Basis Of Estimate –M&S line 1.1.1 Silicon Sensors

1.1.1.1 Probe station setup

Probe station setups are being bought by SUNY Stonybrook and CINVESTAV. The funding for these are fixed costs in the NSF MRI budget so no contingency has been placed on these numbers. Also, as of 2/1/2, the stations have both been purchased. The cost estimate was based on the silicon sensor probing facility has been set up at Kansas State University at no cost to the project. The total we have budgeted is $83,000 per stand.

Here is an estimated cost of one facility based on KSU experience.

Clean Room Equipment

			price	
Dark Box	Ron Jackson, KSU Mechanical Shop	x2-1631	$ 4,300.00	
Keithley 237	Keithley Instrunents	Joanne Pamer	$ 7,195.00	440-248-0400
Rack Mounting kit	Keithley Instrunents	800-552-115 x2757	$ 134.10	
		pamer_joanne@keithley.com		
HP LCR 4284A	Agilent	Bruce Kempin	$ 9,944.00	800 829-4444
Cable option	Agilent	316-636-4934	included	800 829-4433
Test Leads	Agilent	bruce_kempin@AGILENT.COM	$ 320.00	
Isolation Vibration Table	Kinetic Systems 1201-05-11	used from Bid Services	$ 2,336.00	732-863-9500
Probe Station		Harry Vine <HVine@aol.com>	$65,952.77	
REL-6100 8 in. Semi-Auto		$ 42,320.00		
Controller, probe type I	Celeron 450MHz, 64Mb, 6.4GB	$ 2,802.50		
Video adapter		$ 142.50		
Miscrocope 2x,10x,20x		$ 7,983.00		
Digitizer		$ 1,401.25		
positioner left		$ 1,181.50		
positioner right		$ 1,181.50		
positioner right		$ 1,181.50		
Probe FGI07		$ 175.50		
Probe FGI07		$ 175.50		
Probe FGI07		$ 175.50		
coax probe		$ 382.50		
coax probe		$ 382.50		
cables		$ 324.00		
probe points, box of 10		$ 495.00		
Adapter		$ 1,000.00		
Needle, box of 25		$ 133.00		
vacuum, kit		$ 675.00		
pump		$ 475.00		
Installation		$ 2,550.00		
s&h		$ 815.52		
Guard Box	self made			

Storage			
refrigerator			
Misc.			
Filter 20x20x1 type dp 1-40	Airguard Industries	1-866-247-4827	
Filter 12x24x1	Airguard Industries		
Gloves			
Coats (size M/L/xL)			
Hair cover			
Shoe Cover	VWR Critical Environment Solution	1-800-932-5000	
Total equipment cost		$	89,861.87

1.1.1.2 L0 Sensors

The estimates are based on vendor quotes as given below. Since we have quotes, we have assigned 30% contingency.

1.1.1.2.1 Mask Development

Assume two vendors each with a mask cost of $55,000. These are the NRE costs given below

1.1.1.2.2 Prototype sensors

Assume two vendors with 20 prototypes each. We assumed a cost of $1200.

1.1.1.2.3 Production sensors

We need 144 sensors for the detector, we've assumed 50% spares (72) and a cost of $300.

Here is a summary of vendor quotes:

Vendor	NRE cost, $	Prototype cost per sensor, $	Production cost per sensor, $
HPK	$54,810	$1159.71	$276.01
Elma	$50,040	$400.00	$190.00

MOSCOW STATE UNIVERSITY

Institute of Nuclear Physics

119899, Moscow, Russia

Tel.: +7-095-932-9216; FAX: +7-095-939-5948

To: ***Regina Demina***
Physics Department, Kansas State University
116 Cardwell Hall,
Manhattan, KS, 66506, USA
FAX: +1 (785) 532-6787

Quotation

ITEM	Number	Price	Sum
Masks design and engineering: CAD design= 10*68 h@$22.5/h Engineering= 10*67 h@$22/h	**2 sets of 10 masks**	**30,040.00**	**60,080.00**
Masks production: $2,000/mask	**2 sets of 10 masks**	**20,000.00**	**40,000.00**
		Total price:	**100,080.00**

Sincerely,

Mikhail Merkine
11/16/01

1.1.1.3 L1 Sensors

The estimates are based on vendor quotes as given below. Since we have quotes, we have assigned 30% contingency.

1.1.1.3.1 Mask Development

Assume two vendors each with a mask cost of $60,000. These are the NRE costs given below

1.1.1.3.2 Prototype sensors

Assume two vendors with 20 prototypes each. We assumed a cost of $800.

1.1.1.3.3 Production sensors

We need 144 sensors for the detector, we've assumed 50% spares (72) and a cost of $500.

Here is a summary of vendor quotes:

Vendor	NRE cost, $	Prototype cost per sensor, $	Production cost per sensor, $
HPK	$60,465	$544.18	$435.35
Elma	$50,040	$800.00	$345.00

MOSCOW STATE UNIVERSITY

Institute of Nuclear Physics

119899, Moscow, Russia

Tel.: +7-095-932-9216; FAX: +7-095-939-5948

To: ***Regina Demina***
Physics Department, Kansas State University
116 Cardwell Hall,
Manhattan, KS, 66506, USA

Quotation

ITEM	Number	Price	Sum
Masks design and engineering	**1 set**	**3,000.00**	**3,000.00**
Masks production	**1 set**	**4,000.00**	**4,000.00**
Prototype silicon sensor for D0 RunIIb layer L1: 79.1 x 25 mm^2, 384 r/o strips with 58 mkm pitch	**20 wafers**	**400.00**	**8,000.00**
S&H, insurance			**380.00**
		Total price:	**15,380.00**

Sincerely,

Mikhail Merkine
10/10/01

1.1.1.4 L2 Sensors

The estimates are based on vendor quotes as given below. Since we have quotes, we have assigned 30% contingency.

1.1.1.4.1 Mask Development

Assume two sets of mask each with a mask cost of $80,000. These are the NRE costs given below

1.1.1.4.2 Prototype sensors

One run assumed with 100 sensors. We assumed a cost of $750 per prototype.

