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SDC
SOLENOIDAL DETECTOR NOTES

SDC TRIGGER COST

November 10, 1991

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1 Introduction

This document describes the Work Breakdown Structure (WBS) and Cost Estimate for the SDC Trigger System (WBS 5.3). The SDC trigger system costed here is based on a particular implementation of the SDC trigger group conceptual design report [1]. The design is described in [2] and has several subsystems. These include the Level 1 Decision Logic[3, 4], the Level 2 Decision Logic[2] and the Trigger Clock and Control System[5]. The basic Level 1 Trigger system interfaces to front-end electronics crates on the detector for the calorimeter, shower max, tracking and muon subsystems. These are connected with optical fibers[6] to the counting house on the surface, which contains the level 1 decision processing crates. These include the Calorimeter Isolation/Summation crates, the Track/Shower Max Match crates, the Isolated Electron Match crates, the Energy Sum/Jet Threshold crate, the Muon Trigger Crates, and Final Decision crate.

The front-end electronics and trigger crates together form a pipeline structure in which data flows off of the detector crates on 1 Gbit/sec optical fibers into the Calorimeter Isloation/Summation, Track/Shower Max Match and Muon Trigger crates. Data is transmitted from these crates to the Isolated Electron Match and Energy Sum/Jet Threshold crates for further correlation before it is sent to the Final Decision crate. In the case of the Muon Trigger crates, their data is sent directly to the Final Decision crate. The trigger decision pipeline ends at the Final Decision crate, where a Level 1 Accept/Reject is generated and transmitted to the Global Clock/Control Crate for subsequent distribution to all DAQ and Level 1 Trigger crates. Those crates which receive raw data directly from the front end trigger hardware on the detector contain Level 2 Interface Cards. These cards enable copies of the raw data for which Level 1 Accepts were generated to be transmitted to the Level 2 Trigger. Each crate in the system has a backplane processor interface bus. This VME or similiar-type bus is used by the DAQ Interface/Processor card in each crate to program, control and monitor all of the cards in the system. Each crate in the system also has a Level 1 Clock/Control Interface card. This card receives the level 1 clock and trigger control information from the Global Level 1 Processor and distributes it to the cards in the crate.

2 Cost Estimate

2.1 Methodology

The cost for the trigger system was calculated by determining the numbers of ASIC's, boards, crates, and cables. Each electronics board was costed at 2 K$, with 1.2 K$ for parts, .4 K$ for the board, and .4 K$ for assembly. This cost is based on vendor quotes for manufacture and assembly of 270 9U x 400 mm deep 42 MHz VME Trigger Boards built for the Zeus experiment. The quotes are attached as Appendix B. The cost for the SDC boards is increased somewhat to account for stricter impedance control necessary at anticipated speeds in the range 63 - 125 MHz. Each crate was costed at 10 K$, with 2.5 K$ for hardware, 2.5 K$ for power supplies, and 5 K$ for the crate processor. Fiber optic links were costed at $ 300 per link with 35% contingency.

ASIC's and boards were divided into "easy", "average" and "hard" categories. Easy designs were estimated to take 1 man-year (MY) of engineering time. Average designs were estimated to take 2 MY and hard designs were estimated to take 3 MY of engineering time. In addition, each MY of engineering time was assumed to also use a MY of technician time, as well as 12.5 K$ of expenses for travel, supplies and computing (i.e. CAD).

2.2 Interfaces

There are a number of boundaries in the cost responsibilites between the trigger and front end electronics systems. These have been established in joint consultation with front end electronics groups. For central and muon tracking systems, the segment finding is costed with the front end electronics and the segment linking and all that follows is costed with the trigger. For calorimetry, the front end electronics costs all generation of the 8-bit hadronic and electromagnetic sums and the trigger pays for the optical link to bring the data up to the counting house. For the boundary between Level 1 and Level 2, Level 1 pays for the transmission of the data to the Level 2 Interface card (including crate and backplane), while Level 2 pays for the card. For the boundary between DAQ and trigger, the trigger pays for its crate and processor cards, while the DAQ pays for all the links that connect to the processor cards.

2.3 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. Each item has been assigned a technical risk factor, a cost risk factor and a schedule risk factor. Items that involve a new design that differs from established designs, but use existing technology received a technical risk factor of 6. Items that represent new designs that require R&D, but do not advance the state of art of the technology were assigned a technical risk factor of 8. Items

with cost based on in-house estimates based on similar previous experience, were assigned a cost risk factor of 4. Items with cost based on in-house estimates based on minimal actual experience, but related to existing capabilities, were assigned a cost risk factor of 6. All trigger elements were assigned a schedule risk factor of 1 since they do not delay completion of other subsystems. Each risk factor was assigned a weight. The technical risk factor was assigned a weight of 4% since it involves a risk in both design and manufacturing. The cost risk factor was assigned a weight of 2% since it involves risk in both material cost and labor rate. The schedule risk factor used was 1%. Each risk was multiplied by its weighting factor and the total of these products was used as the total contingency for each item.

3 WBS Dictionary

- **5.3** This is the Work Breakdown Structure (WBS) for the Trigger System. There are three main sections to the WBS. Section 5.3.1 contains the Level 1 Trigger, section 5.3.2 contains the Level 2 Trigger, and section 5.3.3 contains the overall Trigger Project Management.

