The Status of the International Linear Collider

Brian Foster (Oxford & GDE)

Symposium on *Physics of Elementary Interactions in the LHC Era*
Warsaw, 22/4/08
The future of particle physics

• The LHC will open up a new world - what it finds will be stranger and more wonderful than any of our theories.

• We must exploit its results to ensure the future of particle physics for our lifetime.

• The main broad thrusts of the future are clear - energy frontier and neutrinos.

• The LHC should expose a rich vista - to understand it we need a complementary, precision, affordable e^+e^- machine and we need it as soon as possible.
Why $e^+e^-$?

- Simple particles
- Well defined: energy, angular momentum
- $E$ can be scanned precisely
- Particles produced democratically
- Final states generally fully reconstructable
**Why/what is ILC?**

- Why do we want to build a high-energy $e^+e^-$ collider?
- Physics case rests on three legs: known phenomena that ILC will definitely study -
  - top quark;
  - the Higgs: for which there is very strong indirect evidence and if LHC doesn’t find it then ILC will be essential to understand why;
  - new particles for which there is very strong theoretical prejudice
Why/what is ILC?

Furthermore the high precision of $e^+e^-$ means that it is sensitive to phenomena far above its CM energy because of quantum corrections – as LEP proved.
ILC Parameters

• \( E_{cm} \) adjustable from 200 – 500 GeV
• Luminosity \( \int L dt = 500 \text{ fb}^{-1} \) in 4 years
  (corresponds to \( 2 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1} \))
• Ability to scan between 200 and 500 GeV
• Energy stability and precision below 0.1%
• Electron polarization of at least 80%
• The machine must be upgradeable to 1 TeV
Global Design Effort Mission

- Produce a design for the ILC that includes a detailed design concept, performance assessments, reliable international costing, an industrialization plan, siting analysis, as well as detector concepts and scope.

- Coordinate worldwide prioritized proposal driven R & D efforts (to demonstrate and improve the performance, reduce the costs, attain the required reliability, etc.)

- B. Barish is GDE Director, assisted by 3 regional directors: BF (Europe); M. Nozaki (Asia); M. Harrison (Americas). New GDE (> 30% FTE)- currently 480 GDE members worldwide.
Overall Layout @ RDR

Reference design completed last August.

1\textsuperscript{st} Stage: 500 GeV; central DR et al. campus; 2 “push-pull” detectors in 14 mrad IR.
## ILC’s Workhorse - SCRF

<table>
<thead>
<tr>
<th>Subdivision</th>
<th>Length (m)</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cavities (9 cells + ends)</td>
<td>1.326</td>
<td>14,560</td>
</tr>
<tr>
<td>Cryomodule (9 cavities or 8 cavities + quad)</td>
<td>12.652</td>
<td>1,680</td>
</tr>
<tr>
<td>RF unit (3 cryomodules)</td>
<td>37.956</td>
<td>560</td>
</tr>
<tr>
<td>Cryo-string of 4 RF units (3 RF units)</td>
<td>154.3 (116.4)</td>
<td>71 (6)</td>
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<tr>
<td>Cryogenic unit with 10 to 16 strings</td>
<td>1,546 to 2,472</td>
<td>10</td>
</tr>
<tr>
<td>Electron (positron) linac</td>
<td>10,917 (10,770)</td>
<td>1 (1)</td>
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</tbody>
</table>
The reference design was “frozen” on 1-12-06 for RDR production, including costs.

Important to realise this is a snapshot; design will continue to evolve, due to R&D, accelerator studies & value engineering.

The value costs have already been reviewed many times; all reviews have been very positive and generally consider there is scope for further cost reductions.
EDR phase

- The period between August and December 07 was one of intensive internal reorganisation and preparation for the EDR phase.

- Installation and staffing of the Project Management Office, led by PM ‘Troika’ : M. Ross (Fermilab) (Chair), N. Walker (DESY) & A. Yamamoto (KEK).

