks on the front. The lookup tables translate the incoming information to transverse energy on several scales. The energy summation tree begins on these cards in order to reduce the amount of data forwarded on the backplane to the Jet Summary card. Separate cable connectors and buffering are also provided for intercrate sharing.

The transverse energy for each of the two 4 x 4 trigger tower regions is independently summed and forwarded to the Jet Summary card. On the Jet Summary card these E_t sums are used to continue the energy summation tree and also compared against a threshold to determine whether any sub-region contained jets. The Et sums are applied to a set of lookup tables to generate E_x and

[1] J. Lackey et al., CMS Calorimeter Level 1 Trigger Conceptual Design, CMS TN/94-284 (1994).

E_y for each 4 x 4 region. A separate adder tree is used to sum up E_x and E_y from the regional values.

In the present baseline design, the Receiver card also has separate lookup tables to provide linearized 7-bit ECAL transverse energy, and H versus E comparison bits, for the electron/photon algorithm. These data are staged to both the cards within the crate at 160 MHz on the backplane, and to the neighboring crates on cables at 40 MHz. The Electron Isolation card receives the data staged to it from the Receiver cards and implements the algorithm discussed above in custom ASIC's. The E_t and isolation bits of the highest E_t electron/photon candidate from each of the two 4×4 trigger tower regions handled by the Electron Isolation cards are passed to the Jet/Summary card. The Jet/Summary card separately sorts these data from all eight Electron Isolation cards in the crate to obtain top four "non-isolated" and "isolated" electron/photon candidates, and passes them on to the global trigger on cables at 40 MHz.

2.3 References

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3. COST

A summary of the cost of the CMS Regional Calorimeter Trigger is contained in Table 1. The unit costs are detailed in Table 2. The costing methodology and WBS definitions are explained in the following sections. The funding profile based on the schedule described in section 4 is shown in Figure 4.

WBS	Item	Prj M&S	Prj EDIA	Prj Total	Conting.	%Ct.	Total
3.1.2	Calorimeter Trigger	3,115,400	1,274,176	4,389,576	1,318,001	30	5,707,577
3.1.2.1	Prototypes	65,260	172,811	238,071	74,938	31	313,009
3.1.2.2	Preproduction ASICs	360,000	268,646	628,646	179,242	29	807,888
3.1.2.3	Test Facilities	60,000	18,000	78,000	20,880	27	98,880
3.1.2.4	Power Supplies	79,200	5,174	84,374	11,479	14	95,853
3.1.2.5	Crates	13,200	23,894	37,094	6,473	17	43,568
3.1.2.6	Backplane	130,020	73,368	203,388	62,419	31	265,807
3.1.2.7	Clock & Control Card	65,120	76,416	141,536	37,387	26	178,923
3.1.2.8	Receiver Card	1,561,120	135,317	1,696,437	529,229	31	2,225,665
3.1.2.9	Electron Isolation Card	649,440	109,013	758,453	243,888	32	1,002,341
3.1.2.10	Jet Summary Card	102,740	76,416	179,156	52,167	29	231,323
3.1.2.11	Cables	7,300	-	7,300	964	13	8,264
3.1.2.12	DAQ Processor	-	-	-	-	-	-
3.1.2.13	Crate Monitor Card	-	-	-	-	-	-
3.1.2.14	Trigger Tests	22,000	315,120	337,120	98,936	29	436,056
3.1.2.15	Trigger Project Management	-	-	-	-	-	

Table 1. Summary of costs of the CMS Calorimeter Trigger.

WBS	Item	Unit M&S Cost	Units	Prj M&S
3.1.2	Calorimeter Trigger	3,240,740	1	3,115,400
3.1.2.1	Prototypes	190,600	1	65,260
3.1.2.2	Preproduction ASICs	360,000	1	360,000
3.1.2.3	Test Facilities	60,000	1	60,000
3.1.2.4	Power Supplies	3,600	22	79,200
3.1.2.5	Crates	600	22	13,200
3.1.2.6	Backplane	5,910	22	130,020
3.1.2.7	Clock & Control Card	2,960	22	65,120
3.1.2.8	Receiver Card	8,870	176	1,561,120
3.1.2.9	Electron Isolation Card	3,690	176	649,440
3.1.2.10	Jet Summary Card	4,670	22	102,740
3.1.2.11	Cables	7,300	1	7,300
3.1.2.12	DAQ Processor	-	1	-
3.1.2.13	Crate Monitor Card	-	1	-
3.1.2.14	Trigger Tests	22,000	1	22,000
3.1.2.15	Trigger Project Management			-

Table 2. Summary of unit costs of CMS Calorimeter Trigger.