- **5.3.1** This is the WBS for the Level 1 Trigger. Section 5.3.1.1 contains the Level 1 Outer Tracking Trigger, section 5.3.1.2 contains the Level 1 Calorimeter Trigger, section 5.3.1.3 contains the Level 1 Muon Trigger, section 5.3.1.4 contains the Level 1 Silicon (inner) Tracking Trigger, section 5.3.1.5 contains the Level 1 Trigger Global Decision Logic, and section 5.3.1.6 contains the Level 1 Clock and Control System.

- **5.3.1.1** This is the WBS for the Level 1 Tracking Trigger. Section 5.3.1.1.1 contains the Local Processing for the Trigger, which is done in crates located on the detector. Section 5.3.1.1.2 contains the Regional Processing for the Trigger, which is done in the counting house on the surface.

- **5.3.1.1.1** This is the WBS for the Local, or on-detector, Processing for the Level 1 Tracking Trigger. The cost includes that of interfacing the front end and DAQ of the Tracking electronics to the trigger system clock and control by placing a Level 1 Clock and Control Board (L1CCB)[2, 5] in each front end crate. The cost includes the that of adding trigger calculations to the Tracking Front End electronics crates. The front end electronics includes in its cost the circuitry to find hit segments in the superlayers. The cost for this section of the trigger is that of linking these segments together. This is done on 16 Segment-Linker Boards in each of the 48 tracking crates. The segment-linker boards contain a segment-linker ASIC. The boards are estimated as easy (1 MY engineering), while the ASIC is estimated to be hard (3 MY engineering). The output from each Segment-Linker board is carried on optical fiber, giving 16 optical fiber trigger-data cables for each Tracking front-end crate. An additional 4 optical fibers link the L1CCB to the Trigger Clock and Control system.

- **5.3.1.1.2** This is the WBS for the Regional, or counting-house, Processing for the Level 1 Tracking Trigger. This processing is contained in the 12 Track/Shower Max Match Crates. These Crates contain 8 double width Track/Shower Max Boards, which are estimated to be hard (3 MY engineering). These boards contain 8 Match ASICs,

which is estimated to be a hard (3 MY engineering) design. The crates also contain a L1CCB.

- **5.3.1.2** This is the WBS for the Level 1 Calorimeter Trigger. Section 5.3.1.2.1 contains the Local Processing for the Trigger, which is done in crates located on the detector. Section 5.3.1.2.2 contains the Regional Processing for the Trigger, which is done in the counting house on the surface.

- **5.3.1.2.1** This is the WBS for the Local, or on-detector, Processing for the Level 1 Calorimeter and Shower Max Trigger. The cost includes that of interfacing the front end and DAQ of the Calorimeter and Shower Max electronics to the trigger system clock and control by placing a L1CCB in each front end crate. The Calorimeter front end electronics includes in its cost the circuitry to find energies in trigger towers to the inputs of 32 optical fiber drivers for each crate. The Shower Max front end electronics includes in its cost the circuitry to provide hits over threshold on the inputs to 16 optical fiber drivers for each crate. Therefore the trigger assumes the cost of transmitting the Calorimeter information on 32 optical fibers and the Shower Max information on 16 optical fibers to the calorimeter and track trigger processing, respectively. An additional 4 optical fibers link the L1CCB to the Trigger Clock and Control system, for a total of 52 fiber optic links per front end crate.

- **5.3.1.1.2** This is the WBS for the Regional, or counting-house, Processing for the Level 1 Calorimeter Trigger. This processing is contained in the 24 Calorimeter Isolation/Summation Crates and the 6 Energy Sum/Jet Threshold Crates. The Isolation/Summation crates contain 8 Memory Lookup Boards, which have 8 Adder ASICs each. These Crates also contain 2 Calorimeter Pattern Recognition Cards, which have 6 Pattern Recognition ASICs apiece. Both boards and ASICs are estimated to be average designs (2 MY engineering apiece), yielding 8 MY total enginering for the Isolation/Summation Crate system. The Energy Sum/Jet Threshold Crates contain 4 Energy Summmation Cards and 4 Jet Threshold Summation Cards. Both boards are estimated to be average designs (2 MY engineering apiece), yielding 4 MY engineering for the Energy Sum/Jet Threshold Crates. All 30 of the Calorimeter Trigger Regional Processing crates contain an L1CCB.

- **5.3.1.3** This is the WBS for the Level 1 Muon Trigger. Section 5.3.1.3.1 contains the Local Processing for the Trigger, which is done in crates located on the detector. Section 5.3.1.3.2 contains the Regional Processing for the Trigger, which is done in the counting house on the surface.

- **5.3.1.3.1** This is the WBS for the Local, or on-detector, Processing for the Level 1 Muon Trigger. The cost includes the that of adding trigger calculations to the Muon Front End electronics crates. The front end electronics includes in its cost the circuitry to find hit segments in the superlayers. The cost for this section of the trigger is that of linking these segments together. This is done on 16 Segment-Linker Boards in each of the 48 Muon crates. The segment-linker boards contain a segment-linker ASIC. The boards are estimated as average (2 MY engineering), while the ASIC is estimated to be hard (3 MY engineering). The output from each Segment-Linker board is carried on optical fiber, giving 16 optical fiber trigger-data cables for each Muon front-end

crate. Each Muon front-end crate also contains an L1CCB. An additional 4 optical fibers link the L1CCB to the Trigger Clock and Control system.