1.1.1.4.3 Production sensors

We need 1900 sensors for the detector, we've assumed 20% spares (380) and a cost of $675.

Here is a summary of vendor quotes:

Vendor	NRE cost, $	Prototype cost per sensor, $	Production cost per sensor, $
HPK	$76,734	$712.75	$671.16

1.1.1.5 Radiation testing

$40K for equipment, supplies, trips and beam time, if using an outside facility.

1.1.1.6 Vendor qualification and monitoring

10 foreign trips $5K each.

1.1.1.7 Sensor Probing

This includes costs associated with probing sensors at KSU and SUNY SB. These costs are incurred directly through the funds supplied by the NSF MRI and are fixed so that no contingency is included. They include costs for supplies, technician time, and indirect costs.

Basis Of Estimate –M&S line 1.1.2 Readout System

The contingencies for this section of costs assume 50% except for those components where we have a quote where we assume 30% or are otherwise noted.

1.1.2.1 SVX4 Readout ICs

1.1.2.1.1 Prototype Wafers

These are based on estimates from Ray Yarema. CDF and D0 will share the costs for 2 prototype runs. The first prototype run will cost a total of $116000 and the second run will cost a total of $250000. We've assigned one half of the cost to D0. The costs are fixed at the vendor so no contingency is assigned.

1.1.2.1.2 Production Wafers

These are based on estimates from Ray Yarema. The production mask cost is $150,000 which D0 and CDF split. We assume a 50% yield on the number of wafers/lot and a lot cost of $50,000. D0 then needs 8 lots (12000 chips). We also add in the wafer thinning, backplating, and dicing costs of $10,000. Folding these three costs in, each lot is $60,375.

1.1.2.1.3 Test Fixtures

Testing Fixtures are needed for wafer probing ($5000) as well as for stimulus board setups ($10,000).e being bought by SUNY Stonybrook and CINVESTAV. The funding for these are fixed costs in the NSF MRI budget so no contingency has been

1.1.2.1.4 Testing

There are two components in this cost:

1. Fixed costs incurred as part of Brown University's portion of the NSF MRI grant to assist in testing the chips amounting to $82,100. There is no contingency placed here.
2. Costs incurred from travel to LBL. We assume that one person will need to spend 3 months time full time there ($15,000) and there will be 5 other trips there at $2000 per trip. We use a 50% contingency on this number.

1.1.2.1.5 LBL Engineering

From cost estimate of Ray Yarema. Total engineering costs remaining are $294,280, D0's share is one half of this. D0 has already been charged $80,000 that is added to this number. We've taken 100% contingency on this number.

1.1.2.2 Hybrids

There are 4 types of hybrids: L0, L1, L2A, L2S. Each hybrid contains: bare substrate, fingers, passive components, AVX connector, and SVX4 chips (priced elsewhere). Also included in each hybrid is the cost for stuffing the bare components, attaching the AVX connector, attaching the SVX4 chips, and wirebonding the SVX4 chip to the hybrid substrate or finger. We have vendor quotes for the stuffing and wirebonding at $100 per unit that is added to the costs. Parts other than the chip total $20 per hybrid. All of the design and layout costs are assuming contracts with George Wolf for 3 iterations of 1 week of his time ($1500) totalling $4500 per type. Fixturing costs are those associated with the stuffing and wirebonding vendor to provide them for wirebonding and are assumed to be $3000 per type of hybrid.

1.1.2.2.1 Fingers

We are not using Fingers anymore so this cost has been zeroed out.

1.1.2.2.2 L0

We assume one prototype run with 25 hybrids. Most of the prototyping will be done with the L1 hybrids which are much more complex than these hybrids. There are a total of 144 of these production hybrids needed with 30% spares. The cost estimates are based on the L1 prototype costs. It is assumed that 3 L0 hybrids fit per wafer for a bare hybrid cost of $380 with $150 per hybrid in NRE cost. Stuffing and parts is $120 for a total of $650 per prototype. The production costs assume $230 per bare hybrid +$120 stuffing and parts for a total of $350. A generic $5000 is assumed to help test these devices.

1.1.2.2.3 L1

We assume 3 prototype runs with 25 prototypes each.
We have a quote from CPT to produce 25 prototype hybrids. In this quote, each bare hybrid is $500 and there is an NRE cost of $3750 ($150/per part) for a total of $650. The additional $120 per prototype for stuffing and parts makes the prototype cost $770. There are 72 hybrids needed for production and we assume 30% spares for a total of 100 hybrids produced. Here, based on quotes from CPT assuming 2 hybrids per wafer, we get a bare hybrid cost of $350 added to the $120 stuffing and parts cost gives a total of $470 per production part. Generic testing costs of $5000 are assumed.

1.1.2.2.4 L2-L5

This includes both the L2A and L2S hybrids. There are two types of hybrids, so two rounds of layout are needed. We assume 2 prototype runs of 20 parts each and scale the L1 prototype costs to determine this cost basis. Scaling the L1 hybrid size to the size of the L2A and L2S hybrids, we have assumed one bare hybrid per wafer for the prototypes, but assume 2 hybrids per wafer for production. Assuming an NRE cost per prototype hybrid of $200 ($4000 NRE/20 parts), $880 per bare hybrid, and $120 for stuffing and parts, we get $1200 per prototype. The total number of L2A+L2S hybrids needed is 672 and assume 30% spares (run2a experience) we get a total of 880 hybrids needed for production. The bare hybrid cost is estimated to be $380 with $120 stuffing and parts, we obtain $500 per production part. The fixturing costs assume $15000 which includes: wirebonding and testing fixtures for the stuffing houses ($10,000), costs associated with pulling pins from the AVX connectors ($2000), and storage boxes and supplies for the stuffing vendors ($3000). Since the bulk of the hybrids are L2A and L2S, the MRI fixed costs associated with hybrid testing are attached to these hybrids. The testing costs are: fixed costs from CSUFresno including personnel, travel, supplies totalling $58,575, fixed costs associated with Univ. of Kansas including testing equipment and engineering for $55,000, and supplies ($5000), shipping ($10000), and modifications to existing test stands ($10000) totalling $25000.