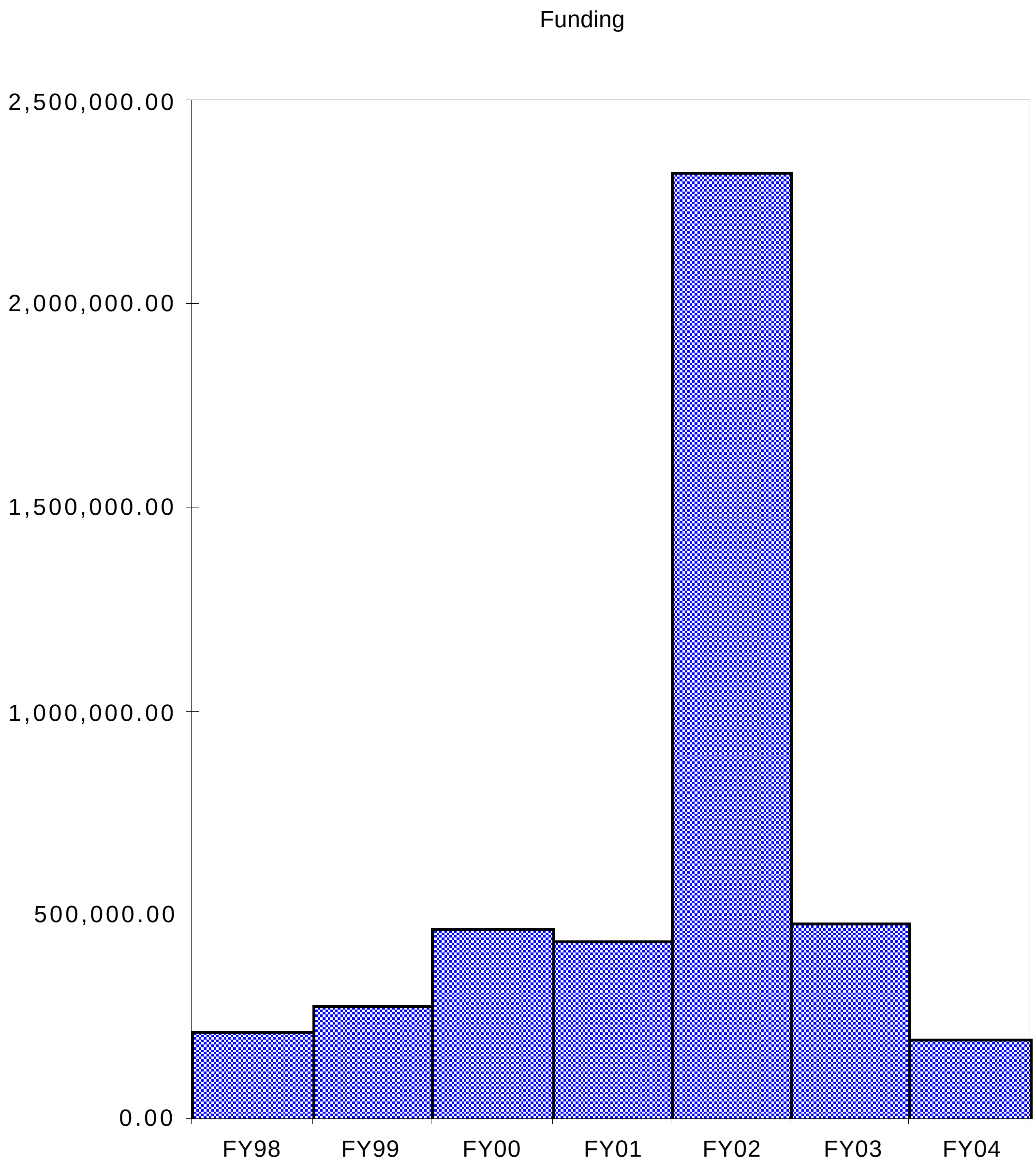

Figure 4. Funding profile for the Regional Calorimeter Trigger Project.

4. SCHEDULE

We foresee the development of the Regional Calorimeter Trigger System in four phases. The prototype design and production phase will continue through 1999. The final design of the various system components will continue until 2002. Production will begin in 2001 and end in 2003. Installation and commissioning will begin in 2003 and continue until 2005. The schedule, at its highest level, is shown in Figure 5 and the schedule milestones are summarized in Figure 6.

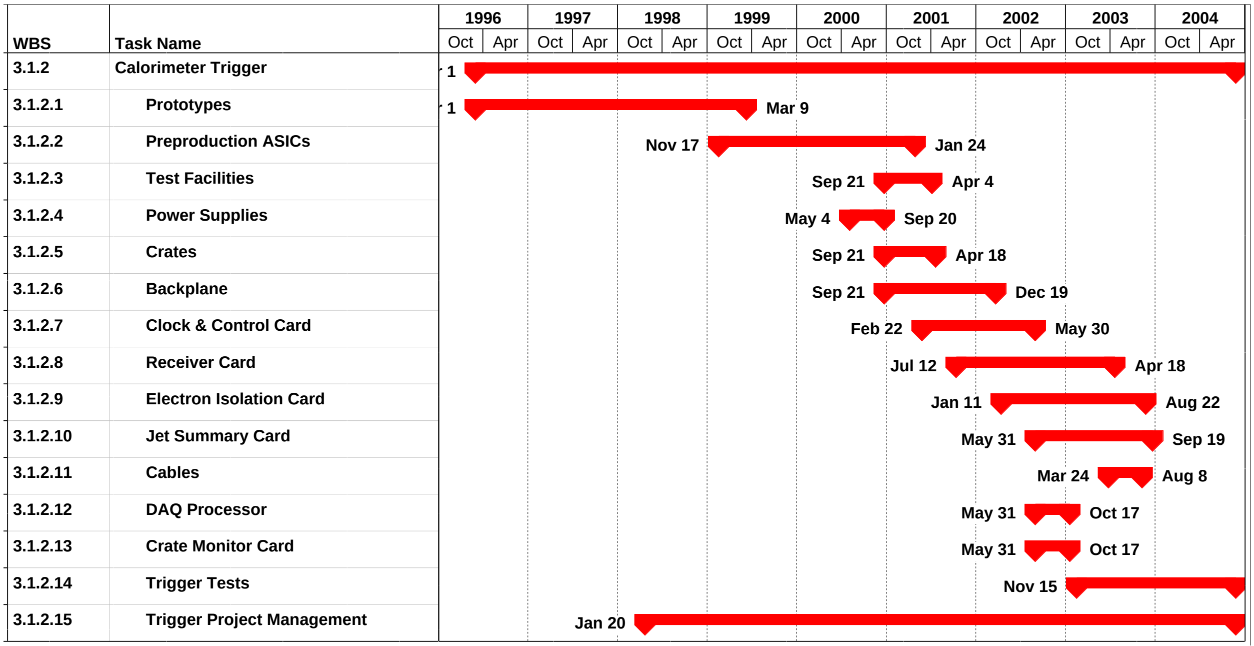

Figure 5. Summary of Calorimeter Trigger Schedule.

