The Art and Science of Making a Major Technical Decision

Choosing the Technology for the International Linear Collider

Barry Barish
HEP Informal Seminar
2-Nov-04
The Linear Collider

2001: The Snowmass Workshop participants produced the statement recommending construction of a Linear Collider to overlap LHC running.

2001: HEPAP, ECFA, ACFA all issued reports endorsing the LC as the next major world project, to be international from the start.

2002: The Consultative Group on High-Energy Physics of the OECD Global Science Forum executive summary stated as the first of its Principal Conclusions:

“The Consultative Group concurs with the world-wide consensus of the scientific community that a high-energy electron-positron collider is the next facility on the Road Map.

“There should be a significant period of concurrent running of the LHC and the LC, requiring the LC to start operating before 2015. Given the long lead times for decision-making and for construction, consultations among interested countries should begin at a suitably-chosen time in the near future.”
“Consensus Document”

April 2003: signed now by ~2700 physicists worldwide.

Worldwide Study of the Physics and Detectors for Future Linear e+ e- Colliders

Understanding Matter, Energy, Space and Time: The Case for the Linear Collider

A summary of the scientific case for the e+ e- Linear Collider, representing a broad consensus of the particle physics community.


(To join this list, go to http://blueox.uoregon.edu/~lc/wwstudy/)
Why ITRP?

- Two parallel developments over the past few years (the science & the technology)
  - The precision information from LEP and other data have pointed to a low mass Higgs; Understanding electroweak symmetry breaking, whether supersymmetry or an alternative, will require precision measurements.
  - There are strong arguments for the complementarity between a \(\sim 0.5-1.0 \text{ TeV} \) LC and the LHC science.
  - Designs and technology demonstrations have matured on two technical approaches for an e^+e^- collider that are well matched to our present understanding of the physics. (We note that a C-band option could have been adequate for a 500 GeV machine, if NLC/GLC and TESLA were not deemed mature designs).
Electroweak Precision Measurements

LEP results strongly point to a low mass Higgs and an energy scale for new physics < 1TeV

\[ \Delta \chi^2 \]

\( m_H [\text{GeV}] \)
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LHC/LC Complementarity

The 500 GeV Linear Collider Spin Measurement

LHC should discover the Higgs

The linear collider will measure the spin of any Higgs it can produce.

The process $e^+e^- \rightarrow HZ$ can be used to measure the spin of a 120 GeV Higgs particle. The error bars are based on 20 fb$^{-1}$ of luminosity at each point.
New space-time dimensions can be mapped by studying the emission of gravitons into the extra dimensions, together with a photon or jets emitted into the normal dimensions.
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  – There are strong arguments for the complementarity between a ~0.5-1.0 TeV LC and the LHC science.
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Based on the physics goals in the consensus document, a group drew up parameters for the Linear Collider:

- $E_{cm}$ continuously adjustable from 200 – 500 GeV
- Luminosity and reliability to allow $\int L dt = 500 \text{ fb}^{-1}$ in 4 years following the initial year of commissioning
- Ability to scan at any energy between 200 and 500 GeV; downtime to set up not to exceed 10% of actual data-taking time
- Energy stability and precision below 0.1%; machine interface must allow energy, differential luminosity spectrum with that precision
- Electron polarization of at least 80%
- 2 intersection regions for experiments; one with crossing angle to enable $\gamma\gamma$ collisions
- Allow calibration at the Z, but with lower luminosity and emittance

Baseline machine
Parameters for the Linear Collider

Should be capable of **Energy Upgrade**

- Energy upgrade to approximately 1 TeV
- Luminosity and reliability to allow 1 ab$^{-1}$ in about 3-4 years
- Capability for running at any energy up to maximum energy (assume L scales as $\sqrt{s}$)
- Beam energy and stability as for baseline machine
Parameters for the Linear Collider

Should preserve Options beyond the Baseline

- Ability to double ∫Ldt at 500 GeV to 1 ab⁻¹ in two additional years
- Ability to collide e⁻e⁻ up to full energy
- Positron polarization to, or above, 50% from 90 GeV to max. energy
- Operation at Z pole with L ~ few x 10^{33} cm⁻²s⁻¹, with positron polarization
- Operation at WW threshold with few x 10^{33} cm⁻²s⁻¹ and dE/E ~ few 10⁻⁵ (not demonstrated)
- Ability to collide photons of arbitrary polarization states at up to 80% of maximum energy, and 30-50% of e⁺e⁻ luminosity
Any linear collider requires:

- Electron source
- Positron production
- Pre-injector accelerators
- Damping rings
- Bunch compressor
- rf power source/delivery
- Low level rf for rf control
- Main linacs
- Beam diagnostics: BPMs, movers
- Final focus system at IP
- Machine protection system

<table>
<thead>
<tr>
<th>Energy</th>
<th>Luminosity</th>
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<tr>
<td>few GeV</td>
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<td>few GeV</td>
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<tr>
<td>few GeV</td>
<td></td>
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<tr>
<td>250-500 GeV</td>
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Features of Specific Machine Realizations

rf bands:

L-band (TESLA) 1.3 GHz $\lambda = 3.7$ cm
S-band (SLAC linac) 2.856 GHz 1.7 cm
C-band (JLC-C) 5.7 GHz 0.95 cm
X-band (NLC/GLC) 11.4 GHz 0.42 cm
(CLIC) 25-30 GHz 0.2 cm

Accelerating structure size is dictated by wavelength of the rf accelerating wave. Wakefields related to structure size; thus so is the difficulty in controlling emittance growth and final luminosity.