1.1.2.3 Cables

This category includes:
-analog flex cables needed for L0 (1.1.2.3.1)
-digital jumper cables for L0-L5 (1.1.2.3.2)
-Twisted pair cables from the jumper card to the adapter card (1.1.2.3.3)
-Clock cables bundled with the twisted pair cables (1.1.2.3.4)
-High mass cables from the adapter card to interface board (1.1.2.3.5)
-High voltage cables

from supplies to adapter cards and down to L0/L1 (1.1.2.3.6) -High voltage cables from supplies to interface boards for L2-L5 (1.1.2.3.7)

1.1.2.3.1 Analog Cables

Design costs – assume five rounds of layouts with an outside designer at $2000 per layout totalling $10,000.
Prototypes – assume 2 vendors supplying 20 prototypes each. Initial costs are based on estimates using old Run2a similar cables ($1000 per part).
Production – 144*2 cables are needed and 30% spares are assumed for 380 cables. Initial contacts with 2 vendors have given us the cost of $400 per part.
Fixturing – includes parts to allow probing of cables and measurements of mechanical properties, a generic $10,000 is assumed.
Testing - Includes costs for companies to make testing parts assuming $10K per vendor.

1.1.2.3.2 Digital Jumper Cables

The costs are assumed based on the KSU MOU for FY2002, see appendix.
Design – from MoU
Prototypes – Assume that Honeywell and Basic Electronics each make 40 cables, and one makes 60 more for a total of 140 cables. The cost is based on KSU MOU numbers assuming the IFT costs to Honeywell inclues NRE.
Production – Assume 888 parts with 30% spares. The cost per cable of $255 assumes: $200 per cable, $20 for ablation, and $35 to mount the connector.
Fixturing and testing costs assume a total of $15000, here the KSU MoU estimates $11000 and we include another $4000 in costs for La Tech.

1.1.2.3.3 Twisted Pair cables

Design – assume two sets of layouts needed at outside house for $1500 per layout.
Prototypes – 20 cables at twice the production costs (below).
Production – Assume 888 cables with 30% spares for a total of 1160 cables. Total $250 per cable: $50 quote from Omnetics assumes connector terminated with twisted pair cable, $100 for 3m of twisted pair cable from a quote from AXON, and $100 for termination on the junction card end.
Fixturing and Testing – Generic $3000 for each.

1.1.2.3.4 Clock cables

Assume we are completely replacing existing clock cables so we need 888 with 30% spares for 1160 parts. The cost of $25 per cable is based on Run2a experience.

1.1.2.3.5 High Mass Cables

Costs are estimated based on Run2a experience assuming 100 cables need to be replaced at $270 per cable.

1.1.2.3.6 High Voltage cables for L0/L1

Assume 216 + 30% spares for a total of 280 cables. $50/cable is WAG.

1.1.2.3.7 High Voltage cables for L2-L5

There are 672 assemblies needed with spares of 30% for a total of 880 cables. $25/cable is WAG.

1.1.2.4 Junction Card

KSU has taken responsibility for these and their cost estimates are shown in appendix below. There are two types of junction cards: L0/L1 and L2-L5.

1.1.2.4.1 Design and Layout

Assume two sets of engineering as costed in the KSU MoU Each set of engineering and layout will provide the 2 different junction card layouts.

1.1.2.4.2 Prototypes

The costs are per channel. For prototypes, we assume 3 prototype runs, each with 70 channels (30 L0/L1, 40 L2-L5). With 10 of L0/L1 prototypes with 3 channels per board: PCB, parts, assembly ($2K+$75/ch)=$4250. For L2-L5, there will be 10 prototype boards with 4 channels each ($2K+$75/ch)=$5000. There is $1000 for testing assumed with these prototypes.

1.1.2.4.3 Production

There are a total of 888 channels needed with 30% spares for 1160 channels. If we include all parts + fabrication for production, the cost is $75 per channel.

1.1.2.4.4 Fixturing

Costs based on KSU MOU

1.1.2.4.5 Testing

Generic amount assumed.

1.1.2.5 Purple Test Card

KSU has taken responsibility for these and their cost estimates are shown in appendix below.

1.1.2.5.1 Design and Layout

Assume one round of engineering as costed in the KSU MoU.

1.1.2.5.2 Prototypes

For prototypes, we assume 10 2 channel cards and 10 2 channel adapters for a total of 20 prototypes. The 2 channel cards cost $2k plus $250 per channel. The 2 channel adapters cost $500 + 100/channel.

1.1.2.5.3 Production

Assume 75 cards each with 2 channels and 50 spare channels for a total of 200 channels
The per channel cost of $250 is based on the KSU quotes for prototypes.

1.1.2.5.4 Fixturing

Costs based on KSU MOU

1.1.2.5.5 Testing

Generic amount assumed.

1.1.2.6 Adapter Cards

KSU has taken responsibility for these and their cost estimates are shown in appendix below. There are two types of adapter cards: 4 channel and 6 channel. The costs are accrued per channel.

1.1.2.6.1 Design and Layout
Assume two rounds of engineering as costed in the KSU MoU.

1.1.2.6.2 Prototypes
For prototypes, we assume 3 rounds each with 72 channels (4 6-channel boards and 16 4-channel boards). For each of the two types there is $2K + $240/channel.

1.1.2.6.3 Production
We need 888 channels plus 30% spares for a total of 1160 channels. Based on KSU MoU the production costs are $210 per channel.

1.1.2.6.4 Fixturing
Costs based on KSU MOU

1.1.2.6.5 Testing
A larger generic amount assumed.

1.1.2.7 Interface Boards

KSU has taken responsibility for these and their cost estimates are shown in appendix below.

1.1.2.7.1 Design and Layout
Assumes new layout of interface board and back plane with one round of engineering based on KSU MoU.