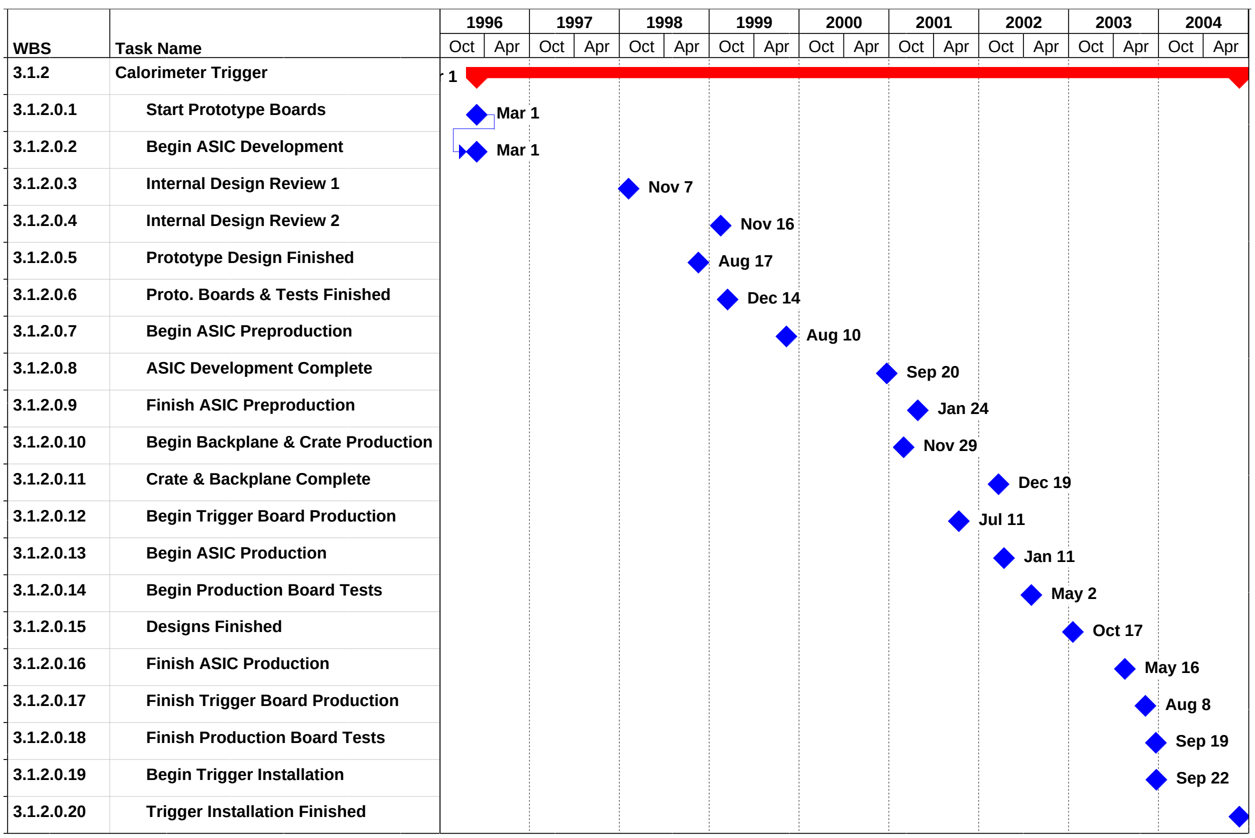

Figure 6. Calorimeter Trigger Major Milestones.

5. US RESPONSIBILITY

The US institutions participating in CMS have undertaken the design and building of the Regional Calorimeter Trigger System. This system begins after the data from the front end electronics is received on optical fibers and translated to signals on copper and ends with cables that transmit the results to the calorimeter global level 1 trigger system. Responsibilities for the front end electronics trigger sums, fiber optics transmission system, global calorimeter trigger and trigger interface to DAQ are assigned to non-US CMS groups.

US Institutions participating in the Regional Calorimeter Trigger:

Institute	Contact Person
University of Wisconsin, Madison	W. Smith
Fermilab	R. Vidal

6. COSTING METHODOLOGY

6.1 Base Cost

The M&S cost for the trigger system was calculated by determining the cost of ASIC's, boards, crates, and cables. The numbers of ASIC's, boards, crates, and cables were determined from the design described above. The cost for the electronics boards was based on actual cost for manufacture and assembly of over 300 9U x 400 mm deep 12-layer 83 MHz VME Calorimeter Trigger Boards and their accompanying crates and infrastructure built for the Zeus experiment over the period 1991 through 1995. The board costs were increased to account for the stricter impedance control necessary at the higher speed of 160 MHz. They were also based on the prototype CMS trigger Backplane and Clock & Control boards already manufactured. The parts costs were determined from scaling of Zeus Trigger Cards and checked against the prototype logic built for the Clock & Control board, the presently laid out prototype Receiver Card and the designs of the individual cards. The ASIC costs are based on the 160 MHz 8 x13-bit Adder ASIC manufactured by Vitesse for the CMS calorimeter trigger. Each ASIC design was carried to a the extent necessary to determine number of pins, approximate floor area and a target package used in consultation with Vitesse to determine the cost.

The EDIA cost for the trigger system was calculated from the EDIA costs for the Zeus Calorimeter Trigger System and checked against the costs already experienced for the design, manufacture and test of the CMS Trigger Adder ASIC, Backplane and Clock & Control prototypes. Production EDIA effort was calculated from the Zeus Calorimeter Trigger system production manufacture, test, and installation. The engineering and technical team charged with producing the CMS calorimeter trigger is the same as the Zeus calorimeter trigger project.

6.2 Contingency

The costs listed in the budget estimate are the base costs of producing each item correctly the first time. There are also explicit costs listed for prototyping where required. The cost contingency is the cost required beyond the base cost to ensure successful completion. The calculation of contingency has been done for each WBS item. The calculation of contingency was determined from an analysis of the Zeus trigger electronics. M&S and Labor costs also took into account the actual experience on these projects before any contingency was determined. In addition, the prototyping experience on CMS trigger electronics was also used as input.

Each item is first assigned a contingency of 20% for M&S and 30% for Labor. This was found to be the appropriate for the most difficult boards in the Zeus trigger system after M&S and Labor costs were increased to take into account the actual experience on Zeus before any contingency was determined. Each item is then assigned a factor based on the degree of difficulty, where 1.0 was assigned to difficult items, 0.8 assigned to average items and 0.6 assigned to easy items. Finally, each item was multiplied by a factor corresponding to its maturity of design, where 1.1 is assigned to items taken from a catalog, 1.2 for items where there is a bid package ready to go out or a quote, 1.3 where the cost is based on an engineering design, and 1.5 where the cost is based on a conceptual design.

7. WBS DICTIONARY AND BASIS OF ESTIMATE

WBS Element: 3.1.2

WBS Element Title: Regional Calorimeter Trigger

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and commission the Regional Calorimeter Trigger. This system processes the electromagnetic and hadronic trigger tower sums from the calorimeter front end electronics and delivers regional information on electrons, photons, jets, and partial energy sums to the global calorimeter level 1 trigger system. The system begins after the data from the front end electronics is received on optical fibers and translated to signals on copper and ends with cables that transmit the results to the calorimeter global level 1 trigger system.

Basis of Estimate:

This element's costs are generated as the sum of lower–level WBS elements

WBS Element: 3.1.2.1

WBS Element Title: Prototypes

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Regional Calorimeter Trigger prototypes that have not yet been built or tested before FY98. These include the prototype Electron Identification Card, Jet Summary Card, and Clock and Control Card. Each of these items is described in its corresponding WBS category below.

Basis of Estimate:

Each of the prototype M&S and EDIA costs have been generated from the costs for the final part as identified in the corresponding WBS element below or the item has been purchased, constructed, and/or tested.

WBS Element: 3.1.2.1.1

WBS Element Title: Prototype Power Supplies

WBS Definition:

This WBS element includes all the effort to procure, install and test the Prototype Regional Calorimeter Trigger crate power supplies.

Basis of Estimate: Already purchased.

WBS Element: 3.1.2.1.2

WBS Element Title: Prototype Crate

WBS Definition:

This WBS element includes all the effort to procure, install and test the Prototype Regional Calorimeter Trigger Crates. The crate is based on standard Eurocard hardware with custom fittings. The height is 9U and the depth approximately 700mm, as determined by the front and rear card insertion. It requires a rack 900 mm deep to handle the crate depth with some reserve for cabling, plumbing, and other services. The front section of the crate is designed to accommodate 280mm deep cards, leaving the major portion of the volume for 400mm deep rear mounted cards.