- Bunch spacing, train length related to rf frequency
- Damping ring design depends on bunch length, hence frequency

Frequency dictates many of the design issues for LC
What has the Accelerator R&D Produced?

The Report Validates the Readiness of L-band and X-band Concepts
The main linacs are based on 1.3 GHz superconducting technology operating at 2 K. The cryoplant, of a size comparable to that of the LHC, consists of seven subsystems strung along the machines every 5 km.

FIGURE 1. TESLA layout
RF accelerator structures consist of close to 21,000 9-cell niobium cavities operating at gradients of 23.8 MV/m (unloaded as well as beam loaded) for 500 GeV c.m. operation.

The rf pulse length is 1370 µs and the repetition rate is 5 Hz. At a later stage, the machine energy may be upgraded to 800 GeV c.m. by raising the gradient to 35 MV/m.
The TESLA cavities are supplied with rf power in groups of 36 by 572 10 MW klystrons and modulators.
The JLC-X and NLC are essentially a unified single design with common parameters.

The main linacs are based on 11.4 GHz, room temperature copper technology.

The main linacs operate at an unloaded gradient of 65 MV/m, beam-loaded to 50 MV/m.

The rf systems for 500 GeV c.m. consist of 4064 75 MW Periodic Permanent Magnet (PPM) klystrons arranged in groups of 8, followed by 2032 SLED-II rf pulse compression systems.
The rf systems and accelerator structures are located in two parallel tunnels for each linac. For 500 GeV c.m. energy, these rf systems and accelerator structures are only installed in the first 7 km of each linac. The upgrade to 1 TeV is obtained by filling the rest of each linac, for a total two-linac length of 28 km.
- The JLC-C is limited to an rf design using main linacs running at 5.7 GHz up to 400–500 GeV c.m.
- The unloaded gradient is about 42 MV/m and the beam-loaded gradient is about 32 MV/m, resulting in a two-linac length at 5.7 GHz of 17 km for a 400 GeV c.m. energy.

FIGURE 4. Schematic of a JLC-C linac rf unit (one of 848 per linac)
In Feb. 2001, ICFA charged a Technology Review Committee, chaired by Greg Loew of SLAC to review the critical R&D readiness issues.

The TRC report in 2003 gave a series of R&D issues for L-band (superconducting rf TESLA), X-band (NLC and GLC), C-band and CLIC. The most important were the R1’s: those issues needing resolution for design feasibility.
**TRC R1 Issues**

**L-Band**: Feasibility for 500 GeV operation had been demonstrated, but 800 GeV with gradient of 35 MV/m requires a full cryomodule (9 or 12 cavities) and shown to have acceptable quench and breakdown rates with acceptable dark currents.

**X-band**: Demonstrate low group velocity accelerating structures with acceptable gradient, breakdown and trip rates, tuning manifolds and input couplers. Demonstrate the modulator, klystron, SLED-II pulse compressors at the full power required.

**R1 issues pretty much satisfied by mid-2004**
Why Decide Technology Now?

- **We have an embarrassment of riches !!!!**
  - Two alternate designs -- “warm” and “cold” have come to the stage where the show stoppers have been eliminated and the concepts are well understood.
  - R & D is very expensive (especially D) and to move to the “next step” (being ready to construct such a machine within about 5 years) will require more money and a concentration of resources, organization and a worldwide effort.
  - A major step toward a decision to construct a new machine will be enabled by uniting behind one technology, followed by a making a final global design based on the recommended technology.
  - The final construction decision in ~5 years will be able to fully take into account early LHC and other physics developments.
The ITRP Members

Jean-Eudes Augustin (FRANCE)
Jonathan Bagger (USA)
Barry Barish (USA) - Chair
Giorgio Bellettini (ITALY)
Paul Grannis (USA)
Norbert Holtkamp (USA)
George Kalmus (UK)
Gyung-Su Lee (KOREA)
Akira Masaike (JAPAN)
Katsunobu Oide (JAPAN)
Volker Soergel (Germany)
Hirotaka Sugawara (JAPAN)

David Plane - Scientific Secretary
ITRP Schedule of Events

- **Six Meetings**
  - RAL (Jan 27, 28 2004) → Tutorial & Planning
  - DESY (April 5, 6 2004)
  - SLAC (April 26, 27 2004) → Site Visits
  - KEK (May 25, 26 2004)
  - Caltech (June 28, 29, 30 2004) → Deliberations
  - Korea (August 11, 12, 13) → Recommendation
- ILCSC / ICFA (Aug 19) → Exec. Summary
- ILCSC (Sept 20) → Final Report
ITRP in Korea

International Technology Recommendation Panel Meeting
August 11 ~ 13, 2004. Republic of Korea
Our Process

• We studied and evaluated a large amount of available materials

• We made site visits to DESY, KEK and SLAC to listen to presentations on the competing technologies and to see the test facilities first-hand.

