This Detector Can't Be Built
without lots of work
SD (Silicon Detector)

- Conceived as a high performance detector for NLC
- Reasonably uncompromised performance
- But
- Constrained & Rational cost
e⁺e⁻ Detectors are Technically Trivial and Linear Collider detectors are extraordinarily trivial

- Cross sections are tiny
- Approximately no radiation issues (compared to real machines!)
- And for linear colliders:
  - Miniscule crossing rate - perhaps triggers are unnecessary
  - Low rate detectors, simple DAQ
  - Very modest data processing requirements
So what is the fuss?

- Precision measurements emphasize:
  - Vertexing and tracking with minimal multiple scattering - no degradation of superb resolution of CCD’s or silicon strips.
  - EM calorimetry optimized for Energy Flow [Is this really true? How good is the case for Energy Flow? Its really expensive!!!]
  - High B Field for cleaning pair backgrounds near VXD and good momentum measurement.
So what is the fuss - continued...

- **Good sense requires cost control:**
  - Detectors (very likely) will have cost caps - [Personal opinion & prediction: there won't be more than $300M (US costing) for a first round instrument] (SD now ~$325M - base + contingency; no escalation)
  - We will want the most physics capability we can imagine: Great
    - Vertexing - Stretched CCD's
    - Tracking - Silicon Strips
    - B - 5T
    - EMCal - Silicon-tungsten
    - Hcal - Cu(??) - R²PC
    - Muon Tracking - Fe- R²PC

- And none of these could be built today!!!
Incremental Cost vs Tracker Radius

![Graph showing the relationship between cost and tracker radius.

Delta M$ \approx$ 2M/cm

|$~2M/cm$
Challenges & Questions

• Many assertions are just that – not backed up by realistic simulation. Before we go much further [perhaps another year] we need rational justification from the physics. Do we really need such performance (particularly if it’s expensive)?
• The subsystems described for SD all exist in some form. No new detector principles are required. But extensive development is needed for every one. Are there new ideas that make it better or cheaper?
Baseline SD Design

Quadrant View

- Beam Pipe
- Trkr
- Ecal
- Hcal
- Coil
- MT
- Endcap
- Endcap_Hcal
- Endcap_Ecal
- VXD
- Endcap_Trkr
Compromises?

- Of course – but not now. We have 3-4 years to figure out these systems. Compromise later – Think now!
VXD

• **Challenges:**
  - Reduce central region MS by supporting CCD’s by stretching from ends...[SLD attached CCD’s to Be substrate...]
  - Minimize forward MS by developing readout ASIC (bump?) bonded to CCD. [SLD had cables]
  - Minimize MS with very thin Be beampipe - fixed end conditions? [Is this still helping?]
Tracker

• Atlas has developed a beautiful chirped interferometric alignment system - a full geodetic grid tying together the elements of their tracker. Can such a system reduce requirements on the space frame precision and stability - reducing its mass and cost?

• Could a silicon layer provide some fast timing? NLC is 190 bunches 1.4 ns apart. We probably need some elementary identification of tracks with bunches.

• Are there any problems with 5T (or for the EMCal)?
Tracker Electronics

- Plan might be to string 10 cm square detectors to barrel half lengths and readout from ends.
- Design “end” detectors to route strips to rectangular grid (mm scale) for bump bonding to read out chip (ROC).
- ROC is ASIC with all preamplification, shaping, discrimination, compression, and transmission functionality (ie fiber). Includes power pulsing.
- Hasn’t been done!
Silicon Tungsten EMCal

- Figure of merit something like $BR^2/\sigma$, where $\sigma$ is like the rms sum of Moliere radius of the calorimeter and the pixel size.
  - Maintain the great Moliere radius of tungsten by minimizing the gaps between ~2.5 mm tungsten plates. Dilution is $(1+R_{gap}/R_w)$
  - Could a layer of silicon/support/readout etc fit in a 2.5 mm gap? Even less?? This is ~60 tonnes of tungsten!
- Requires clever electronic-mechanical integration!
EMCal, continued

• Diode pixels between 5 – 10 mm square on largest hexagon fitting in largest available wafer. (6” available now – 300 mm when??)

• Develop readout electronics of preamplification through digitization, zero suppression, optical fiber drive integrated on wafer. Fallback is separate chip diffusion or bump bonded to detector wafer. (R&D opportunity!)

• Optimize shaping time for small diode capacitance. Probably too long for significant bunch localization within train. But some detector element needs good time resolution!!!
EMCal Readout Board

Silicon Diode Array

Readout Chip

Network Interconnect

~1m
Channel Counts [Forget Them!!]

- We are used to pixel counts in CCD’s ...
  - $3 \times 10^8$ last time, $1 \times 10^9$ this time, no problem
- Silicon Strip Tracker $\sim 5 \times 10^6$ strips (channels??)
- EMCal $\sim 5 \times 10^7$ pixels (channels??)
- Don’t even think about multiplying channels by $O(\$10)$

- Must solve the cluster technology challenges.
HCal

- Hcal assumed to be $4\lambda$ thick, with 34 layers 2 cm thick alternating with 1 cm gaps.
- Could use “digital” detectors, eg high reliability RPC's (Have they been invented yet???)
- Hcal radiator non-magnetic metal – probably copper or stainless
  - Tungsten much too expensive
  - Lead possible, but mechanically more painful.
- Hcal thickness important cost driver, even though Hcal cost small. And where is it relative to coil?
Hcal Location Comparison

Inside

Outside

10 July 2001
Note Scale - Relative to Inside @4 L!!

Hcal Inside Coil

Hcal Outside Coil
Coil and Iron

- Solenoid field is 5T - A mere factor of ~3 in field from detector coils that have been run. CMS will be 4T.
- Coil concept based on CMS 4T design. 4 layers of superconductor about 72 x 22 mm, with pure aluminum stabilizer and aluminum alloy structure.
- Coil $\Delta r$ about 85 cm
- Stored energy about 1.7 GJ (for Tracker Cone design, $R_{Trkr}=1.25m$, $\cos\theta_{barrel}=0.8$). (TESLA is about 2.4 GJ) [Aleph is largest existing coil at 130 MJ]
Conclusions & Comments

• The previous epoch of NLC Detector R&D has clearly started things moving, particularly for simulation tools.
• It’s now time to really justify claims, because they likely will drive the architecture of the detector.
• It’s time to start supporting people to develop hardware concepts.
  – The universities need good engineers and techs..
• TNRLC was great for SSC R&D support. Can we re-invent it?