- **5.3.1.3.2** This is the WBS for the Regional, or counting-house, Processing for the Level 1 Muon Trigger. There are 6 Muon Trigger Crates that contain 8 Muon Logic Cards and 1 Muon Summation Card each. The Muon Logic Card is estimated to be a hard design (3 MY engineering) and the Muon Summation Card is estimated to be an average design (2 MY engineering). The crates also contain a L1CCB.

- **5.3.1.4** This is the WBS for the Level 1 Silicon Tracking Trigger System. Since the Silicon tracking system does not provide information for the Level 1 Trigger, there is no processing of trigger information. Therefore, this WBS only contains the local processing sufficient to itnerface the Level 1 Trigger clock and control to the 64 Crates of the Silicon Tracking System in the counting house.

- **5.3.1.4.1** This is the WBS for the Local Level 1 Silicon Tracking Trigger System. This consists only of the circuitry to interface the Level 1 Clock and Control system to the Level 1 Tracking system. This includes one L1CCB per Silicon Tracking Electronics Crate. These electronics are located on the electronics counting house on the surface.

- **5.3.1.5** This is the WBS for the Global Level 1 Trigger system. Section 5.3.1.5.1 contains regional processing of Level 1 Triggers. Section 5.3.1.5.2 contains global processing of Level 1 Triggers. These electronics are located in the counting house on the surface.

- **5.3.1.5.1** This is the WBS for the Regional Processing of the Global Level 1 Trigger System. This processing is contained in the 6 Isolated Electron Match Crates. The Isolated Electron Match Crates each contain 8 Isolated Electron Region Match Cards and 3 Isolated Electron Hit Summary Cards. Both boards are estimated to be average designs (2 MY engineering apiece). These crates also include an L1CCB.

- **5.3.1.5.2** This is the WBS for the Global Processing of the Global Level 1 Trigger System. This processing is contained in the Final Decision Crate. This Crate contains an Isolated Electron Hit summary Card, an Energy Summation Card, a Jet Threshold Summation Card, and a Muon Summation Card. Each of these cards is also used in Regional Trigger processing and their engineering costs are assigned to the appropriate regional processing categories. Two cards must be designed for the Final Decision Crate. These are the Final Decision Memory Lookup Card and the Final Decision Logic Card. These cards are both hard designs (3 MY engineering apiece) due to the systems issues involved in correlating different subsystems in the trigger.

- **5.3.1.6** This is the WBS for the Level 1 Trigger Clock and Control System. Section 5.3.1.6.1 contains regional distribution of the clock and control. Section 5.3.1.6.2 contains global processing of the clock and control.

- **5.3.1.6.1** This is the WBS for the Regional Distribution of the Level 1 Trigger Clock and Control. This includes 8 Local Clock/Control Crates which provide Clock and Control Signals for 40 Crates apiece, providing these signals for the 256 Front End Crates and 50 Trigger Crates. The Front End Electronics Systems are responsible for the the cost of the optical fiber links and L1CCB's in their crates. Each Local

Clock/Control Crate contains a L1CCB and 16 Level 1 Clock and Control Fanouts (L1CCF). The L1CCB and L1CCF are average designs (2 MY engineering apiece).

- **5.3.1.6.2** This is the WBS for the Global Processing of the Level 1 Trigger Clock and Control. This is contained in the Global Clock/Control Crate. This Crate contains a Machine Clock Interface Card, a Beam Pickup Interface Card, a Deadtime Monitor Card, a Final Decision Interface Card, a Global Clock Master Card and a Global Control Master Card. Each of these boards is an easy design (1 MY engineering apiece) for a total engineering time of 6 MY. The crate also contains 2 L1CCF's.

- **5.3.2** This is the WBS for the Level 2 Trigger. Section 5.3.2.1 contains the Level 2 Outer Tracking Trigger, section 5.3.2.2 contains the Level 2 Calorimeter Trigger, section 5.3.2.3 contains the Level 2 Muon Trigger, section 5.3.2.4 contains the Level 2 Silicon (inner) Tracking Trigger, and section 5.3.2.5 contains the Level 2 Trigger Global Decision Logic.

- **5.3.2.1** This is the WBS for the Level 2 Outer Tracking Trigger. This system consists of 12 Level 2 Interface Cards that reside in the 12 Level 1 Trigger Track/Shower Max Match Crates, as well as 4 Regional Crates with 16 Regional Cards and one Regional Master Card apiece.

- **5.3.2.2** This is the WBS for the Level 2 Calorimeter Trigger. This system consists of 24 Level 2 Interface Cards that reside in the 24 Level 1 Trigger Calorimeter Isolation/Summation Crates, as well as 4 Regional Crates with 16 Regional Cards and one Regional Master Card apiece.

- **5.3.2.3** This is the WBS for the Level 2 Muon Trigger. This system consists of 6 Level 2 Interface Cards that reside in the 6 Level 1 Trigger Muon Crates, as well as 4 Regional Crates with 16 Regional Cards and one Regional Master Card apiece.