Basis of Estimate: Already constructed and tested.

WBS Element: 3.1.2.1.3

WBS Element Title: Prototype Backplane

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Prototype Regional Calorimeter Trigger Backplanes. The backplane is a monolithic, custom, 9U high printed circuit board with front and back card connectors. The top 3U of the backplane holds 4 row (128 pin) DIN connectors, capable of full 32 bit VME. The first two front slots of the backplane will, however, use three row (96 pin) DIN connectors in the P1 and P2 positions with the standard VME pinout. The bottom 6U of the backplane, in the data processing section of the crate, utilizes a single high speed, controlled impedance, connector for both front and rear insertion at each card position. The design is based around a 340 pin connector, by AMP Inc., to handle the high volume of data transmitted from the Receiver cards to the Electron Identification and Jet Summary Cards.

Basis of Estimate: Already constructed and tested.

WBS Element: 3.1.2.1.4

WBS Element Title: Prototype Receiver Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Prototype Regional Calorimeter Trigger Receiver Cards. The Receiver card is 9U by 400mm. The rear side of the card receives the calorimeter data from optical fibers, translates from fiber to copper, and converts from serial to parallel format. The front side of the card contains circuitry to synchronize the incoming data with the local clock, and check for data transmission errors. There are also lookup tables and adder blocks on the front. The lookup tables translate the incoming information to transverse energy on several scales. The energy summation tree begins on these cards in order to reduce the amount of data forwarded on the backplane to the Jet Summary card. Separate cable connectors and buffering are also provided for intercrate sharing.

Basis of Estimate: Under construction and paid for. This task is rated difficult and the estimate of the cost to test (which is the only project cost) is based on the engineering design.

WBS Element: 3.1.2.1.5

WBS Element Title: ASIC Development (EID, Sort)

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test prototype Electron ID ASIC and Sort ASIC. The Electron Identification ASIC, used on the Electron Identification Card, inputs 4 electromagnetic energies on an 8-bit scale every 6.25 nsec, as well as hadronic tower information and implements the algorithm described above to identify electrons. The Sort ASIC is used on the Jet Summary Card to find the four largest of 32 10-bit values by shifting data in at 8 values every 6.25 nsec and outputting the four largest of the 32 within 100 nsec.

Basis of Estimate:

The Electron ID ASIC and Sort ASIC's M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The prototype Sort ASIC exists and the prototype Electron IS ASIC has been bid.These prototype ASIC's cost have been paid under the R&D program. This task is rated difficult and the estimate of the cost to test (which is the only project cost) is based on the engineering design.

WBS Element: 3.1.2.1.6

WBS Element Title: Prototype Electron Identification Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Prototype Regional Calorimeter Trigger Electron Identification Card. The Electron Identification Card receives data at 160 MHz in a staged fashion from the Receiver Cards and performs the electron identification algorithm described above. The Electron Isolation card is 9U x 280mm and resides in the front of the crate. The electron isolation algorithm is performed on this card and the final results sorted to identify the 4 highest rank electron candidates.

Basis of Estimate: Under construction and paid for. This task is rated difficult and the estimate of the cost to test (which is the only project cost) is based on the engineering design.

WBS Element: 3.1.2.1.7

WBS Element Title: ASIC Development (BScan, Synch)

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test the prototype Synchronization and Boundary Scan ASIC's. The Synchronization ASIC on the Receiver Card is designed to receive four channels of parallel data from the serial/parallel converters at 40 MHz and align this data with the local trigger clock at an output rate of 160 MHz. It also handles the error detection code logic. The Boundary Scan ASIC will provide access to registers on the outputs of the boards, driving backplane lines and board registers placed for diagnostics.

Basis of Estimate:

The Synchronization and Boundary Scan ASIC's M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The prototype Sort ASIC exists and the prototype Electron IS ASIC has been bid.These prototype ASIC's cost have been paid under the R&D program. This task is rated difficult and the estimate of the cost is based on the quote and actual cost of the Adder ASIC.

WBS Element: 3.1.2.1.8

WBS Element Title: Prototype Jet Summary Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Prototype Regional Calorimeter Trigger Jet Summary Card. The Jet Summary Card is a 9U x 280mm board the middle of the trigger data processing section of each regional trigger crate. It collects and summarizes data from both the Receiver cards and the Electron Isolation cards at 160 MHz. It produces the jet, electron, total E_t, E_x, and E_y information and transmits it to the Global Calorimeter Trigger Processor.

Basis of Estimate:

The M&S and EDIA costs are based on the conceptual design of the Jet Summary Card, analysis of the layout of the prototype Receiver Card, the full-size prototype Clock and Control Card already constructed and tested, and design and manufacture of the 9U x 400 mm 83 MHz cards built for the Zeus trigger system, particularly the Zeus calorimeter trigger Adder Card that summarized information in a crate and transmitted it to the Zeus Global Calorimeter Trigger. This card is simpler than the Receiver Card and Electron Identification Cards, and it uses much of the circuitry already developed for them. Therefore, it is rated of average difficulty and the cost is based on a conceptual design.

WBS Element: 3.1.2.1.9

WBS Element Title: Prototype Clock & Control Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Prototype Regional Calorimeter Trigger Clock and Control Card. This card receives, aligns and logs the external 160 MHz clock and control signals and distributes them with adjustable delays along individual lines to each of the cards in the regional trigger crate.

Basis of Estimate:

The M&S and EDIA costs are based on the boards produced for the Zeus Calorimeter Trigger system and checked against the full-size prototype Clock and Control Card already constructed and tested. Since this card is a revision of the prototype already constructed, its costs can be based on the quote for the first prototype. Experience with the first prototype showed that this card is of average difficulty.

WBS Element: 3.1.2.1.10

WBS Element Title: Prototype Crate Monitor Card

WBS Definition:

This WBS element includes all the effort to procure, install and test the Prototype Regional Calorimeter Trigger Crate Monitor Card. This modules serves as the crate environment monitor which may or may not be a commercial board. The decision to purchase or create a custom design will depend on the final requirements of the environmental monitoring system

Basis of Estimate:

The cost, servicing, operation and maintenance of the Prototype Crate Monitor Card is the responsibility of the Lisbon CMS group and there is no cost for this to US CMS.

WBS Element: 3.1.2.2

WBS Element Title: Preproduction ASIC's

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test the Preproduction ASIC's. These include the Electron ID ASIC, Adder ASIC, Sort ASIC, Synch ASIC and Boundary Scan ASIC.

