SiD DBD Costs

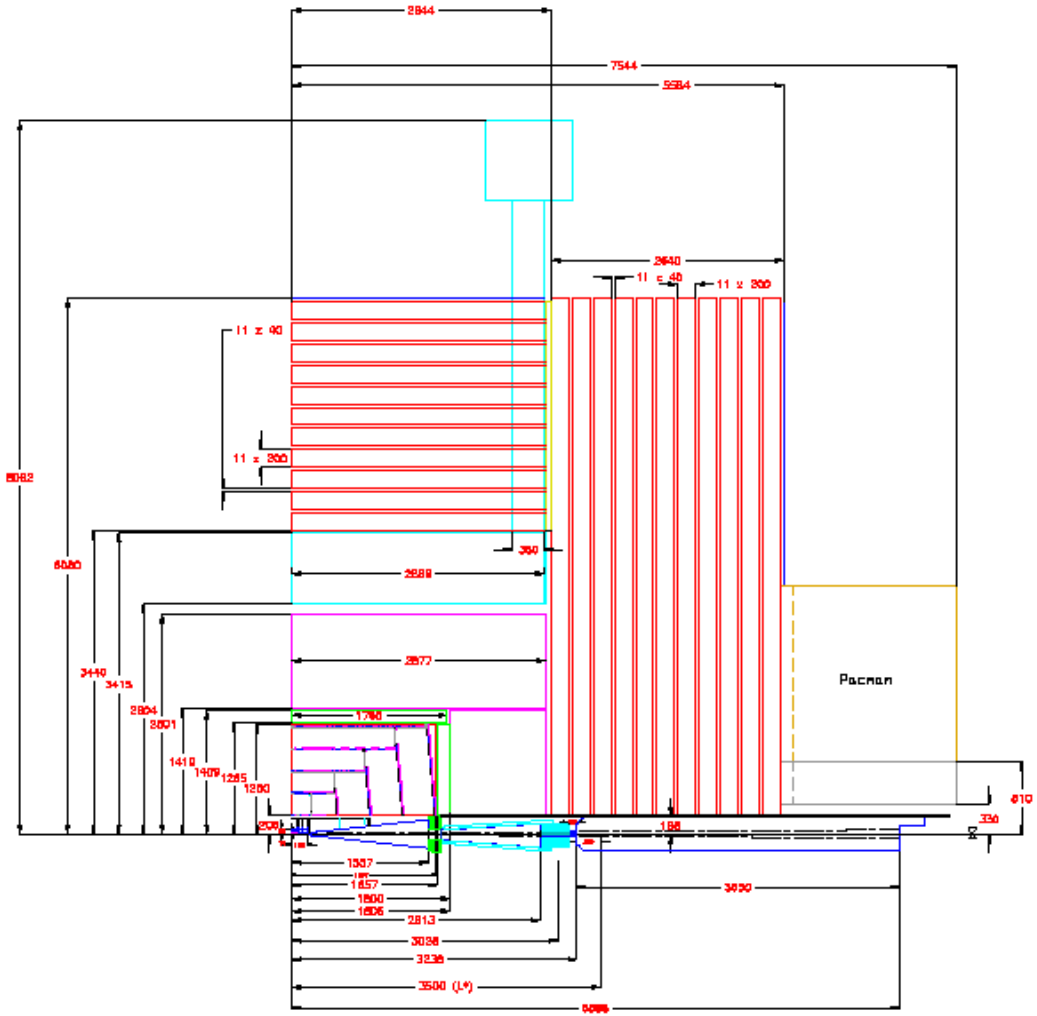
M. Breidenbach

1.1.3	Tracker	1 each	@CF=Tracker	15,446,950	5,869,383	11,473,252	4,015,638	36,805,223
1.1.3.1	Tracker ED&I	1 each		0	0	7,761,320	2,716,462	10,477,782
1.1.3.1.1	Mechanical Engineer	20 man year		0	0	140,000	49,000	3,780,000
1.1.3.1.2	Mechanical Designer	10 man year		0	0	91,520	32,032	1,235,520
1.1.3.1.3	Mechanical Tech	40 man year	WAG	0	0	101,153	35,404	5,462,262
1.1.3.2	Tracker Mechanics	1 each		2,900,000	1,375,000	1,200,325	420,114	5,895,439
1.1.3.2.1	Tracker Space Frame, Barrel	1 lot		1,250,000	625,000	0	0	1,875,000
1.1.3.2.2	Outer Endcap Frame[0]	2 lot		250,000	125,000	0	0	750,000
1.1.3.2.3	Tracker Cooling	1 lot		150,000	150,000	0	0	300,000
1.1.3.2.4	Tracker Alignment System	1 each		1,000,000	350,000	0	0	1,350,000
1.1.3.2.5	Mechanical Engineer	1 man year		0	0	140,000	49,000	567,000
1.1.3.2.6	Mechanical Designer	3 man year		0	0	91,520	32,032	370,656
1.1.3.2.7	Mechanical Tech	5 man year		0	0	101,153	35,404	682,783
1.1.3.3	Tracker Silicon Detectors	1 each		11,546,950	4,244,383	2,511,607	879,063	19,182,003
1.1.3.3.1	Barrel	1 each		6,340,450	2,341,108	1,531,015	535,855	10,748,428
1.1.3.3.1.1	Tracker Barrel Module	8,130 each	Parametric	665	248	188	66	9,487,528
1.1.3.3.1.1.1	Tracker Silicon	0.01 Sq.m.		30,000	10,500	0	0	405
1.1.3.3.1.1.2	Tracker Module Mechanics Barrel	1 each		65	23	0	0	88
1.1.3.3.1.1.3	Tracker KPiX	1 each		100	35	0	0	270
1.1.3.3.1.1.4	Tracker Cable	1 each		100	50	0	0	150
1.1.3.3.1.1.5	Mechanical Tech	2 man hour		0	0	54	19	145
1.1.3.3.1.1.6	Procurement Officer	1.5 man hour		0	0	54	19	109
1.1.3.3.1.2	Level 1 Concentrator, Tracker	467 each		2,000	700	0	0	1,260,900
1.1.3.3.1.3	Level 2 Concentrator, Tracker	1 each		0	0	0	0	0
1.1.3.3.2	Endcaps	2 each		2,603,250	951,638	490,296	171,604	8,433,575
1.1.3.4	Tracker Integration	1 lot		1,000,000	250,000	0	0	1,250,000

Outline

- The Optimization Process
- CLIC Coordination on costs
- Open Issues
- Cost Sensitivity to selected "commodity" inputs.
- Results

Consistent Dimensions



CLIC ILD Agreed Unit Costs

NOTE: In this version of the table, values have been converted to US dollars, using the very approximate conversion factors CHF = 1 US dollar, 1 Euro = 1.5 US dollar

	agreed unit cost	agreed error margin
Tungsten for HCal [1]	105 $ / kg	45 $ / kg
Tungsten for ECal [2]	180 $ / kg	75 $ / kg
Steel for Yoke (semi-product) [3]	1000 $ / ton	300 $ / ton
Steel for Yoke (final product, including assembly supervision) [4]	6000 $ / ton	2000 $ / ton
Stainless Steel for HCal [5]	4500 $ / ton	1000 $ / ton
Silicon Detector [6]	6 $ / cm^2	3 $ / cm^2

[1] from CERN WHCAL prototype (2010) - standard plate sizes, assembly by construction; purity W>90%, paramagnetic with μ<=1.01 dimensions and roughness <±0.2mm, flatness <±0.5 mm

[2] from Catherine Clerc and Marc Anduze, consistent with data from Marty Breidenbach