- All positions in project office filled.
EDR phase - technical areas

- The R&D will be divided into 15 technical areas:

<table>
<thead>
<tr>
<th>Technical Area Groups</th>
<th>Technical Area</th>
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<tbody>
<tr>
<td>1. Cavity Processing</td>
<td>1.1 Cavity Processing</td>
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<tr>
<td>1.2 Cavity Production and Integration</td>
<td>1.2 Cavity Production and Integration</td>
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<tr>
<td>1.3 Cryomodules</td>
<td>2.1 Civil Engineering and Services</td>
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<tr>
<td>1.4 Cryogenics</td>
<td>2.2 Conventional Facilities Process Management</td>
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<tr>
<td>1.5 High Level RF</td>
<td>2.3 Controls</td>
</tr>
<tr>
<td>1.6 Main Linac Integration</td>
<td>3.1 Electron Source</td>
</tr>
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<td></td>
<td>3.2 Positron Source</td>
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<td></td>
<td>3.3 Damping Ring</td>
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<td></td>
<td>3.4 Ring To Main Linac</td>
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<tr>
<td></td>
<td>3.5 Beam Delivery Systems</td>
</tr>
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<td></td>
<td>3.6 Simulations</td>
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</tbody>
</table>
“Black December”

- “Black December” saw UK funding agency, STFC, withdraw from ILC. In unrelated move, US cut funding in FY08 – in principle closing it down for remainder of FY.

- However, enough US money remained unspent to permit GDE Common Fund to be paid and the GDE organisation to remain in being.

- Nevertheless, this has been a major blow to the project.
FALC Meeting

• FALC met 17/18.1.2008 & confirmed that the physics motivation for a linear collider remains unchanged.

• The R&D underway in all three regions is fulfilling an important mission to establish the feasibility and technology necessary for the next large collider.

• FALC recognized that funding stability is the key to any international collaborative effort so none of the partners’ investment is jeopardized.
ICFA/ILCSC Meeting

• ICFA Statement on Funding for the Linear Collider

• ICFA expresses its deepest concern about the recent decisions in the United Kingdom and the United States of America on spending for long-term international science projects…..
ICFA/ILCSC Meeting

• …the sudden cuts implemented by two partner countries have devastating effects.

• ICFA feels an obligation to make policy makers aware of the need for stability in the support of major international science efforts.

• It is important for all governments to find ways to maintain the trust needed to move forward international scientific endeavours.
ILC in Europe

- Agreement to continue LC programme in UK @ ~ 25% of previous. Spain signed MoU.
- HiGrade is for “Preparatory Phase” and is intended for projects on the ESFRI Road Map.
- We have now agreed the boundaries of the project, EU starting documents received – started on Feb 1\textsuperscript{st}. “Site selection & governance” is ~ 50% of effort; remainder in SCRF and cavity production on back of XFEL.
- EUCARD - “Son of EuroTeV” - submitted – substantial request joint ILC-CLIC “generic” LC development. Lots of competition.
ILC in US

• The only thing predictable about the US pp budget is that it is unpredictable.

• However, signs seem positive. GDE request for DoE budget line increased from 30M (50% of the level hoped for after Black December) to 31.5M. MH has detailed plan for restoring work in FY09.

• Now working its way through Congressional process

• But election year –may have to survive on continuing resolution until ~ Feb?
ILC in Asia

• Japanese budget still dominated by construction and completion of JPARC. Firm commitment to ILC R&D & TDR phase.

Federation of Diet Members for promotion of the ILC project

• Built in 2006 (June 15th):
• Members: At present more than 60 Diet members.
• Chair: Mr. Kaoru Yosano (former Cabinet Secretary, Minister of MEXT, METI,..)
• Secretary: Mr. Takeo Kawamura
  (former Minister of MEXT)

• India has joined MoU for GDE Common Fund.

• Discussions with Chinese political leaders @ GDE Beijing meeting last November
GDE response - the Technical Phase

• The last 4 months have been ones of turmoil and substantial rethinking.
• ALL of the major areas developed by the RDR were led by US or UK scientists.
• It can’t be business as usual when such a large fraction of resources lost ~ 30 FTEs in UK – round £3M/year from UK - $60M -> $15M in US.
• New plan for TD phase concentrates and reduces work and lengthens timesales.
GDE response - the Technical Phase

- Particular concentration in early phase of TP is on cost reduction. Task forces at Sendai met for two days looking at very many ideas – some crazy, some obvious – as to how to reduce the cost of the RDR machine significantly.