- **5.3.2.4** This is the WBS for the Level 2 Silicon Inner Tracking Trigger. This system consists of 4 racks with 8 crates containing printed circuit boards with 3 custom integrated circuits (Associate Memory Chip 1, Associate Memory Chip 2, L2TC Chip) and ECL logic. This is the WBS for the Overall Level 2 Trigger System.

- **5.3.2.5** This is the WBS for the Global Level 2 Trigger system. Section 5.3.2.5.1 contains regional processing of Level 2 Triggers. Section 5.3.2.5.2 contains global processing of Level 2 Triggers. These electronics are located in the counting house on the surface.

- **5.3.2.5.1** This is the WBS for the Regional Interface of the Global Level 2 Trigger System. This consists of 4 Regional Crates with 16 Regional Cards and 1 Regional Master apiece. This WBS contains the engineering for the Regional Cards and Regional Master Cards. Due to the system engineering involved. these are both hard designs (3 MY engineering apiece).

- **5.3.2.5.2** This is the WBS for the Global Processing of the Global Level 2 Trigger. This consists of a Global Processing Crate with 16 GLobal Logic Cards and a single Global Logic Master. Due to the system engineering involved, these are both hard designs (3 MY engineering apiece).

- **5.3.3** This is the WBS for the Project Management of the Trigger System. This involves engineering for system, resource, cost, schedule, and integration of the trigger system.

4 Crate and Card Usage in the Trigger System

4.1 Crate Summary

Summary of Crate Usage in the Level 1 Trigger System:

Crate Type	Quantity
Calorimeter Isolation/Summation	24
Track/Shower Max Match	12
Isolated Electron Match	6
Energy Sum/Jet Threshold	1
Muon Trigger	6
Final Decision	1
Local Clock/Control Fanout	8
Global Clock/Control	1
Total Crates:	59

Summary of Crate Usage in the Level 2 Trigger System:

Crate Type	Quantity
Calorimeter	4
Track	4
Muon	4
Silicon	8
Regional	4
Global	1
Total Crates:	25

4.2 Card Summary

Summary of Card Usage in the Level 1 Trigger System:

Card Type	Nominal per Crate Usage	Total Quantity	Comments
Calorimeter MLU	8	192	
Calorimeter PRA	2	48	
Calorimeter Energy	1	24	
Track/Shower Max Match	8	96	
Isolated Electron RMC	8	48	
Isolated Electron HSC	2-3	16	incl. 1 card in Final Dec. Crate
Energy Summation	4	5	incl. 1 card in Final Dec. Crate
Jet Threshold Summation	4	5	incl. 1 card in Final Dec. Crate
Muon Logic	8	48	
Muon Summation	1	7	incl. 1 card in Final Dec. Crate
Final Decision MLU	1	1	
Final Decision Logic	1	1	
L1 Clock/Control Interface	1	59	1 each in all crates
L1 Clock/Control Fanout	16	128	
DAQ Interface/Processor	1	59	1 each in all crates
L2 Trigger Interface	1	42	only in crates with L2 connection

Summary of Card Usage in the Level 2 Trigger System:

Card Type	Nominal per Crate Usage	Total Quantity	Comments
Regional Cards	16	256	
Regional Master	1	16	
L2TC Cards	30	240	
Global Cards	16	16	
Global Master	1	1	

5 Cost Breakdown

Appendix A gives the detail cost breakdown for the SDC Trigger System. The WBS numbers follow the description given in the WBS section above. The total cost is 24,753K plus 8,107K contingency, giving a total project cost of 32,861K. Of this total project cost, 23,854K is for Level 1, 8,294K is for Level 2 and 712K is for project management.

References

[1] A. Lankford *et al.*, *Conceptual Design of the SDC Trigger from the SDC Trigger Group*, SDC Note SDC-91-00098, 1991.

[2] W. H. Smith, T. Gorski, J. Lackey, *SDC Trigger Preliminary Conceptual Design*, SDC Note SDC-91-00089, 1991.

[3] T. Gorski, J. Lackey, W.H. Smith, *Level 1 Trigger Decision Design for the SDC*, SDC Note SDC-91-00088, 1991.

[4] T. Gorski, J. Lackey, W.H. Smith, W. Temple, *Isolated Electron Pattern Logic Design and Performance at the SSC*, SDC Note SDC-91-00087, 1991.

[5] W. H. Smith, T. Gorski, J. Lackey, *SDC Global Level 1 Processor: Clock & Control*, SDC Note SDC-91-00090, 1991.

[6] M. Thompson, *Fiber Optic Data Transmission for the SDC Detector*, SDC Note SDC-91-00092, 1991.