[3] semi – product, laminated steel beams

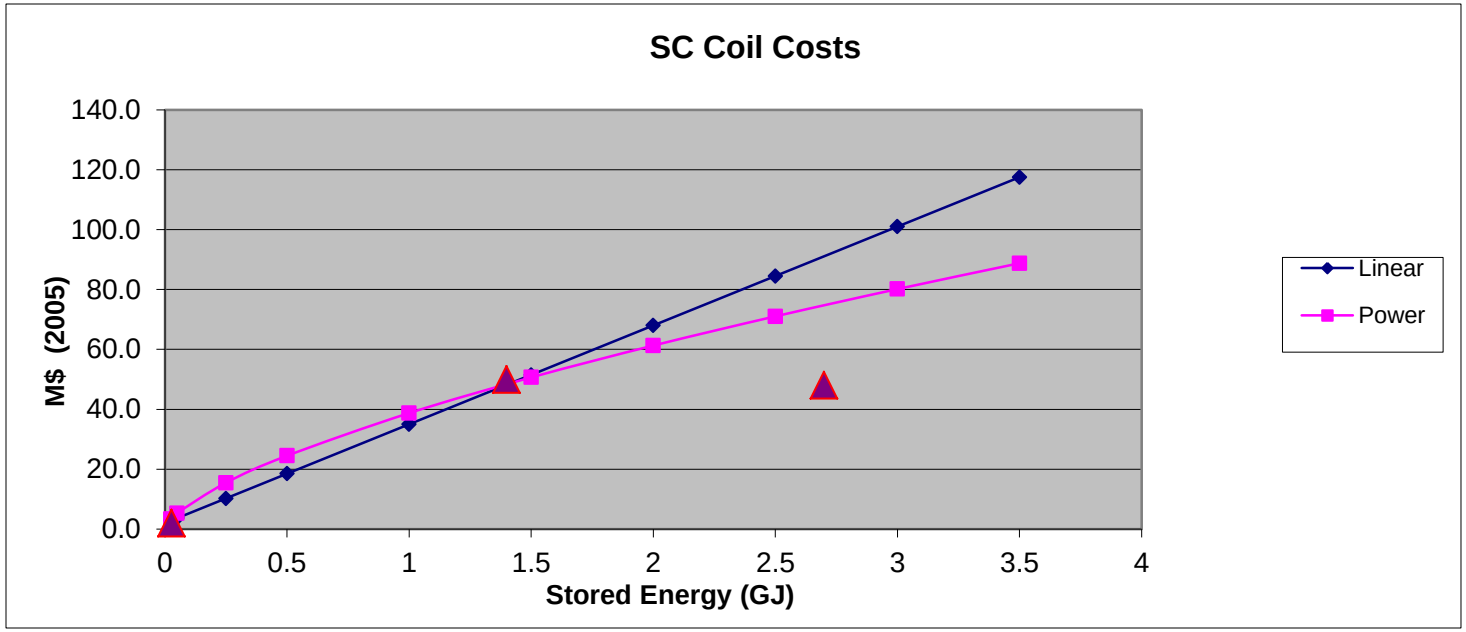
[4] The number SiD uses (7 $/kg) is for steel fabricated into the full detector, for example including fasteners and trial assembly, delivery, and final assembly engineering supervision. On the other hand, CMS has been built using a contract - today considered unlikely to be obtained again - of just under 4000 CHF/kg with similar specifications.

[5] stainless steel grade SS304 (CERN catalog, September 2010), and in close agreement with values obtained by Marty Breidenbach

[6] based on discussions with Hamamatsu, September 2010

Superconducting Solenoid

- Superconducting coils of this scale are difficult to estimate.
- Usual practice is to scale by stored energy, either a + bE or
- $cE^{0.66}$
- Attempt was made to extract the CMS cost for cold mass and cryostat - ~$48M.
- Obtained industrial estimate for SiD coil; ~same cost; but ½ the stored energy!



Superconducting Coil, continued

- We have chosen to be conservative, and are using the linear fit to Babar at the low end and the industrial estimate to get the slope.
- SiD is pursuing R&D on an advanced conductor that would be significantly simpler than the CMS conductor.
- Extensive discussions with ILC Detector Cost Group and CLIC.
- Conclusion:
  - ILD will stay with "in house" construction (CERN, Saclay, other)
  - SiD will stay with industrial production to a performance specification.
  - ILD has lower cost, "owns" the risk.
  - SiD has higher cost, pays industry to take some risk.
  - Difference hard to quantify because ILD does not include vacuum vessel with solenoid, perhaps $20M.