Basis of Estimate:

The ASIC M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The costs included in this WBS item are only the engineering costs and costs for Vitesse or another vendor to produce a test run of ASIC's. The production costs are assigned to the individual boards below. Based on the experience with the Adder ASIC, these tasks are of average difficulty. The costs are based on conceptual designs.

WBS Element: 3.1.2.2.1

WBS Element Title: Electron ID ASIC

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test the Preproduction Electron ID ASIC. The Electron Identification ASIC, used on the Electron Identification Card, inputs 4 electromagnetic energies on an 8-bit scale every 6.25 nsec, as well as hadronic tower information and implements the algorithm described above to identify electrons.

Basis of Estimate:

The Electron ID ASIC M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The costs included in this WBS item are only the engineering costs and costs for Vitesse or another vendor to produce a test run of ASIC's. The production costs are assigned to the individual boards below. Based on the experience with the Adder ASIC, these tasks are of average difficulty. The costs are based on conceptual designs.

WBS Element: 3.1.2.2.2

WBS Element Title: Adder ASIC

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test the Preproduction Adder ASIC. The Adder ASIC, used on the Receiver Card and Jet Summary Card, sums 8 13-bit (10 bit value, and one bit for sign, input overflow and arithmetic overflow) numbers in a single 25 nsec crossing.

Basis of Estimate:

The Adder ASIC M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The final Adder ASIC will be a modification of this prototype ASIC, which has the full speed and function of the final ASIC. The costs included in this WBS item are only the engineering costs and costs for Vitesse or another vendor to produce a test run of ASIC's. The production costs are assigned to the individual boards below. Based on the experience with the Adder ASIC, these tasks are of average difficulty and the costs are based on the engineering design and actual cost for the Adder ASIC.

WBS Element: 3.1.2.2.3

WBS Element Title: Sort ASIC

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test the Preproduction Sort ASIC. The Sort ASIC is used on the Jet Summary Card to find the four largest of 32 10-bit values by shifting data in at 8 values every 6.25 nsec and outputting the four largest of the 32 within 100 nsec.

Basis of Estimate:

The Sort ASIC M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The costs included in this WBS item are only the engineering costs and costs for Vitesse or another vendor to produce a test run of ASIC's. The production costs are assigned to the individual boards below. Based on the experience with the Adder ASIC, these tasks are of average difficulty. The costs are based on conceptual designs.

WBS Element: 3.1.2.2.4

WBS Element Title: Synch ASIC

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test the Preproduction Sort ASIC. The Synchronization ASIC on the Receiver Card is designed to receive four channels of parallel data from the serial/parallel converters at 40 MHz and align this data with the local trigger clock at an output rate of 160 MHz. It also handles the error detection code

Basis of Estimate:

The Sort ASIC M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The costs included in this WBS item are only the engineering costs and costs for Vitesse or another vendor to produce a test run of ASIC's. The production costs are assigned to the individual boards below. Based on the experience with the Adder ASIC, these tasks are of average difficulty. The costs are based on conceptual designs.

WBS Element: 3.1.2.2.5

WBS Element Title: Boundary Scan ASIC

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, and test the Preproduction Boundary Scan ASIC. The Boundary Scan ASIC will provide access to registers on the outputs of the boards, driving backplane lines and board registers placed for diagnostics.

Basis of Estimate:

The Boundary Scan ASIC M&S and EDIA cost is based on the prototype 8 x 13-bit 160 MHz Adder ASIC already manufactured and tested by Vitesse in GaAs. The costs included in this WBS item are only the engineering costs and costs for Vitesse or another vendor to produce a test run of ASIC's. The production costs are assigned to the individual boards below. Based on the experience with the Adder ASIC, these tasks are of average difficulty. The costs are based on conceptual designs.

WBS Element: 3.1.2.3

WBS Element Title: Test Facilities

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, test and commission the Regional Calorimeter Trigger test facilities that will be used to check, diagnose and repair the production trigger production boards.

Basis of Estimate:

The cost is based on the assembled full production test facilities for the Zeus trigger system, which continue to operate for maintenance of this system. The costs are also based on the CMS trigger test facility already assembled and operated for test of the CMS Calorimeter Trigger Clock and Control Board and Backplane. Based on this experience, these tasks are of average difficulty. The test facilities are based on a conceptual design.

WBS Element: 3.1.2.3.1

WBS Element Title: Design Test Facilities

WBS Definition:

This WBS element includes all the effort to design the Regional Calorimeter Trigger test facilities that will be used to check, diagnose and repair the production trigger production boards.

Basis of Estimate:

The cost is based on the assembled full production test facilities for the Zeus trigger system, which continue to operate for maintenance of this system. The costs are also based on the CMS trigger test facility already assembled and operated for test of the CMS Calorimeter Trigger Clock and Control Board and Backplane. Based on this experience, this tasks is of average difficulty. The test facilities are based on a conceptual design.

WBS Element: 3.1.2.3.2

WBS Element Title: Procure Test Facilities

WBS Definition:

This WBS element includes all the cost to procure the Regional Calorimeter Trigger test facilities that will be used to check, diagnose and repair the production trigger production boards.

Basis of Estimate:

The cost is based on the assembled full production test facilities for the Zeus trigger system, which continue to operate for maintenance of this system. The costs are also based on the CMS trigger test facility already assembled and operated for test of the CMS Calorimeter Trigger Clock and Control Board and Backplane. Based on this experience, these tasks are of average difficulty. The test facility is based on a conceptual design.

WBS Element: 3.1.2.3.3

WBS Element Title: Assemble Test Facilities

WBS Definition:

This WBS element includes all the effort to assemble, test and commission the Regional Calorimeter Trigger test facilities that will be used to check, diagnose and repair the production trigger production boards.

Basis of Estimate:

The cost is based on the assembled full production test facilities for the Zeus trigger system, which continue to operate for maintenance of this system. The costs are also based on the CMS trigger test facility already assembled and operated for test of the CMS Calorimeter Trigger Clock and Control Board and Backplane. Based on this experience, this task is of average difficulty. The test facility is based on a conceptual design.

WBS Element: 3.1.2.4

WBS Element Title: Power Supplies

WBS Definition:

This WBS element includes all the effort to select and procure the Regional Calorimeter Trigger crate power supplies.

Basis of Estimate:

The cost is based on the power supplies purchased for the Zeus Calorimeter Trigger system and checked against those purchased for the prototype Regional Calorimeter Trigger Crate. This is an easy task. The supplies are ordered from a catalog. The testing is included in the Crate Testing (WBS 3.1.2.5.3).

WBS Element: 3.1.2.4.1

WBS Element Title: Select Power Supplies

WBS Definition:

This WBS element includes all the effort to select the Regional Calorimeter Trigger crate power supplies.