APPENDIX A:

SDC TRIGGER WBS 5.3

WBS	Element Name	ENG	TECH	PROC	EXP	TOTAL	Ct%	tc	cs	sc	tw	cw	sw	Cont. $	TOTAL
5.3	**Trigger Systems**	**7,300,800**	**6,084,000**	**10,318,696**	**1,050,000**	**24,753,496**								**8,107,044**	**32,860,540**
5.3.1	**First Level Trigger**	**4,867,200**	**4,056,000**	**8,123,800**	**725,000**	**17,772,000**								**6,082,410**	**23,854,410**
5.3.1.1	**Tracking Systems**	**936,000**	**780,000**	**2,550,200**	**200,000**	**4,466,200**								**1,567,838**	**6,034,038**
5.3.1.1.1	Local Processing	374,400	312,000	1,960,000	80,000	2,726,400	39	8	6	1	4	1	1	1,063,296	3,789,696
5.3.1.1.2	Regional Processing	561,600	468,000	590,200	120,000	1,739,800	29	6	4	1	4	1	1	504,542	2,244,342
5.3.1.2	**Calorimeter Systems**	**1,123,200**	**936,000**	**2,662,200**	**150,000**	**4,871,400**								**1,583,426**	**6,454,826**
5.3.1.2.1	Local Processing	0	0	1,707,200	0	1,707,200	39	8	6	1	4	1	1	665,808	2,373,008
5.3.1.2.2	Regional Processing	1,123,200	936,000	955,000	150,000	3,164,200	29	6	4	1	4	1	1	917,618	4,081,818
5.3.1.3	**Muon Systems**	**936,000**	**780,000**	**2,051,400**	**125,000**	**3,892,400**								**1,407,086**	**5,299,486**
5.3.1.3.1	Local Processing	468,000	390,000	1,862,400	62,500	2,782,900	39	8	6	1	4	1	1	1,085,331	3,868,231
5.3.1.3.2	Regional Processing	468,000	390,000	189,000	62,500	1,109,500	29	6	4	1	4	1	1	321,755	1,431,255
5.3.1.4	**Silicon Tracking**	**0**	**0**	**128,000**	**0**	**128,000**								**37,120**	**165,120**
5.3.1.4.1	Local Processing	0	0	128,000	0	128,000	29	6	4	1	4	1	1	37,120	165,120
5.3.1.5	**Global System**	**936,000**	**780,000**	**307,000**	**125,000**	**2,148,000**								**721,060**	**2,869,060**
5.3.1.5.1	Regional Processing	374,400	312,000	245,000	50,000	981,400	39	8	6	1	4	1	1	382,746	1,364,146
5.3.1.5.2	Global Processing	561,600	468,000	62,000	75,000	1,166,600	29	6	4	1	4	1	1	338,314	1,504,914
5.3.1.6	**Clock Control System**	**936,000**	**780,000**	**425,000**	**125,000**	**2,266,000**								**765,880**	**3,031,880**
5.3.1.6.1	Regional Distributor	374,400	312,000	351,000	50,000	1,087,400	39	8	6	1	4	1	1	424,086	1,511,486
5.3.1.6.2	Global Processing	561,600	468,000	74,000	75,000	1,178,600	29	6	4	1	4	1	1	341,794	1,520,394
5.3.2	**Second Level Trigger**	**2,152,800**	**1,794,000**	**2,194,896**	**287,500**	**6,429,196**								**1,864,467**	**8,293,663**
5.3.2.1	**Tracking Systems**	**0**	**0**	**315,000**	**0**	**315,000**	29	6	4	1	4	1	1	**91,350**	**406,350**
5.3.2.2	**Calorimeter Systems**	**0**	**0**	**435,000**	**0**	**435,000**	29	6	4	1	4	1	1	**126,150**	**561,150**
5.3.2.3	**Muon Systems**	**0**	**0**	**255,000**	**0**	**255,000**	29	6	4	1	4	1	1	**73,950**	**328,950**
5.3.2.4	**Silicon Tracker**	**1,029,600**	**858,000**	**793,896**	**137,500**	**2,818,996**	29	6	4	1	4	1	1	**817,509**	**3,636,505**
5.3.2.5	**Global System**	**1,123,200**	**936,000**	**396,000**	**150,000**	**2,605,200**								**755,508**	**3,360,708**
5.3.2.5.1	Regional Interface	561,600	468,000	264,000	75,000	1,368,600	29	6	4	1	4	1	1	396,894	1,765,494
5.3.2.5.2	Global Processor	561,600	468,000	132,000	75,000	1,236,600	29	6	4	1	4	1	1	358,614	1,595,214
5.3.3	**Project Management**	**280,800**	**234,000**	**0**	**37,500**	**552,300**	29	6	4	1	4	1	1	**160,167**	**712,467**

5.3 TRIGGER SYSTEMS

5.3.1 FIRST LEVEL TRIGGER

5.3.1.1 TRACKING SYSTEMS

5.3.1.1.1 Local Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Clock Control Board	1	2,000	2,000	
Segment Linker Boards	16	2,000	32,000	
Fiber Optic Links	20	300	6,000	
Total Cost per Crate			40,000	
Total Barrel Crates	32	40,000	1,280,000	
Total Inter Crates	16	40,000	640,000	
TOTAL CRATE COST	48	40,000	1,920,000	
Prototype	1	40,000	40,000	
Engineering in Man Years	4	93,600	374,400	360
Technical in Man Years	4	78,000	312,000	300
Misc. Expenses				
Travel			20,000	
Computing			40,000	
Supplies			20,000	
TOTAL LOCAL PROCESSING			2,726,400	