Parametric Model

- Self consistent Excel model of SiD
  - e.g. tracking layers and disks adjusted to fit allocated space
  - Calorimeters adjusted to nest properly with the tracker
  - Solenoid is adjusted for its radius and field
  - Iron is adjusted to return the flux.
- Fundamental parameters can be varied:
  - e.g Tracker radius and aspect ratio; N layers
  - Calorimeter N layers, thickness, materials, gaps
- Costs calculated for each system:
  - Cost driving component counts are calculated
    - e.g. tungsten plate area, silicon detectors, and KPiX for the EMCal
  - Model has cost tables for these M&S items and associated tech labor in hours
  - Costs that are ~fixed, e.g. engineering or fixturing, are imported from the Work Breakdown Structure.
- Macros allow easy variation of parameters to calculate cost derivatives.

Work Breakdown Structure

- Hierarchical structure breaking down SiD to "recognizable and understandable" units.
- Separate tables for purchased M&S and labor.
- Contingencies for each item, propagated through the WBS.
- Cost are estimated in 2008 US$.
- Labor both costed in $ and summed by man-years.
- Labor is estimated in ~50 different types, e.g. Project Engineer, plumber, iron worker – and condensed to the ILC categories Engineering, Technical, and Administrative.
- The "ILC" style cost is defined here as the base M&S cost without contingencies, plus the labor in man-years in the 3 categories.

- WBS agrees with parametric costing at few % level. WBS is the base for cost numbers shown here.

Open Issues

- VXD Technology – ok to delay
- HCal Detector Technology - costs uncertain
- Muon System costing – extremely new!!

SiD w New Unit Costs (4.5 Λ Hcal)

ILC Costs

		M&S Base (M$)	M&S Contingency (M$)	Engineering (MY)	Technical (MY)	Administrative (MY)
1.1.1	Beamline Systems	3.7	1.4	4.0	10.0	
1.1.2	VXD	2.8	2.0	8.0	13.2	
1.1.3	Tracker	18.5	7.0	24.0	53.2	
1.1.4	EMCal	104.8	47.1	13.0	288.0	
1.1.5	Hcal	51.2	23.6	13.0	28.1	
1.1.6	Muon Sys	8.3	3.0	5.0	22.1	
1.1.7	Electronics	4.9	1.6	44.1	41.7	
1.1.8	Magnet	115.7	39.7	28.3	11.8	
1.1.9	Installation	4.1	1.1	4.5	46.0	
1.1.10	Management	0.9	0.2	42.0	18.0	30.0
Totals		314.9	126.7	186.0	532.1	30.0

Cost Systems

- US:
  - Cost everything!
  - Convert labor years to $$
- Europe:
  - Contingency uncertain, "time is contingency".
  - Usually labor not included.
  - Escalation usually not estimated.