1.1.2.7.2 New J1 backplane
We will need 10 new backplanes. The cost of $3000 per backplane is based on Run2a costs.

1.1.2.7.3 Interface Board Modifications
Each board will be modified by electrical technicians. Estimates of time required for the changes imply a labor time cost of $25 per board.

1.1.2.7.4 Testing
A large generic amount is assumed.

1.1.2.7.5 Additional boards
10 additional boards will be built at a cost based on the Run2a cost.

.

1.1.2.8 DAQ Improvements

1.1.2.8.1 Sequencer
We assume that we don't need to replace the existing boards. However, since

the upstream electronics will be modified we allocate $30000 for possible improvements of the current sequencers which covers also the related infrastructure (crates, racks, cooling) and sequencer power supplies. The modifications may include, for example, input signal receivers. Some firmware modifications will be needed in any case.

1.1.2.8.2 VRB/VTM
We don't need to replace the existing boards. Since they have been extensively commissioned both at CDF and D0, chances of modifications are small. However, the total number of VRBs and VTMs is large, 120 boards of each type so we allocate $15000 for unforseen simple modifications and spares. Some firmware modifications may be needed.

1.1.2.8.3 VRBC
We assume that we don't need to replace the existing boards. The total number of VRBCs is 12. This board currently is not fully commissioned so chances of modifications are not negligible. We allocate $15000 for this purpose. Some firmware modifications may be needed.

1.1.2.8.4 Integration tests
A guess has been made to cover electronics parts, cooling boxes, VME racks and Power supplies, software upgrades, and firmware upgrades.

1.1.2.9 Power Supplies

1.1.2.9.1 Low Voltage
Assumes design and engineering costs at $10,000, one prototype costing $5000, 10 production supplies costing $7000 each and generic testing costing $5000.

1.1.2.9.2 High Voltage
We will buy enough equipment to implement Run2b detector with Run2a design and supplies. There will be 25 new motherboards needed at $2600 per board, 380 pods (assumes 10% spares) at $370 per pod, 2 VME crates at $10,000 per crate, and 12 fanout boxes at $2000 per box.

APPENDIX - KSU MOU on Datapath items

KSU FY2002 MOU Request: Oct 1, 2001 to Sept 30, 2002 12/20/01

A) Silicon Microstrip Detector Datapath
Scope: Design, fabricate new parts for Run 2b datapath.

Contact:	**Bolton, Demina, Reay, Sidwell, Stanton, Taylor**
People:	Bolton, Reay, Sidwell, Stanton, R. Taylor (KSU EDL) & EDL staff

1) Interface card maintenance (Run2a) & modification of spares for Run2b teststands

Quantity: 8 repairs, 8 modified for Run2b
assumes 8 need repair & checkout@ 8 hr each; 8 spares modified for Run2b @8hr each

		REQUEST from FNAL	Funds from KSU
Senior EE, R. Taylor (40hr @$60)		$2,400	
Parts		$500	
Technician (128 h @ $20)		$2,560	
shipping and insurance		$500	
	Subtotal	**$5,960**	

2) Active Adapter Cards
Quantity: 20 Prototypes (four 6-channel; 16- 4 channel)

Tasks: Design, fab, test, tweak new active adapter cards for Run2 b Test Stands

		REQUEST from FNAL	Funds from KSU
Engineering: R. Taylor (400 h @$60)		$24,000	
Layout: tech (160h@$35/h)		$5,600	
test fixtures, and test cards		$4,000	
Prototype Production: PCB, Parts, assembly ($2k+$240/chan)		$23,120	
Digital 4-channel, 1GHz oscilloscope			$16,200
SRS DG535 pulser			$4,400
Prototype Adapter card testing (function generator & pulser) (EE 40hr, tech 80hr)		$4,000	
Engineer trips to FNAL (3@$750)			$2,250
shipping & insurance		$200	
	Subtotal	**$60,920**	**$22,850**

3) Junction Cards

Quantity: 10 L1 prototypes w 3 channels each, 10 L2-5 prototypes with 4 channels

Tasks: Design, fab, test, passive prototype junction cards for Run 2b
Two types of cards are needed for L0,-L1, and L2-5.

Engineering: senior EE R Taylor (200 h @$60)		$12,000	
Layout (120hrs @$35)		$4,200	
test fixtures		$2,000	
L0-11 Prototypes: PCB, Parts, assembly ($2K+$75/chan)		$4,250	
L2-5 Prototypes: PCB, Parts, assembly ($2K+$75/chan)		$5,000	
Prototype Junction card testing		$1,000	
Engineer trips to FNAL (2@$750)			$1,500
shipping & insurance		$200	
	Subtotal	**$28,650**	**$1,500**

4) New interface card crate J1 backplane
Quantity: 1 prototype
Purpose: eliminate fuse panel
Tasks: Design, fab, test, passive J3 backplane for Run 2b teststands

Engineering and design (40hr@$60)		$2,400	
Layout (80hr @$35)		$2,800	
test fixtures		$1,000	
Production: PCB, Parts, assembly (1)		$4,000	
testing		$1,000	
Engineer trips to FNAL (1@$750)			$750
shipping & insurance (1% of value)		$100	
	Subtotal	**$11,300**	**$750**

4) Digital Jumper Cables for L0-L5
Assume cables have same pinout for L0,L1, and L2-L5; at least 4 lengths are required

L2-L5 50-cm prototypes(10):		
Prototypes: Honeywell	******* IFT	
Prototypes: Basic Electronics Inc, 10 short, 20 long		$3,531
Connectors		$500
Ablation masks &labor(Applied Laser Inc)		$2,640
L0-1 50cm prototype cables(10):		
Honeywell	IFT	
Basic electronics inc		$2,250
Ablation		$1,760
L2-L5 100-cm prototypes(20):		