- Will continue to be a priority at future meetings.
# TDP R&D - SCRF

<table>
<thead>
<tr>
<th>Calendar Year</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
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<tbody>
<tr>
<td><strong>EDR</strong></td>
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<td><strong>TDP1</strong></td>
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<td><strong>TDP-II</strong></td>
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<td><strong>S0:</strong></td>
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<tr>
<td>Cavity Gradient (MV/m)</td>
<td>30</td>
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<td>35</td>
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<td></td>
<td>(&gt; 50%)</td>
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<tr>
<td><strong>KEK-STF-0.5a:</strong> 1 Tesla-like/LL</td>
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<tr>
<td><strong>KEK-STF1:</strong> 4 cavities</td>
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<tr>
<td><strong>S1</strong>-Global (AS-US-EU)</td>
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<tr>
<td>1 CM (4+2+2 cavities)</td>
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<tr>
<td><strong>S1(2)</strong> - ILC-NML-Fermilab</td>
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<td>CM1- 4 with beam</td>
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<td><strong>S2:</strong> STF2/KEK:</td>
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<tr>
<td>1 RF-unit with beam</td>
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</tbody>
</table>

- KEK-STF-0.5a: 1 Tesla-like/LL
- KEK-STF1: 4 cavities
- S1-Global (AS-US-EU): 1 CM (4+2+2 cavities)
- S1(2) - ILC-NML-Fermilab: CM1- 4 with beam
- S2: STF2/KEK: 1 RF-unit with beam

- CM (4\textsubscript{AS}+2\textsubscript{US}+2\textsubscript{EU}) <31.5 MV/m>
- CM2 Fabrication in industries
- CM3 STF2 (3 CMs) Assemble & test
**Overall Plan:** Test ILC RF units
- 3 CM, Klystron, Modulator, LLRF
- Move A0 Injector to provide ILC like beam
- New bldg: diagnostic, AARD, new cryo plant
- ILC Twin tunnel design to allow 2nd RF unit and to study tunnel layout and maintenance issues
TDP R&D – BDS/MDI

• Perhaps group most strongly affected by “Black December” – dominated by UK/US.

• A great deal will have to be put on hold – but work is continuing on highest priority issues.

• ATF2 in KEK due to come on line in Oct! Will be of major importance for BDS studies and much more!
TDP R&D – BDS/MDI

- ATF collaboration > 200 scientists, 20 institutions. ATF2 designed for ILC.
TDP R&D – DR

• One of areas where significant critical R&D remains to be done – if particular in properties and defences against electron-cloud effect.

• CESR-TA project (funding ~agreed from NSF with some matching funds from DoE)
ILC-CLIC synergy

- Meetings going on and planned before “Black December”. Latest @ CERN in Feb.

Conclusions - CFS

- Interaction Area is obvious area where resources can be shared
- Civil Engineering models can be worked on ‘in parallel’ for ILC & CLIC.
- Other possible areas of collaboration in the TS area: Ventilation, Electricity, Handling….
- Resources to be defined, if limited, then perhaps Joint ‘Value Engineering’ exercises could be the way forward, rather than full blown studies….
- First milestone: At Sendai meeting develop deliverables for 2008 for ILC Value Engineering and ILC/CLIC common efforts
- Identify link persons for highlighted areas
- CFS Video meetings will continue with possible CLIC input on specific subjects
Next GDE plenary – Dubna 6/08
Civil Construction Timeline

- TBM \( \varnothing_{\text{finished}} = 5 \text{m} \)
- MS TBM \( \varnothing = 5 \text{m} \)
- Cavern finishing
- Shaft/cavern excavation
- TBM setup
- TBM transport
- TBM removal
- Finishing work

Install CFS services in Detector halls & Shaft base caverns

B. Foster - Warsaw - 4/08
Design philosophy

- Aim for SiW calorimeter with best possible resolution
- Keep radius small to make this affordable
- Compensate by high B-field (5 T) and very precise tracking (Si)
- Fast timing of Silicon to suppress background
Design philosophy

- Fine resolution calorimeter for particle flow
- Gaseous tracking for high tracking efficiency and redundancy
- Large enough radius and high enough B-field (B=4 T) to get required momentum resolution

(NB – above is actually LDC detector!)
Detectors - 4th concept

- Pixel Vertex (PX)  5-micron pixels
- Drift chamber based on CHLOE design
- Crystal dual-readout ECAL
- Triple-readout fiber HCAL: scintillation/Cerenkov/neutron (new)
- Muon dual-solenoid geometry (new), with ATLAS drift tubes.
Summary

• “Black December” a major setback to the prospects of the ILC particularly in UK & US

• It has precipitated a major rethink of the way forward and we now have a new plan.

• Many details need to be resolved to get all the R&D back on the road in a coherent way.

• No sign of any “domino” effect; promising efforts to restore significant efforts in UK & US and new countries committing to MoUs. Strong determination among all to stay the course and produce design for this machine.