Basis of Estimate:

The cost is based on the power supplies purchased for the Zeus Calorimeter Trigger system and checked against those purchased for the prototype Regional Calorimeter Trigger Crate. This is an easy task. The supplies are ordered from a catalog.

WBS Element: 3.1.2.4.2

WBS Element Title: Procure Power Supplies

WBS Definition:

This WBS element includes all the cost and effort to procure the Regional Calorimeter Trigger crate power supplies.

Basis of Estimate:

The cost is based on the power supplies purchased for the Zeus Calorimeter Trigger system and checked against those purchased for the prototype Regional Calorimeter Trigger Crate. This is an easy task. The supplies are ordered from a catalog.

WBS Element: 3.1.2.5

WBS Element Title: Crates

WBS Definition:

This WBS element includes all the effort to procure, install and test the Regional Calorimeter Trigger Crates. The crate is based on standard Eurocard hardware with custom fittings. The height is 9U and the depth approximately 700mm, as determined by the front and rear card insertion. It requires a rack 900 mm deep to handle the crate depth with some reserve for cabling, plumbing, and other services. The front section of the crate is designed to accommodate 280mm deep cards, leaving the major portion of the volume for 400mm deep rear mounted cards.

Basis of Estimate:

The M&S and EDIA costs are based on the costs to produce the crates for the Zeus Calorimeter Trigger system and checked against the full-size prototype CMS Trigger Crate already constructed and tested. This is an easy task. The Crates are ordered from a catalog.

WBS Element: 3.1.2.5.1

WBS Element Title: Design Crates

WBS Definition:

This WBS element includes all the effort to design the Regional Calorimeter Trigger Crates.

Basis of Estimate:

The M&S and EDIA costs are based on the costs to produce the crates for the Zeus Calorimeter Trigger system and checked against the full-size prototype CMS Trigger Crate already constructed and tested. This is an easy task. The Crates are ordered from a catalog.

WBS Element: 3.1.2.5.2

WBS Element Title: Procure Crates

WBS Definition:

This WBS element includes all the effort to procure the Regional Calorimeter Trigger Crates.

Basis of Estimate:

The M&S and EDIA costs are based on the costs to produce the crates for the Zeus Calorimeter Trigger system and checked against the full-size prototype CMS Trigger Crate already constructed and tested. This is an easy task. The Crates are ordered from a catalog.

WBS Element: 3.1.2.5.3

WBS Element Title: Test Crates

WBS Definition:

This WBS element includes all the effort to test the Regional Calorimeter Trigger Crates.

Basis of Estimate:

The M&S and EDIA costs are based on the costs to produce the crates for the Zeus Calorimeter Trigger system and checked against the full-size prototype CMS Trigger Crate already constructed and tested. This is an easy task. The Crates are ordered from a catalog.

WBS Element: 3.1.2.6

WBS Element Title: Backplane

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Regional Calorimeter Trigger Backplanes. The backplane is a monolithic, custom, 9U high printed circuit board with front and back card connectors. The top 3U of the backplane holds 4 row (128 pin) DIN connectors, capable of full 32 bit VME. The first two front slots of the backplane will, however, use three row (96 pin) DIN connectors in the P1 and P2 positions with the standard VME pinout. The bottom 6U of the backplane, in the data processing section of the crate, utilizes a single high speed, controlled impedance, connector for both front and rear insertion at each card position. The design is based around a 340 pin connector, by AMP Inc., to handle the high volume of data transmitted from the Receiver cards to the Electron Identification and Jet Summary Cards.

Basis of Estimate:

The M&S cost for the PC Board is based on extrapolations of the Zeus Trigger PC Boards. The cost for the connectors is based on verbal quotes from AMP, Inc. The EDIA cost is based on the design and production of the Zeus Trigger Boards. The total cost is also checked against the full-size prototype backplane already constructed and tested. This is a difficult task. The cost is based on the engineering design of the backplane and on the actual cost of the prototype backplane.

WBS Element: 3.1.2.6.1

WBS Element Title: Design Backplane

WBS Definition:

This WBS element includes all the effort to design the Regional Calorimeter Trigger Backplanes.

Basis of Estimate:

The EDIA cost is based on the design of the Zeus Trigger Boards and of the full-size prototype backplane already constructed and tested. This is a difficult task. The cost is based on the engineering design of the backplane and on the actual cost to design the prototype backplane.

WBS Element: 3.1.2.6.2

WBS Element Title: Backplane Procure

WBS Definition:

This WBS element includes all the effort to procure the Regional Calorimeter Trigger Backplanes.

Basis of Estimate:

The M&S cost for the Backplane PC Board is based on extrapolations of the Zeus Trigger PC Boards and on the full-size prototype backplane already constructed and tested. The cost for the connectors is based on verbal quotes from AMP, Inc. The EDIA cost is based on the production of the Zeus Trigger Boards. The total cost is also checked against the full-size prototype backplane already constructed and tested. This is a difficult task. The cost is based on the engineering design of the backplane and on the actual cost of the prototype backplane.

WBS Element: 3.1.2.6.3

WBS Element Title: Backplane Test

WBS Definition:

This WBS element includes all the effort to test the Regional Calorimeter Trigger Backplanes.

Basis of Estimate:

The EDIA cost is based on the experience with production testing of the Zeus Trigger Boards and checked against the full-size prototype backplane already constructed and tested. This is a difficult task. The cost is based on an engineering design.

WBS Element: 3.1.2.7

WBS Element Title: Clock & Control Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Regional Calorimeter Trigger Clock and Control Card. This card receives, aligns and logs the external 160 MHz clock and control signals and distributes them with adjustable delays along individual lines to each of the cards in the regional trigger crate.

Basis of Estimate:

The M&S and EDIA costs are based on the boards produced for the Zeus Calorimeter Trigger system and checked against the full-size prototype Clock and Control Card already constructed and tested. Based on the experience with the prototype Clock and Control Card, this is a task of average difficulty. The cost is based on an engineering design.

WBS Element: 3.1.2.7.1

WBS Element Title: Design Clock & Control Card

WBS Definition:

This WBS element includes all the effort to design the Regional Calorimeter Trigger Clock and Control Card.

Basis of Estimate:

The EDIA costs are based on the boards produced for the Zeus Calorimeter Trigger system and checked against the full-size prototype Clock and Control Card already constructed and tested. Based on the experience with the prototype Clock and Control Card, this is a task of average difficulty. The cost is based on an engineering design.

WBS Element: 3.1.2.7.2

WBS Element Title: Procure Clock & Control Card

WBS Definition:

This WBS element includes all the effort to procure the Regional Calorimeter Trigger Clock and Control Card.