Material - Cu-clad kapton for prototypes		$3,000	
Prototypes: Honeywell	******* IFT		
Prototypes: Basic Electronics Inc		$9,200	
Ablation		$2,640	
Connectors		$500	
<u>L0-L1 100-cm prototypes(20):</u>			
Prototypes: Honeywell	******* IFT		
Prototypes: Basic Electronics Inc		$6,644	
Ablation		$1,760	
Connectors		$500	
<u>L2-L5 cables for test stands (40 pieces):</u>			
Prototypes: Honeywell	******* IFT		
Prototypes: Basic Electronics Inc		$4,620	
Ablation		$1,760	
Connectors		$500	
Engineering (50hr @$60)		$3,000	
Layout (L1, L2-L5) 40hr @$35		$1,400	
Fixturing, and test boards		$4,000	
L1-L5 Testing(tech, 60hr@$20)		$1,200	
connector installation (40 hr, tech)		$800	
Shipping and Insurance		$1,000	
Subtotal		**$53,205**	**$0**
5) Test Cards for Test Stands (Purple card)			
Engineering and design (120hr @ $60)		$7,200	
drawings, schematic, layout (120hr@$35)		$4,200	
10 2-chan prototypes @$250/channel + $2k setup		$7,000	
connector adapter module (10@100+$500 setup)		$1,500	
fixtures for testing		$2,000	
Production of 75 two-chan cards @$250/chan	FY03		
test cards 1.5hr each @$20/hr	FY03		
		$21,900	**$0**
	<u>REQUEST from FNAL</u>		**<u>Funds from KSU</u>**
Total Request		**$181,935**	**$160,816**
<u>*** IFT (Interagency funds transfer)</u>**	**<u>IFT</u>**		
Honeywell FM&T, Kansas City			
L2-l5 development prototypes 50cm (10)		$5,970	
L2-l5 development prototypes 100cm (10)		$6,632	
L2-L5 cables for test stands, 100cm (20)		$6,166	
L0-L1 development prototypes 50cm(10)		$4,360	

L0-L1 development prototypes 100cm(20)	$6,122
Total Interagency transfer	**$29,250**

Basis Of Estimate –M&S line 1.1.3 Mechanical Design and Fabrication

The contingencies for this section of costs assume 50% except for those components where we have less experience and assign a contingency of 60%. Those areas where we have no technical experience a contingency of 100% has been assumed.

1.1.3.1 Layer 0

1.1.3.1.1 Support Structure Design

The University of Washington carries the main responsibility for the design of the layer 0 and layer 1 support structure. Most of the design work is based at Washington. The cost for the design for the layer 0 support structure is estimated at $76,800:
620 hours of senior engineering
224 hours of junior engineering
160 hours of machine shop time at $10,600
Materials (carbon fiber, pyrolitic graphite, cooling tubes) at $11,750
Total $76,800

1.1.3.1.2 Prototype Structural Analysis

Stringent constraints are imposed on the layer 0 support structure both in terms of mechanical stability and heat transfer. A cost of $20,000 is associated with performing the structural analysis based on 200 hours of senior engineering time.
Total: $20,000

1.1.3.1.3 Assembly Fixtures

One set of assembly fixtures is foreseen for assembling the layer 0 support structure at a cost of $36,500:
80 hours of senior engineering time
80 hours of junior engineering time
80 hours of machine shop time,
Materials: $1000
Total: $36,500

1.1.3.1.4 Support Structure Fabrication Tooling Design

The design for tooling for fabrication of the support structure for layer 0 is based on:
40 hours of senior engineering time
16 hours of junior engineering time
80 hours of machine shop time
20 hours of junior engineering for prototyping
20 hours of senior engineering time for redesign of prototypes
80 hours of junior engineering time for redesign of prototypes and final drawings
Total: $13,100

1.1.3.1.5 Support Structure Tooling

The production of the tooling for the support structure is estimated at:
Junior engineering time: 16 hours
Machine shop time: 240 hours

Materials: $1000
Total: $17,500

1.1.3.1.6 Support Structure Fabrication

Because of the difficulty in fabricating the support structure it is assumed that the first support structure to be built will be built twice. The detector calls for two support structures for each half of the silicon detector, north and south. The cost breaks down as:
140 hours of senior engineering at $16,000
160 hours of machine shop time at $11,000
Materials at $15,000
Total $42,000

1.1.3.2 Layer 1

1.1.3.2.1 Support Structure Design

The cost for the design for the layer 0 support structure is estimated at $63,700:
500 hours of senior engineering
176 hours of junior engineering
120 hours of machine shop time at $7,950
Materials (carbon fiber, pyrolitic graphite, cooling tubes) at $10,350
Total $63,700

1.1.3.2.2 Prototype Structural Analysis

Stringent constraints are imposed on the layer 0 support structure both in terms of mechanical stability and heat transfer. A cost of $20,000 is associated with performing the structural analysis based on 200 hours of senior engineering time.
Total: $20,000

1.1.3.2.3 Assembly Fixtures

One set of assembly fixtures is foreseen for assembling the layer 0 support structure at a cost of $31,500 based:
80 hours of senior engineering time
80 hours of junior engineering time
80 hours of machine shop time
Materials: $1000.
Total: $31,500

1.1.3.2.4 Support Structure Fabrication Tooling Design

The design for tooling for fabrication of the support structure for layer 0 is based on:
40 hours of senior engineering time
16 hours of junior engineering time
80 hours of machine shop time
20 hours of junior engineering for prototyping
20 hours of senior engineering time for redesign of prototypes
80 hours of junior engineering time for redesign of prototypes and final drawings
Total: $13,100

1.1.3.2.5 Support Structure Tooling
The production of the tooling for the support structure is estimated at:
Junior engineering time: 16 hours
Machine shop time: 240 hours
Materials: $1000
Total: $17,500

1.1.3.2.6 Support Structure Fabrication
Because of the difficulty in fabricating the support structure it is assumed that two sets of support structure will be built. The detector calls for two support structures for each half of the silicon detector, north and south. The cost breaks down as:
160 hours of senior engineering
28 hours of junior engineering
120 hours of machine shop time at $7,950
Materials at $26,000 (with $15,000 for pyrolitic graphite)
Total $48,000