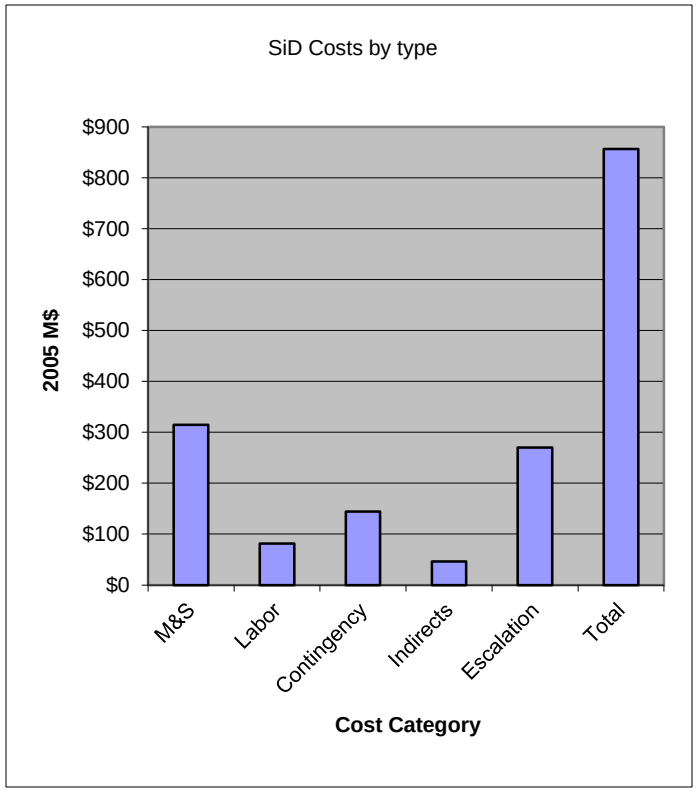
Cost Systems

	M&S		Labor	Totals
Base	$315		$81	$396
Contingency	$127		$18	$144
Total	$442		$99	$540
Indirect rates	0.06		0.20	
Indirects	$26		$20	$46
Totals w indirects	$468		$119	$587
Total in FYXXXX M$		2008		**586.7**
Start Year	2016			
Construction Duration	6	years		
Inflation	1.035	per year.		
Factor	1.460			
Total Escalation				269.9
Total, TYM$				***856.6***