Basis of Estimate:

The M&S costs are based on the boards produced for the Zeus Calorimeter Trigger system and checked against the full-size prototype Clock and Control Card already constructed and tested. Based on the experience with the prototype Clock and Control Card, this is a task of average difficulty. The cost is based on an engineering design.

WBS Element: 3.1.2.7.3

WBS Element Title: Test Clock & Control Card

WBS Definition:

This WBS element includes all the effort to test the Regional Calorimeter Trigger Clock and Control Card.

Basis of Estimate:

The EDIA cost is based on the experience with production testing of the Zeus Trigger Boards and checked against the full-size prototype Clock & Control Card already constructed and tested. Based on the experience with the prototype Clock and Control Card, this is a task of average difficulty. The cost is based on an engineering design.

WBS Element: 3.1.2.8

WBS Element Title: Receiver Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Regional Calorimeter Trigger Receiver Cards. The Receiver card is 9U by 400mm. The rear side of the card receives the calorimeter data from optical fibers, translates from fiber to copper, and converts from serial to parallel format. The front side of the card contains circuitry to synchronize the incoming data with the local clock, and check for data transmission errors. There are also lookup tables and adder blocks on the front. The lookup tables translate the incoming information to transverse energy on several scales. The energy summation tree begins on these cards in order to reduce the amount of data forwarded on the backplane to the Jet Summary card. Separate cable connectors and buffering are also provided for intercrate sharing.

Basis of Estimate:

The M&S and EDIA costs are based on the design of the prototype Receiver Card being prepared for manufacture, and the design and manufacture of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task and the cost is based on a conceptual design.

WBS Element: 3.1.2.8.1

WBS Element Title: Design Receiver Card

WBS Definition:

This WBS element includes all the effort to design the Regional Calorimeter Trigger Receiver Cards.

Basis of Estimate:

The EDIA costs are based on the design of the prototype Receiver Card being prepared for manufacture, and the design and manufacture of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task and the cost for the final board is based on a conceptual design.

WBS Element: 3.1.2.8.2

WBS Element Title: Receiver Card Procure

WBS Definition:

This WBS element includes all the effort to procure the Regional Calorimeter Trigger Receiver Cards.

Basis of Estimate:

The M&S and EDIA costs are based on the design of the prototype Receiver Card being prepared for manufacture, and the design and manufacture of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task and the cost for the final board is based on a conceptual design.

WBS Element: 3.1.2.8.3

WBS Element Title: Test Receiver Card

WBS Definition:

This WBS element includes all the effort to test the Regional Calorimeter Trigger Receiver Cards.

Basis of Estimate:

The EDIA costs are based on the design of the prototype Receiver Card being prepared for manufacture, and the production testing of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task and the cost for the final boards is based on a conceptual design.

WBS Element: 3.1.2.9

WBS Element Title: Electron Identification Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Regional Calorimeter Trigger Electron Identification Card. The Electron Identification Card receives data at 160 MHz in a staged fashion from the Receiver Cards and performs the electron identification algorithm described above. The Electron Isolation card is 9U x 280mm and resides in the front of the crate. The electron isolation algorithm is performed on this card and the final results sorted to identify the 4 highest rank electron candidates.

Basis of Estimate:

The M&S and EDIA costs are based on the conceptual design of the Electron Identification Card, analysis of the layout of the prototype Receiver Card, and the design and manufacture of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task.

WBS Element: 3.1.2.9.1

WBS Element Title: Design Electron Identification Card

WBS Definition:

This WBS element includes all the effort to design the Regional Calorimeter Trigger Electron Identification Card.

Basis of Estimate:

The EDIA costs are based on the conceptual design of the Electron Identification Card, analysis of the layout of the prototype Receiver Card, and the design and manufacture of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task.

WBS Element: 3.1.2.9.2

WBS Element Title: Electron Identification Card Procure

WBS Definition:

This WBS element includes all the effort to procure the Regional Calorimeter Trigger Electron Identification Cards.

Basis of Estimate:

The M&S and EDIA production costs are based on the conceptual design of the Electron Identification Card, analysis of the layout of the prototype Receiver Card, and the design and manufacture of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task.

WBS Element: 3.1.2.9.3

WBS Element Title: Test Electron Identification Card

WBS Definition:

This WBS element includes all the effort to test the Regional Calorimeter Trigger Electron Identification Cards.

Basis of Estimate:

The M&S and EDIA costs are based on the conceptual design of the Electron Identification Card, analysis of the layout of the prototype Receiver Card, and the design and manufacture of the Zeus 9U x 400 mm 83 MHz trigger boards. This is a difficult task.

WBS Element: 3.1.2.10

WBS Element Title: Jet Summary Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Regional Calorimeter Trigger Jet Summary Card. The Jet Summary Card is a 9U x 280mm board the middle of the trigger data processing section of each regional trigger crate. It collects and summarizes data from both the Receiver cards and the Electron Isolation cards at 160 MHz. It produces the jet, electron, total E_t, E_x, and E_y information and transmits it to the Global Calorimeter Trigger Processor.

Basis of Estimate:

The M&S and EDIA costs are based on the conceptual design of the Jet Summary Card, analysis of the layout of the prototype Receiver Card, the full-size prototype Clock and Control Card already constructed and tested, and design and manufacture of the 9U x 400 mm 83 MHz cards built for the Zeus trigger system, particularly the Zeus calorimeter trigger Adder Card that summarized information in a crate and transmitted it to the Zeus Global Calorimeter Trigger. This card is simpler than the Receiver Card and Electron Identification Cards, and it uses much of the circuitry already developed for them. Therefore, it is rated of average difficulty and the cost is based on a conceptual design.

WBS Element: 3.1.2.10.1

WBS Element Title: Design Jet Summary Card

WBS Definition:

This WBS element includes all the effort to design the Regional Calorimeter Trigger Jet Summary Card.

Basis of Estimate:

The M&S costs are based on the conceptual design of the Jet Summary Card, analysis of the layout of the prototype Receiver Card, the full-size prototype Clock and Control Card already constructed and tested, and design and manufacture of Zeus trigger cards. This card is simpler than the Receiver Card and Electron Identification Cards, and it uses much of the circuitry already developed for them. Therefore, it is rated of average difficulty.

WBS Element: 3.1.2.10.2

WBS Element Title: Jet Summary Card Procure

WBS Definition:

This WBS element includes all the cost to procure the Regional Calorimeter Trigger Jet Summary Cards.

Basis of Estimate:

The M&S and EDIA costs are based on the conceptual design of the Jet Summary Card, analysis of the layout of the prototype Receiver Card, the full-size prototype Clock and Control Card already constructed and tested, and the production of the cards built for the Zeus trigger system. This card is simpler than the Receiver Card and Electron Identification Cards, and it uses much of the circuitry already developed for them. Therefore, it is rated of average difficulty.