1.1.3.3 Layer 0-1 Assembly

1.1.3.3.1 Support Membranes
The support membranes support the inner layer structures at z=0 and z=630mm, and provide for the connection with the outer layers. The production of 5 support membranes is foreseen at $3000 per membrane. The total cost breaks down as:
40 hours of senior engineering
80 hours of machine shop time
Materials at $1,000
Total $15,000

1.1.3.3.2 Layer 0-1 Assembly Fixturing
The costs are mainly in engineering for the design for 5 sets of assembly fixtures
80 hours of senior engineering
96 hours of junior engineering
80 hours of machine shop time at $5,300
Materials at $500
Total $14,000

1.1.3.3.3 Layer 0-1 Installation Tooling
The tooling cost is also based on 5 sets of tooling needed:
48 hours of senior engineering
100 hours of junior engineering
40 hours of machine shop time at $2,650
Materials at $500
Total $11,500

1.1.3.3.4 Travel
This item covers travel by the engineers from the Engineering Department of the University of Washington to travel to Fermilab during the assembly of the structures. Ten trips are foreseen at $1000 per trip.
Total $10,000

1.1.3.4 Layer 2-5 Stave and Module Parts
The cost estimate for the outer layers is based largely on the experience we have gained with the Run2a silicon detector. Most of the time estimates for machine shop time are directly derived from Run2a.

1.1.3.4.1 Cooling Tubes
A total of 205 cooling tubes are required for the staves of the new detectors for a total cost of $18,656. The cost elements are:
Five fixtures at $1,200 each
PEEK tubing, 1200 ft. at $3.38 per foot (quote)
Nozzles, 410 at $10 a piece (quote)
Leak checking for both halves of the silicon detector at $2000 each
Connecting tubes, 1250 ft. at $0.40 per foot (quote)
Total: $18,656.

1.1.3.4.2 Stave Cores
The cost for stave cores breaks down as:
Four fixtures at $1,200 each
Carbon fiber, 25 lbs at $1,200 per lbs
Aluminized mylar, 250 sq. ft, at $3.00 per square foot
Kapton, 250 sq. ft, at $3.00 per square foot
Total: 36,300

1.1.3.4.3 Stave Shells
Five fixtures at $1,200 each
Carbon fiber, 52 lbs. at $1,000 per lbs.
Total $58,000

1.1.3.4.4 Component Fixturing
This element has been eliminated during subsequent design

1.1.3.4.5 Readout Module Assembly
The design calls for three different readout-modules, 10-10, 10-20 and 20-20 modules. To have adequate production capacity, four modules of each type are foreseen. The cost is broken down as:
Machine shop time at 400 hours
Materials at $1,200 per assembly for 12 assemblies
Total: $34,400

1.1.3.4.6 Wirebonding Fixtures
A total of six wirebonding fixtures are foreseen, with a cost breakdown:
Machine shop time at 200 hours

Materials at $200 per fixture
Total: $11,200

1.1.3.4.7 Stave Assembly Fixtures

A total of eight stave assembly fixtures are foreseen, with a cost breakdown:
Machine shop time: 400 hours
Materials at $250 per fixture
Total: $22,000

1.1.3.4.8 Cover Gluing Fixture

After the modules have been mounted onto a stave core, the stave will be covered with a carbon fiber structure to protect the wirebond and guide the digital jumper cable. Fixtures will be needed to mount the covers. A total of four fixtures are foreseen with a cost breakdown:
Machine shop time: 96 hours
Materials at $400 per fixture
Total: $6,400

1.1.3.4.9 Silicon Positioning Bulkhead

The design calls for three two positioning bulkheads for each half of the silicon detector, one at z=0 and one at z=630mm. The cost for the four bulkheads is broken down as:
Machine shop time: 400 hours
Materials for fixtures at $250 per bulkhead
Carbon fiber, 3.2 lbs, at $1,200 per lbs
Positioning rings, 4 at $1,350
Total: $30,240

1.1.3.4.10 Support Cylinders

Two support cylinders are needed, one for each half, to hold the silicon detector. The estimate is based on producing four cylinders. Note that the experiment has extensive experience for producing carbon fiber cylinders gained from building the cylinders for the fiber tracker for Run2a. The cost is broken down as:
Mandrels, 2, at $7,500 each
Machine shop time at 40 hours
Materials for fixtures for two sets at $1,000 per set
Carbon fiber, 17 lbs., at $1,200 per lbs.
Total: $39,400

1.1.3.4.11 Extension Cylinders

Only two extensions cylinders are needed for the experiment but four are costed with a breakdown:
Machine shop time: 40 hours
Materials for fixtures at $250 per cylinder
Carbon fiber, 6 lbs, at $1,200 per lbs
Positioning rings, 4 at $1,350
Total: $17,600

1.1.3.4.12 North – South Mating Fixture

Machine shop time: 60 hours

Materials for fixtures at $1,000
Total: $4,000

1.1.3.4.13 Rotating Fixture
A rotating fixture is needed to rotate the support cylinder and bulkheads in which the staves are mounted. Though only one is needed, two are costed:
Machine shop time: 60 hours
Materials for fixtures at $1,000 each
Total: $8,700

1.1.3.4.14 Stave Installation Fixture
Only one stave installation fixture is needed but two are costed with a breakdown:
Machine shop time: 60 hours
Materials for fixtures at $3,500 per fixture
Total: $10,000

1.1.3.4.15 Hardware and Miscellaneous Components
This covers various miscellaneous components, like epoxies, special screws, additional fixtures, etc., for a total cost of $30,000.

1.1.3.5 Coolant and Anchoring Bulkhead

Two coolant manifolds are needed for the distribution of the coolant to the different staves and inner layer detectors. The cost estimate assumes four coolant bulkheads will be built.

1.1.3.5.1 Procurement of Sub-Assemblies
It is anticipated that the coolant manifolds will be composed of subassemblies. Eight subassemblies are foreseen with an associated cost of $6,700 per subassembly.