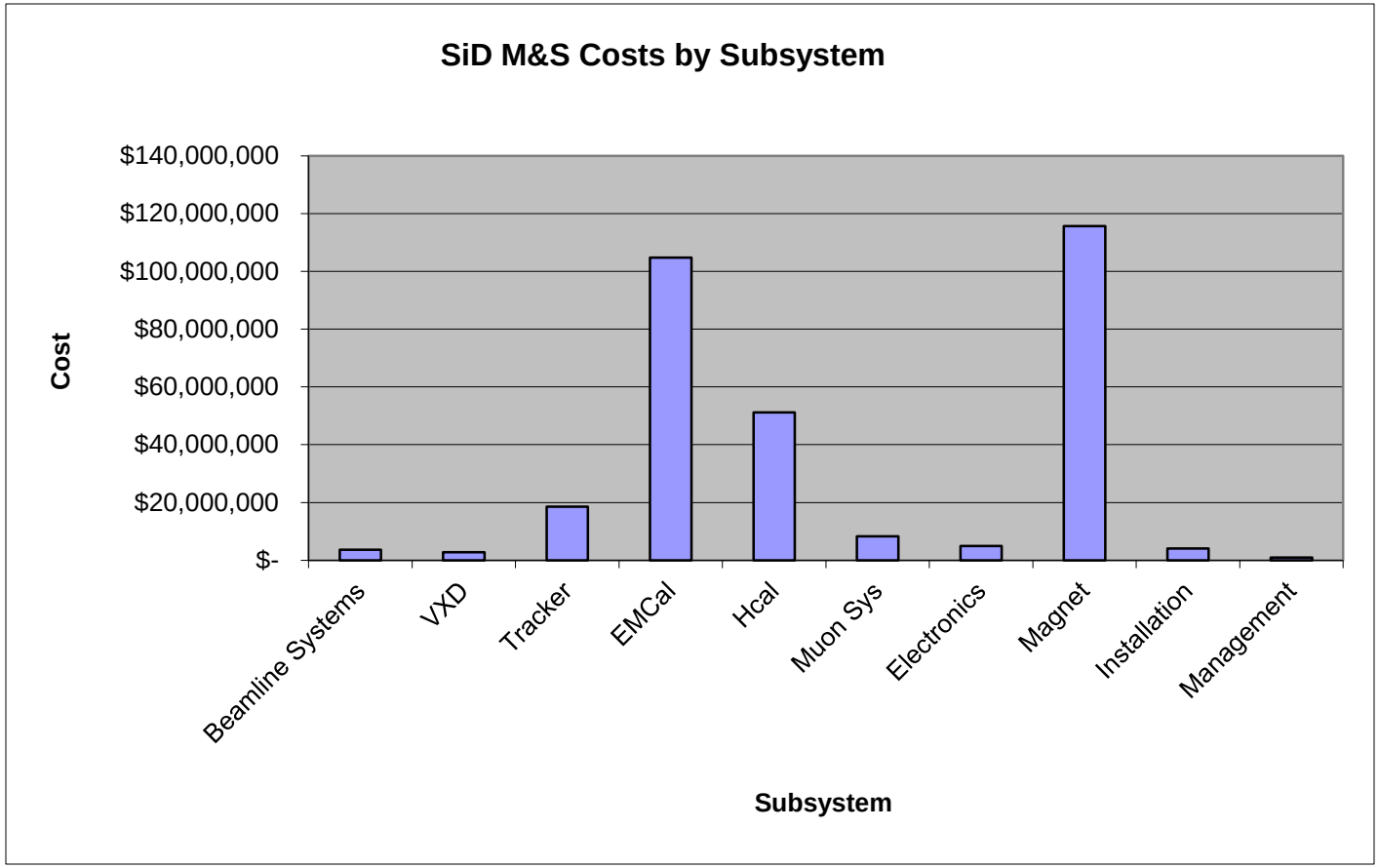
~x 2.7

Costs by Type

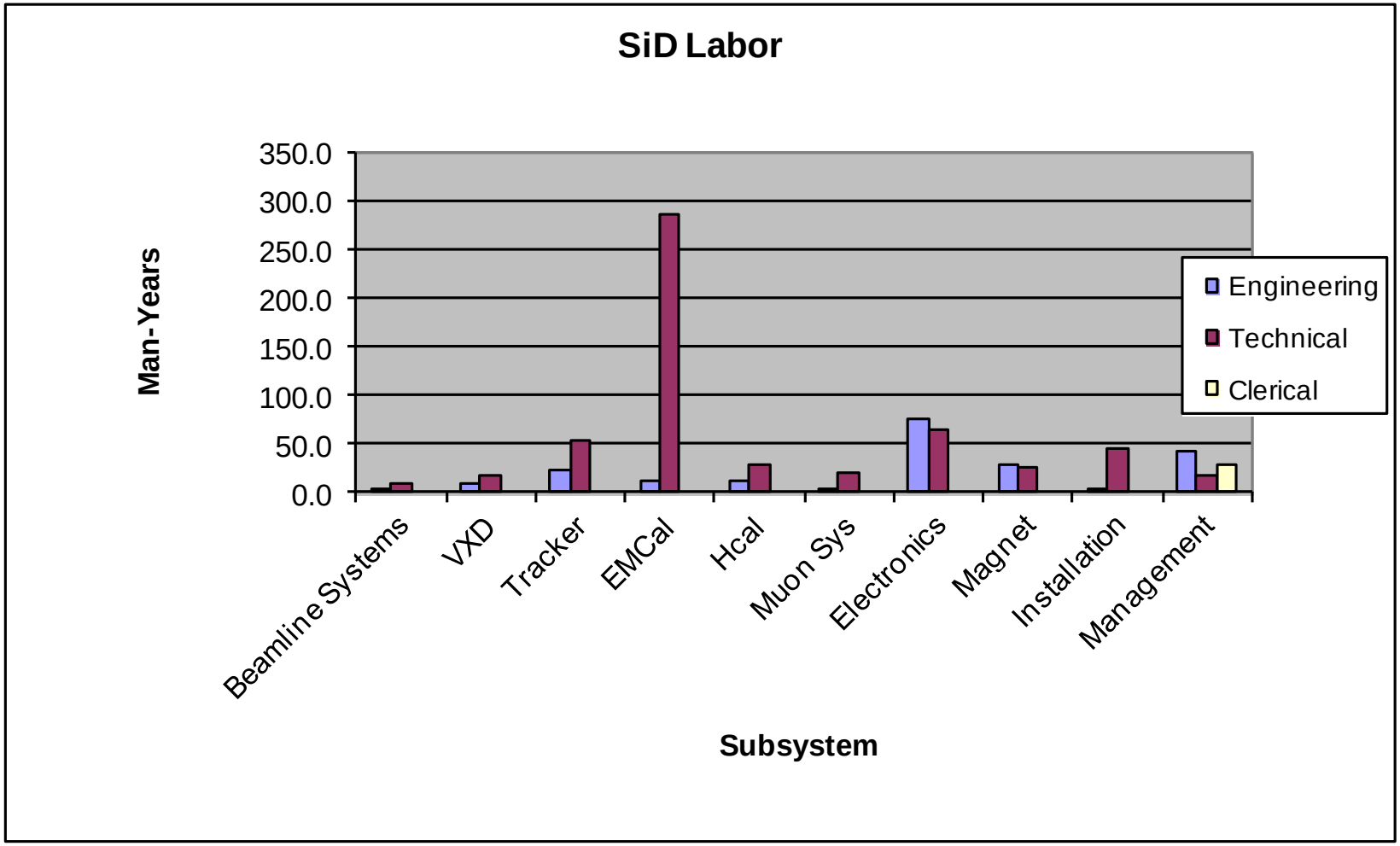
SiD Costs by type	
M&S	$315
Labor	$81
Contingency	$144
Indirects	$46
Escalation	269.9
Total	$857