5.3.1.1.2 Regional Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Track/Sh. Max Match Crate				
Trk./Sh. Max Match Card	8	4,000	32,000	
Match ASIC	64	100	6,400	
Clock/Control Board	1	2,000	2,000	
Crate Hardware	1	2,500	2,500	
Power Supplies	1	2,500	2,500	
Cost per Crate			45,400	
TOTAL CRATE COST	12	45,400	544,800	
Prototype Crate	1	45,400	45,400	
Engineering in Man Years	6	93,600	561,600	360
Technical in Man Years	6	78,000	468,000	300
Misc. Expenses				
Travel			30,000	
Computing			60,000	
Supplies			30,000	
TOTAL REGIONAL PROCESSING			1,739,800	

5.3.1.2 CALORIMETER SYSTEM

5.3.1.2.1 Local Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Fiber Optic Links	52	300	15,600	
Clock Control Board	1	2,000	2,000	
Total cost per unit			17,600	
Total Barrel	64	17,600	1,126,400	
Total Int.	32	17,600	563,200	
Prototype	1	17,600	17,600	
TOTAL LOCAL PROCESSING			1,707,200	

5.3.1.2.2 Regional Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Isolation/Summation Crate				
Calorimeter MLU Board	8	2,000	16,000	
Adder ASIC	64	70	4,480	
Calorimeter PRA Card	2	2,000	4,000	
PRA ASIC	12	300	3,600	
Clock/Control Board	1	2,000	2,000	
Crate Hardware	1	2,500	2,500	
Power Supplies	1	2,500	2,500	
Cost per Crate			35,080	
Total Crate Cost	24	35,080	841,920	
Prototype	1	35,080	35,080	
Egy Sum/Jet Thresh Crate				
Energy Sum Card	4	4,000	16,000	
Jet Thresh Sum Card	4	4,000	16,000	
Clock/Control Board	1	2,000	2,000	
Crate Hardware	1	2,500	2,500	
Power Supplies	1	2,500	2,500	
Cost per Crate			39,000	
Total Crate Cost	1	39,000	39,000	
Prototype	1	39,000	39,000	
Engineering in Man Years	12	93,600	1,123,200	360
Technical in Man Years	12	78,000	936,000	300
Misc. Expenses				
Travel			60,000	
Computing			60,000	
Supplies			30,000	
TOTAL REGIONAL PROCESSOR COSTS			3,164,200	

5.3.1.3 MUON SYSTEMS

5.3.1.3.1	Local Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Segment Linker Board	16	2,000	32,000	
	Fiber Optics	16	300	4,800	
	Clock/control Board	1	2,000	2,000	
	Total Cost per Unit			38,800	
	Barrel Crates	32	38,800	1,241,600	
	Inter Crates	16	38,800	620,800	
	TOTAL BOARD COST	48	38,800	1,862,400	
	Engineering in Man Years	5	93,600	468,000	360
	Technical in Man Years	5	78,000	390,000	300
	Misc. Expenses				
	Travel			25,000	
	Computing			25,000	
	Supplies			12,500	
	TOTAL LOCAL PROCESSING			2,782,900	

5.3.1.3.2	Regional Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Muon Trigger Crate				
	Muon Logic Card	8	2,000	16,000	
	Muon Summation Card	1	4,000	4,000	
	Clock/Control Board	1	2,000	2,000	
	Crate Hardware	1	2,500	2,500	
	Power Supplies	1	2,500	2,500	
	Cost per Crate			27,000	
	Total Crate Cost	6	27,000	162,000	
	Prototype	1	27,000	27,000	
	Engineering in Man Years	5	93,600	468,000	360
	Technical in Man Years	5	78,000	390,000	300
	Misc. Expenses				
	Travel			25,000	
	Computing			25,000	
	Supplies			12,500	
	TOTAL REGIONAL PROCESSING SYSTEM			1,109,500	

5.3.1.4 SILICON TRACKING

5.3.1.4.1	Local Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Clock Control card	1	2,000	2,000	
	Cost per Crate			2,000	
	Total Crate Cost	64	2,000	128,000	
	TOTAL LOCAL PROCESSING			128,000	

5.3.1.5 GLOBAL SYSTEM

5.3.1.5.1	Regional Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Isolated Electron Match Crate				
	Isolated Electron RMC	8	2,000	16,000	
	Isolated Electron HSC	3	4,000	12,000	
	Clock/Control Board	1	2,000	2,000	
	Crate Hardware	1	2,500	2,500	
	Power Supplies	1	2,500	2,500	
	Cost per Crate			35,000	
	Total Crate Cost	6	35,000	210,000	
	Prototype	1	35,000	35,000	
	Engineering in Man Years	4	93,600	374,400	360
	Technical in Man Years	4	78,000	312,000	300
	Misc. Expenses				
	Travel			20,000	
	Computing			20,000	
	Supplies			10,000	
	TOTAL REGIONAL PROCESSING			981,400	

5.3.1.5.2	Global Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Final Decision Crate				
	Isolated Electron HSC	1	4,000	4,000	
	Energy Sum Card	1	4,000	4,000	
	Jet Thresh Sum Card	1	4,000	4,000	
	Muon Summation Card	1	4,000	4,000	
	Final Decision MLU Card	1	4,000	4,000	
	Final Decision Logic	1	4,000	4,000	
	Clock/Control Board	1	2,000	2,000	
	Crate Hardware	1	2,500	2,500	
	Power Supplies	1	2,500	2,500	
	Cost per Crate			31,000	
	Total Crate Cost	1	31,000	31,000	
	Prototype	1	31,000	31,000	
	Engineering in Man Years	6	93,600	561,600	360
	Technical in Man Years	6	78,000	468,000	300
	Misc. Expenses				
	Travel			30,000	
	Computing			30,000	
	Supplies			15,000	
	TOTAL GLOBAL PROCESSING			1,166,600	