1.1.3.5.2 Assembly Fixtures
One set of fixtures is needed for the coolant bulkhead fabrication at $2,500.

1.1.3.6 Junction Card Mountings

A special mounting structure is needed to hold the junction cards. Two such sets are needed for the north and south side of the detector. The cost is broken down as:
Machine shop time at 60 hours
Materials for assembly fixture at $1,000
Carbon fiber, 20 lbs. at $100 per lbs
Total: $6,000

1.1.3.7 Adhesives

1.1.3.7.1 Silver Epoxy
Materials: 400 packages at $11 per package (quote)

1.1.3.7.2 High Purity Epoxy and Testing
Five gallons of epoxy at $300 per gallon (quote)

1.1.3.7.3 Structural Adhesives
Five gallons of adhesive at $200 per gallon (quote)
.

1.1.3.8 Cooling System

1.1.3.8.1 Chillers for -20 C Operation
Two chillers for lowering the coolant temperature from the -15 C operating temperature of the Run2a silicon detector to -20 C for operation during Run2b are included in the cost estimate.
Equipment: $15,000 per chiller (quote)
Total: $30,000

1.1.3.8.2 Vacuum Insulated Piping
Materials: 300 feet at $17 per foot (quote)
Total: $5,100

1.1.3.8.3 Vacuum Equipment
The cooling system is operated at sub-atmospheric pressure. Two vacuum pumps are needed at $6000 each.
Equipment: $6000
Total $12,000

1.1.3.8.4 Vessels
Although only two vessels are needed for the cooling system, three are costed at a total cost of $6,000.

1.1.3.8.5 Filters
Four filters at $100 a piece are needed.
Total $400

1.1.3.8.6 Deionization Equipment
Two sets of deionization equipment is needed at $250 per set.

1.1.3.8.7 Instrumentation
Gauges, 48, at $200 a piece
Total $9,600

1.1.3.8.8 System Test at SiDet

A full system test of a small fraction of the total number of readout channels is foreseen at SiDet. The cost will include technician time, machine shop charges, gauges, etc. to set up the cooling system at SiDet at a total estimated cost of $20,000.

1.1.3.8.9 Welding, Pipe Fitting
The work estimated for welding and pipefitting to integrated the new system with the Run2a silicon system is estimated at $5,000.

1.1.3.9 Dry Gas Purge
The upgrade of the dry gas purge consists of an additional compressor, additional gas storage, upgrade to the gas bottle trailer and two sets of regular maintenance. Based on quotes the cost breaks down as given below.

1.1.3.9.1 Additional Compressor
Equipment: $40,000
Total: $40,000

1.1.3.9.2 Additional Gas Storage
Equipment: $10,000
Total: $10,000

1.1.3.9.3 Compressor Maintenance
One lot: $15,000
Total: $30,000

1.1.3.9.4 Tube Trailer Maintenance
One lot: $6,000
Total: $6,000

1.1.3.10 Interlocks and Safety Monitors
The upgrade of the interlock system consists of the replacement of the PLC system, one set of readout modules and the necessary spares.

1.1.3.10.1 Replacement PLC System
Equipment: $60,000
Total: $60,000

1.1.3.10.2 Readout Modules
One lot: $70,000
Total: $70,000

1.1.3.10.3 Spares

One lot: $30,000
Total: $30,000

1.1.3.11 Beam Tube

A new drilled beam tube is needed for an estimated cost, based on a quote, is $125,000.

1.1.3.12 Capital Equipment at SiDet

Project contribution to the purchase of a new Coordinate Measuring Machine at $35,000, based on an actual purchase.

Basis Of Estimate –M&S line 1.1.4 Detector Assembly and Testing

1.1.4.1 Refurbished Test Stands

There will be 15 standalone test stands. It is assumed that the current teststand SASEQs will be refurbished for these stands. A contingency of 25% is assumed as these stands have been built before.

1.1.4.1.1 PCs

Each test stand will need to upgrade their PC to handle the new software requirements. Each PC is asuumed to cost $3000 with the necessary video equipment and disk based on current market prices.
Total $45,000

1.1.4.1.2 Infrastructure

This includes new shelving fixtures and cabling ($500), SASEQ reprogramming, and low voltage supplies ($1500).
Total: $30,000

1.1.4.2 Hybrid burn-in test stand

There will be 2 hybrid burn-in stands at Fermilab, each capable of testing 16 hybrids at one time. These test stands will be refurbished from the test stands used in Run2a.

1.1.4.2.1 PCs

Market price for a PC with the correct video and disk capabilities needed to run the new software is $3000 per PC. A 25% contingency is assumed.
Total $6,000

1.1.4.2.2 SASEQs

There are a total of 16 saseqs needed for these stands with 4 spares making a total number of 20 to be purchased. Based on a cost quote for new SASEQs, the price is $1315 per unit. A contingency of 30% is assumed because we have a quote.
Total: $26,300

1.1.4.2.3 Infrastructure

This includes new shelving fixtures and cabling ($500), SASEQ reprogramming, and low voltage supplies ($1500).
Total: $4,000

1.1.4.3 Module burn-in test stand

There will be two burn-in test stands for long-term tests of the silicon modules. Each setup will be able to readout 32 hybrids at a time. The readout module used is a Stand-Alone Sequencer (SaSeq) which has two readout channels per module.