Subsystem M&S



SiD Labor by Subsystem



Cost Sensitivity

Effect of doubling the nominal unit cost

Material	Base Cost	Delta Cost	Fractional Delta
Magnet Iron	6.00 /Kg	48M	1.16
Silicon Sensors	6.00 /cm^2	79M	1.26
Tungsten	180, 105 /Kg	14M	1.05
Stainless	4.5 /Kg	2M	1.01
HCal Detector	12K /m^2	42M	1.14

Cost Comments I

- This estimate is adequate for a Letter of Intent. No systematic reviews were done for the DBD.
- It is not adequate for a DOE Project Review (Lehman)
- Adding contingency would be advised when thinking about these numbers.
- Many commodity costs remain unstable – but we now use many of the same numbers as CLIC.

Cost Comments II

- SiD now stands at $309M Base + $116M Contingency + 770 MY
- ILD (LOI) was 407 MILCU + 1400 MY.

- The nominal model for funding is in-kind contributions from the governments – about the same model as for ILC.

- ILC is strenuously working to reduce and control costs.

SiD Next Steps

- Set HCal thickness.
- This decisions should be based on physics performance! Need to evaluate new 1 TeV benchmark performance, and think about performance comparisons to ILD.
- With the HCal parameters set, we can do a small iteration on the detector mechanics, and have a better model of cracks and dead areas.
- The DBD will not be a TDR!!!

The Bottom Line

- Actually building SiD would take 5-6 years from a TDR and funding.
- It will take 3±1 years and funding to produce a TDR, which will include:
  - All technology choices except (perhaps) the VXD.
  - Beam and B field tested prototype detectors.
  - Production Prototype detectors
  - Complete electronics designs with fully functional prototypes
  - Reviewable plans for actual design, management, costs, and funding.
- ILC appears to be headed for a TDR-lite.
- The DBD is not a TDR!

Backup Slides

WBS

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U.S. DOE style costing

- Contingencies are assigned to M&S and labor
  - Allows extra funding to hold a schedule in the face of unforeseen problems.
  - Fund items that were missed in the estimate
  - Provide some relief from under-estimates
- Transform labor to $ value using SLAC salary numbers including benefits, but not overhead.
- Compute indirects as fraction of M&S and Labor. SLAC large Project numbers are used.
- Escalation (inflation) calculated assuming a start date, a 6 year construction cycle, and an inflation rate.
  - Assume 2016 start, inflation = 3.5%/year
  - These assumptions are uncertain
  - The escalation is substantial

Interface Assumptions

- IR Hall, with finished floor & walls, lighting, and HVAC are provided by ILC.
- Utilities, including 480 VAC power, LCW, compressed air, and internet, are provided on the hall wall.
- External He compressor system with piping to the hall is provided. The refrigeration and associated piping is an SiD cost.
- Any surface buildings, gantry cranes, and hall cranes are provided by ILC.
- Data storage and offline computing are provided by others.
- Detector motion rails (both for push-pull and detector opening in beamline and garage positions) are installed by SiD in suitable channels provided by ILC.