5.3.1.6 CLOCK/CONTROL SYSTEM

5.3.1.6.1 Regional Distribution	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Local Clock/Control Crate				
Clock Control Board	16	2,000	32,000	
Clock Control Fanout	1	2,000	2,000	
Crate Hardware	1	2,500	2,500	
Power Supplies	1	2,500	2,500	
Cost per Crate			39,000	
Total Crate Cost	8	39,000	312,000	
Prototype	1	39,000	39,000	
Engineering in Man Years	4	93,600	374,400	360
Technical in Man Years	4	78,000	312,000	300
Misc. Expenses				
Travel			20,000	
Computing			20,000	
Supplies			10,000	
TOTAL REGIONAL DISTRIBUTION			1,087,400	

5.3.1.6.2 Global Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Global Clock/Control Crate				
Mach. Clock Interface	1	4,000	4,000	
Beam Pickup Interface	1	4,000	4,000	
Deadtime Monitor	1	4,000	4,000	
Final Decision Interface	1	4,000	4,000	
Global Clock Master	1	4,000	4,000	
Global Control Master	1	4,000	4,000	
Clock Control Fanout	2	4,000	8,000	
Crate Hardware	1	2,500	2,500	
Power Supplies	1	2,500	2,500	
Cost per Crate			37,000	
Total Crate Cost	1	37,000	37,000	
Prototype	1	37,000	37,000	
Engineering in Man Years	6	93,600	561,600	360
Technical in Man Years	6	78,000	468,000	300
Misc. Expenses				
Travel			30,000	
Computing			30,000	
Supplies			15,000	
TOTAL GLOBAL PROCESSING			1,178,600	

GRAND TOTAL LEVEL 1 **17,772,000**

5.3.2 SECOND LEVEL TRIGGER

3.2.1 TRACKING SYSTEMS

Regional Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Level 2 Interface Cards	12	2,000	24,000	
Regional Crate	1	5,000	5,000	
Regional Cards	16	2,000	32,000	
Regional Master	1	2,000	2,000	
Total Regional Crates	4	63,000	252,000	
Prototype	1	63,000	63,000	
TOTAL REGIONAL PROCESSING SYSTEM			315,000	

5.3.2.2 CALORIMETER SYSTEM

Regional Processor	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Level 2 Interface Cards	24	2,000	48,000	
Regional Crate	1	5,000	5,000	
Regional Cards	16	2,000	32,000	
Regional Master	1	2,000	2,000	
Total Regional Crates	4	87,000	348,000	
Prototype	1	87,000	87,000	
TOTAL REGIONAL PROCESSOR COSTS			435,000	

5.3.2.3 MUON SYSTEMS

Regional Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
Level 2 Interface Cards	6	2,000	12,000	
Regional Crate	1	5,000	5,000	
Regional Cards	16	2,000	32,000	
Regional Master	1	2,000	2,000	
Total Regional Crates	4	51,000	204,000	
Prototype	1	51,000	51,000	
TOTAL REGIONAL PROCESSING SYSTEM			255,000	

5.3.2.4	**SILICON TRACKER**	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	L2TC Chips	10,000	20	200,000	
	Assoc. Mem. Chip 1	10,000	15	150,000	
	Assoc. Mem. Chip 2	10,000	15	150,000	
	PC Boards	240	300	72,000	
	ECL Chips	120	100	12,000	
	Card Assy./Test	240	125	30,000	
	Crates and Power Supp.	8	12,750	102,000	
	Racks	4	750	3,000	
	Total Equipment			719,000	
	Spare	24	2,996	71,900	
	Prototype	1	2,996	2,996	
	Engineering	11	93,600	1,029,600	360
	Technician	11	78,000	858,000	300
	Travel			55,000	
	Computing			55,000	
	Supplies			27,500	
	TOTAL SILICON TRACKER SYSTEM			2,818,996	

5.3.2.5	**GLOBAL SYSTEM**				
5.3.2.5.1	Regional Interface	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Regional Crate	1	10,000	10,000	
	Regional Cards	16	2,000	32,000	
	Regional Master	1	2,000	2,000	
	Total Regional Crates	4	44,000	176,000	
	Spare	1	44,000	44,000	
	Prototype	1	44,000	44,000	
	Engineering	6	93,600	561,600	360
	Technician	6	78,000	468,000	300
	Travel			30,000	
	Computing			30,000	
	Supplies			15,000	
	TOTAL REGIONAL PROCESSING SYSTEM			1,368,600	

5.3.2.5.2	Global Processing	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Global Crate	1	10,000	10,000	
	Global Cards	16	2,000	32,000	
	Global Master	1	2,000	2,000	
	Total Global Crates	1	44,000	44,000	
	Spare	1	44,000	44,000	
	Prototype	1	44,000	44,000	
	Engineering	6	93,600	561,600	360
	Technician	6	78,000	468,000	300
	Travel			30,000	
	Computing			30,000	
	Supplies			15,000	
	TOTAL GLOBAL PROCESSING SYSTEM			1,236,600	
	GRAND TOTAL LEVEL 2			**6,429,196**	