1.1.4.3.1 PCs

Equipment, two PC's at $3000 each
Total $6,000

1.1.4.3.2 Crate Power Supply
A crate and power supply for the VME crate, based on quotes, for the two stands
Total $4,650

1.1.4.3.3 Bit 3
Readout interface module to transfer data from the VME backplane to the PC. One module each is needed for each burn-in stand. This is a commercial product and cost is based on quote.
Total $6,800

1.1.4.3.4 SaSeq
A total of 40 Stand-Alone sequencers are needed for the module burn-in test stand at $1,315 each. A quote has been received for production of these boards.
Total: $52,600

1.1.4.3.5 Low Voltage SVX4
Two sets of commercial low voltage power supplies to power the SVX4 chips, based on a quote
Total: $2,400

1.1.4.3.6 Crate Power Supply
Two sets of power supplies for to power the various readout components, based on quotes.
Total: $6,000

1.1.4.3.7 High Voltage Modules
Ten high voltage motherboards are needed to provide the bias power to the silicon sensors. Each motherboard can hold eight high voltage pods. Quotes have been received to build these motherboards, which are identical to the ones used in Run1 and Run2a. Total: $24,000

1.1.4.3.8 High Voltage Pods
To populate the ten high voltage motherboards, each holding eight slots, a total of eighty high voltage pods are needed. Quotes have been received to build these motherboards, which are identical to the ones used in Run1 and Run2a.
Total: $32,000

1.1.4.3.9 J2 Backplane
For the two readout crates a new J2 backplane is needed, each at a cost of $600. The backplanes are identical to the Run2a ones.
Total: $1,200

1.1.4.3.10 Fans, Chillers
Fans and chillers to operate the electronics and the silicon sensors.
Total: $2,000

1.1.4.4 Cooling for test stands

This assumes two chillers are needed for the module burn-in stands, each costed from quotes at $13,650. Since there might be price fluctuations or need for another chiller, a 50% contingency is assumed.
Total: $27,300.

1.1.4.5 Test stand spare parts

This includes any mechanical infrastructure extra needs, extra purple cards, cables, sequencers, computer supplies or software, laser stand setups, etc. This is a generic amount with only a 25% contingency as it is spare parts.
Total: $20,000

1.1.4.6 Dry Boxes

There will be 3 dry boxes purchased each at $3000 based on quotes from Run2a
Total: $ 9,000

1.1.4.7 Hybrid Boxes

We will need 400 boxes similar to those made for Run2a. Each of those boxes is priced at $50 based on Run2a costs. Since some of the boxes will be refurbished from Run2a, only a 30% contingency is assumed.
Total: $20,000

1.1.4.8 L0 Module boxes

An initial design was made and the materials and machining time were estimated. It looks like 1 hour of machining and about $30 for materials, assume $100 per box. Given the number of L0 modules, we need 80 boxes. A general 50% contingency is assumed.
Total: $8,000

1.1.4.9 L1 Module boxes

An initial design was made and the materials and machining time were estimated. It looks like 1 hour of machining and about $30 for materials, assume $100 per box. Given the number of L1 modules, we need 80 boxes. A general 50% contingency is assumed.
Total: $8,000

1.1.4.10 10/10 Module boxes

An initial design was made and the materials and machining time were estimated. It looks like 1 hour of machining and about $30 for materials, assume $100 per box. Given the number of 10/10 modules, we need 90 boxes. A general 50% contingency is assumed.
Total: $9,000.

1.1.4.11 20/20 Module boxes

An initial design was made and the materials and machining time were estimated. It looks like 1 hour of machining and about $30 for materials, assume $100 per box. Given the number of 10/20 and 20/20 modules, we need 150 boxes (one half the total number). A general 50% contingency is assumed.
Total: $15,000.

1.1.4.12 Commercial Software Licenses

These are the software licenses for windows products, exceed, and database management. Assume that 20 sets of licenses are needed each at $1000. A 25% contingency is assumed.
Total: $20,000.

1.1.4.13 Full System Test

This is a generic amount to cover: cooling infrastructure and tubes including a chiller if needed ($15000), fixtures to hold staves and dark boxes, and extra readout and DAQ modules if needed. Since this is not fulling planned out yet, a 50% contingency is assumed.
Total: $30,000.

1.1.4.14 Stave cooling test

This is a generic amount to cover: cooling infrastructure and tubes, fixtures to hold staves and dark boxes ($10000), and extra readout and DAQ modules if needed ($10000). Since this is not fulling planned out yet, a 50% contingency is assumed.
Total: $30,000.

Basis Of Estimate –M&S line 1.1.5 Monitoring

1.1.5.1 Radiation monitoring

Assume 30% contingency as all of the stuff has been quoted and built before for Run2a

1.1.5.1.1 Si diodes

Based on Run2a costs for equivalent number of channels
Total $3,000

1.1.5.1.2 Si diode hybrids

Based on Run2a costs for equivalent number of channels
Total: $30,000

1.1.5.1.3 Low mass cables

Based on Run2a costs for equivalent number of channels
Total: $5,000

1.1.5.1.4 High mass cables

Based on Run2a costs for equivalent number of
Total: $2,000

1.1.5.1.5 Readout electronics

Based on Run2a costs for equivalent number of channels
Total: $3,000

1.1.5.2 Temperature Monitoring

Assumes you need to purchase 1553 or other readout modules at $20,000 based on Run2a prices and you pay for engineering and technician time at RICE for a total of $20,000
A contingency of 50% is assumed as system isn't totalling designed yet.
Total: $40,000.

Basis Of Estimate –M&S line 1.1.6 Installation

1.1.7.1 Transportation cart

1 cart will be assembled assuming fixturing costs based on Run2a detector. Since this was built before, a contingency of 25% is assumed.
Total $10,000

1.1.7.2 Installation trolley

1 Trolley will be assembled assuming the fixturing costs based on the same item type for the Run2a detector. Designs do not exist yet so a 50% contingency is assumed.
Total: $30,000.

1.1.7.3 Cooling and dry gas

Based on the Run2a amounts used and the current market prices. A 50% contingency is assumed.
Total: $50,000.

Basis Of Estimate –M&S line 1.1.7 Computing

1.1.7.1 CPUs

Assume 14 replacement CPUs purchased at the expected market price of $3000 per CPU. A contingency of 25% is assumed based on market variations.
Total $3,000

1.1.7.2 Laptops

Assumes market price for laptop of $3000 and 3 laptops purchased. For contingency a nominal amount of 10% is assumed.
Total: $9,000.

1.1.7.3 QA Database

From the UIC fixed costs associated with the MRI. This includes personnel and overhead on personnel as well as a server computer. No contingency is assumed.
Total: $50,000.