WBS Element: 3.1.2.10.3

WBS Element Title: Test Jet Summary Card

WBS Definition:

This WBS element includes all the effort to develop, produce, assemble, install and test the Regional Calorimeter Trigger Jet Summary Card.

Basis of Estimate:

The M&S and EDIA costs are based on the conceptual design of the Jet Summary Card, analysis of the layout of the prototype Receiver Card, the full-size prototype Clock and Control Card already constructed and tested, and production testing of the Zeus trigger cards. This card is simpler than the Receiver Card and Electron Identification Cards, and it uses much of the circuitry already developed for them. Therefore, it is rated of average difficulty.

WBS Element: 3.1.2.11

WBS Element Title: Cables

WBS Definition:

This WBS element includes all the effort to procure, install and test the Regional Calorimeter Trigger Cables. Each Receiver card sends some of its data off crate at 80 MHz to up to 5 neighboring crates. The 19 crates are located in pairs in a row of 10 adjacent racks. Crate to crate communication is handled by special cables running between the Receiver cards. The maximum amount of information shared between two Receiver cards in different crates is carried on 204 twisted pair (102 in each direction) at 80 MHz.

Basis of Estimate:

The amount of cable is based on the number of interchanged signals and the crate layout in the racks in the electronics barracks. The cost for the cable is based on the cost for halogen free twist and flat differential-pair signal cable that carried signals for the Zeus trigger system. This is an easy task and the cables are ordered from a catalog.

WBS Element: 3.1.2.12

WBS Element Title: DAQ Processor

WBS Definition:

This WBS element includes all the effort to procure, install and test the Regional Calorimeter Trigger DAQ Processor. This is the readout crate controller and communication module (ROC) provided by the CMS DAQ group.

Basis of Estimate:

The cost, servicing, operation and maintenance of the DAQ Processor is the responsibility of the Lisbon CMS group and there is no cost for this to US CMS.

WBS Element: 3.1.2.13

WBS Element Title: Crate Monitor Card

WBS Definition:

This WBS element includes all the effort to procure, install and test the Regional Calorimeter Trigger Crate Monitor Card. This modules serves as the crate environment monitor which may or may not be a commercial board. The decision to purchase or create a custom design will depend on the final requirements of the environmental monitoring system.

Basis of Estimate:

The cost, servicing, operation and maintenance of the Crate Monitor Card is the responsibility of the Lisbon CMS group and there is no cost for this to US CMS.

WBS Element: 3.1.2.13.1

WBS Element Title: Crate Monitor Card Procure

WBS Definition:

This WBS element includes all cost to procure the Regional Calorimeter Trigger Crate Monitor Card.

Basis of Estimate:

The cost, servicing, operation and maintenance of the Crate Monitor Card is the responsibility of the Lisbon CMS group and there is no cost for this to US CMS.

WBS Element: 3.1.2.13.2

WBS Element Title: Crate Monitor Card Spares

WBS Definition:

This WBS element includes all cost to procure 2 spare Regional Calorimeter Trigger Crate Monitor Cards.

Basis of Estimate:

The cost, servicing, operation and maintenance of the Crate Monitor Card is the responsibility of the Lisbon CMS group and there is no cost for this to US CMS.

WBS Element: 3.1.2.14

WBS Element Title: Trigger Tests

WBS Definition:

This WBS element includes all the effort to perform Calorimeter Regional Trigger system tests of fully instrumented crates, ship these crates to the CMS Hall at CERN, and commission the installation site, install, test, and commission the full Calorimeter Regional Trigger system in the CMS Hall electronics barracks.

Basis of Estimate:

The EDIA costs for testing of the fully instrumented crates are based on the experience in production testing of the Zeus Calorimeter Trigger electronics, a system of comparable size and number of high speed large electronics boards. The M&S for the shipping costs are based on the actual costs per crate of electronics incurred in shipping the Zeus Calorimeter Trigger electronics to DESY. The EDIA cost to commission the installation site, install, test, and commission the full Calorimeter Regional Trigger system in the CMS Hall electronics barracks is based on the actual experience in doing similar activities for the Zeus Calorimeter Trigger system at DESY. A considerable amount of effort will be physicist labor paid by the DoE base program at U. Wisconsin. This effort is only used for contingency. Therefore, while this task is difficult, it has the multiplier of 1.0 for a fixed cost since additional EDIA contingency is available from the DoE base program at U. Wisconsin.

WBS Element: 3.1.2.14.1

WBS Element Title: Trigger Subsystem Tests

WBS Definition:

This WBS element includes all the effort to perform Calorimeter Regional Trigger system tests of fully instrumented crates.

Basis of Estimate:

The EDIA costs for testing of the fully instrumented crates are based on the experience in production testing of the Zeus Calorimeter Trigger electronics. This task is difficult, but it has the multiplier of 1.0 for a fixed cost since additional EDIA contingency is available from the DoE base program at U. Wisconsin.

WBS Element: 3.1.2.14.2

WBS Element Title: Trigger System Installation

WBS Definition:

This WBS element includes all the effort and cost to ship the Calorimeter Regional Trigger crates to the CMS Hall at CERN, and commission the installation site, install, test, and commission the full Calorimeter Regional Trigger system in the CMS Hall electronics barracks.

Basis of Estimate:

The M&S for the shipping costs are based on the actual costs per crate of electronics incurred in shipping the Zeus Calorimeter Trigger electronics to DESY. The EDIA cost to commission the installation site, install, test, and commission the full Calorimeter Regional Trigger system in the CMS Hall electronics barracks is based on the actual experience in doing similar activities for the Zeus Calorimeter Trigger system at DESY. This task is difficult, but it has the multiplier of 1.0 for a fixed cost since additional EDIA contingency is available from the DoE base program at U. Wisconsin.

WBS Element: 3.1.2.15

WBS Element Title: Trigger Project Management

WBS Definition:

This WBS element includes all the effort to provide project managment of the Calorimeter Trigger project.

Basis of Estimate:

The effort involved is based on the Project Management of the Zeus Calorimeter System and the SDC Trigger System. The required 5% of an FTE engineer is provided by the U. Wisconsin base program and therefore there is no cost to the US CMS project.

WBS Element: 3.1.2.15.1

WBS Element Title: Tracking and Reporting

WBS Definition:

This WBS element includes all the effort to provide tracking and reporting of the Calorimeter Trigger project.

Basis of Estimate:

The effort involved is based on the tracking and reporting of the Zeus Calorimeter System and the SDC Trigger System. The required 5% of an FTE engineer is provided by the U. Wisconsin base program and therefore there is no cost to the US CMS project.