5.3.3	**PROJECT MANAGEMENT**	Unit	Cost/unit	Total Cost/Unit	Labor Rate
	Engineering	3	93,600	280,800	360
	Technician	3	78,000	234,000	300
	Travel			15,000	
	Computing			15,000	
	Supplies			7,500	
	TOTAL PROJECT MANAGEMENT			552,300	
	GRAND TOTAL LEVEL 3			**552,300**	
	GRAND TOTAL TRIGGER			**24,753,496**	

APPENDIX B:

VENDOR QUOTES FOR PC BOARDS AND ASSEMBLY

spectra

May 13, 1991

Pat Leggett
Purchasing Agent
University of Wisconsin - Madison
Purchasing Services
750 University Avenue, 2nd Floor Reception
Madison, Wisconsin 53706-1490

RE: Bid Number 91-0623

Dear Pat:

I am pleased to provide price and delivery information for the following part:

QTY	PART/DESCRIPTION	U/P	TOTAL PRICE
272	TRIGGER ENCODER CARD	$298.00	$81,056.00
257	SAME	298.00	76,586.00
1	TOOLING	930.00	930.00
1	ELECTRICAL/IMPEDANCE TEST	4,500.00	4,500.00
Bid Total			**$163,072.00**

General Provisions

- Delivery will be made in two releases, 272 pieces in 5 weeks with the balance of 257 pieces on your dock in 6 weeks. Either quantity, if placed as a single order, can be shipped to arrive on your dock in 5 weeks.
- Terms: Net 30, F.O.B. Destination.
- Customer references will gladly be supplied upon request.

Technical Provisions

- Soldermask type will be DuPont Vacrel 8130. Other processes are available.
- Our Excellon Laser Plotter's largest aperture is one-half an inch.
- Automated optical inspection of layers before lamination is performed on a 100% basis at Spectra, in all cases.
- Impedance characteristics shall be maintained through the following procedure:

P.O. Box 420, Clarksburg, MD 20871 • (301) 428-7222

1) The design will be analyzed using Spectra proprietary software. This analysis will determine if any adjustments to the copper weight, trace widths, or dielectric thicknesses are required, in relation to the specific materials to be used and process parameters at Spectra.

2) Any adjustments will be discussed and approval sought from the customer before fabrication.

3) 100% of the finished boards will be tested for the specified impedance characteristics using TDR analysis. Certificates of compliance will be provided.

Please call me if you or members of your staff have any questions. I thank you for the opportunity to bid on this requirement.

Regards,

Erik Clark
Sales Representative

P.O. Box 25903, Milwaukee, WI 53225-0903 • Fax (414) 252-2201 • Phone (414) 252-2200

Ms. Pat Leggett
Purchasing Services
University of Wisconsin-Madison
750 University Ave.
Madison, Wisconsin 53706

October 7, 1991

QUOTATION NO: Q-910081

QUOTATION

This quotation will provide pricing for the Trigger Encoder Card assembly. All components are to be provided by the University of Wisconsin Physical Sciences Laboratory.

Subject to the attached terms and conditions, we are pleased to provide the following quotation for contract services for this assembly.

ITEM	DESCRIPTION	QUANTITY	U/M	UNIT PRICE
1.	Surface Mount and Leaded assembly.	264	ea.	$346.62
2.	Set up charges	1	ea.	$275.00
3.	Non-recurring Engineering charges	1.	ea.	$1135.00

Please see below for the assumptions used for this quotation and more detail on each of the items quoted above.

ASSUMPTIONS

1. University of Wisconsin Physical Sciences Laboratory to provide PWB's and all components.
2. All Components to be on Tape and Reel, in conductive tubes, or in waffle packs.
3. All components to be cleaned in Flux Off E series or water unless specified.
4. University of Wisconsin Physical Sciences Laboratory to provide complete assembly documentation.
5. University of Wisconsin Physical Sciences Laboratory to provide artwork generation for solder stencil.

PCB ASSEMBLY SERVICE

Thor Technology will provide the following services:

1. Procurement of all process materials
2. Assembly and soldering of components to the circuit board.
3. 100% visual inspection of solder joints.
4. Cleaning in Fluxoff E series or water.
5. Packing for shipment.

NONRECURRING ENGINEERING CHARGE

The following NRE charges apply to this quotation:

a. Placement machine program.
b. Solder Stencil.
c. Wave Solder Tooling

SETUP CHARGES

A $275.00 set-up charge is uncured each time a production release is run. This covers the cost of installing the materials on our placement machines, logging the transactions and doing a first piece inspection of the populated board.

DELIVERY: Based on a pre-arranged production schedule. It is possible to deliver 40 assemblies 2 weeks ARO providing that artwork needed for a solder stencil and the components are provided along with the purchase order

F.O.B: University of Wisconsin Physical Sciences Laboratory
3725 Schneider Drive, Rt 4
Stoughton, Wisconsin 53589

QUOTATION TO REMAIN FIRM FOR 30 DAYS.

John Seitz
Contract Sales Manager

JAS/wam

Enclosure

cc: File
P.R.I.S.M.