• We have also heard presentations on both C-band and CLIC technologies

• We interacted with the community at LC workshops, individually and through various communications we received

• We developed a set of evaluation criteria (a matrix) and had each proponent answer a related set of questions to facilitate our evaluations.

• We assigned lots of internal homework to help guide our discussions and evaluations
What that Entailed

- We each traveled at least 75,000 miles
- We read approximately 3000 pages
- We had constant interactions with the community and with each other
- We gave up a good part of our “normal day jobs” for six months
- We had almost 100% attendance by all members at all meetings
- We worked incredibly hard to “turn over every rock” we could find.

from Norbert Holtkamp
The Charge to the International Technology Recommendation Panel

General Considerations

The International Technology Recommendation Panel (the Panel) should recommend a Linear Collider (LC) technology to the International Linear Collider Steering Committee (ILCSC).

On the assumption that a linear collider construction commences before 2010 and given the assessment by the ITRC that both TESLA and JLC-X/NLC have rather mature conceptual designs, the choice should be between these two designs. If necessary, a solution incorporating C-band technology should be evaluated.

Note -- We have interpreted our charge as being to recommend a technology, rather than choose a design.
Evaluating the Criteria Matrix

• We analyzed the technology choice through studying a matrix having six general categories with specific items under each:
  – the scope and parameters specified by the ILCSC;
  – technical issues;
  – cost issues;
  – schedule issues;
  – physics operation issues;
  – and more general considerations that reflect the impact of the LC on science, technology and society

• We evaluated each of these categories with the help of answers to our “questions to the proponents,” internal assignments and reviews, plus our own discussions
Evaluation: Scope and Parameters

• The Parameters Document describes a machine with physics operation between 200 and 500 GeV.
  – The luminosity of this machine must be sufficient to acquire 500 fb\(^{-1}\) of luminosity in four years of running, after an initial year of commissioning.
  – The baseline machine must be such that its energy can be upgraded to approximately 1 TeV, as required by physics.
  – The upgraded machine should have luminosity sufficient to acquire 1 ab\(^{-1}\) in an additional three or four years of running.

• The ITRP evaluated each technology in the light of these requirements, which reflect the science goals of the machine. It examined technical, cost, schedule and operational issues.
Evaluation: Scope and Parameters

• The Panel’s general conclusion was that each technology would be capable, in time, of achieving the goals set forth in the Parameters Document.

• The Panel felt that the energy goals could be met by either technology.
  – The higher accelerating gradient of the warm technology would allow for a shorter main linac.

• The luminosity goals were deemed to be aggressive, with technical and schedule risk in each case.
  – On balance, the Panel judged the cold technology to be better able to provide stable beam conditions, and therefore more likely to achieve the necessary luminosity in a timely manner.
Evaluation: Technical Issues

• The Panel was gratified to see the C-band progress
  – The C-band technology was originally conceived as an alternative to X-band for acceleration up to 500 GeV.
  – The technology is feasible and can be readily transferred to industry, with applications in science (XFELs) and industry (e.g. medical accelerators).

Spring-8 Compact SASE Source
Evaluation: Technical Issues

- **Compact Linear Collider Study (CLIC)**

  The main linac rf power is produced by decelerating a high-current (150 A) low-energy (2.1 GeV) drive beam. In the short (300 m), low-frequency drive beam accelerator, a long beam pulse is efficiently accelerated in fully loaded structures.

- The Panel was impressed with the state of CLIC R&D.
  - CLIC will face many challenges to demonstrate the feasibility of high-current beam-derived rf generation.
  - A vigorous effort to attack these issues at CTF3 at CERN.
Evaluation: Technical Issues

- The Panel evaluated the main linacs and subsystems for X-band and L-band to identify performance-limiting factors for construction and commissioning.
  - In general, the Panel found the LC R&D to be far advanced. The global R&D effort uncovered a variety of issues that were mitigated through updated designs.

Evolution of RF Unit Scheme

<table>
<thead>
<tr>
<th>Year</th>
<th>GLC</th>
<th>NLC</th>
</tr>
</thead>
<tbody>
<tr>
<td>~1996</td>
<td>1-mode DLDS 67MW x 4 0.75 µs 1.3m DS</td>
<td>SLED-II 50MW x 2 1.5 µs 1.8m DDS</td>
</tr>
<tr>
<td>~1999</td>
<td>2-mode DLDS 75MW x 8 1.5 µs 1.8m RDDS</td>
<td></td>
</tr>
<tr>
<td>~2001</td>
<td>1-mode DLDS 75MW x 8 1.6 µs 0.9m HDDS</td>
<td>2-mode DLDS 75MW x 8 3.2 µs 0.9m HDDS</td>
</tr>
<tr>
<td>~2002</td>
<td>2-mode SLED-II 75MW x 2 1.6 µs 0.6m HDDS</td>
<td></td>
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</tbody>
</table>
Evaluation: Technical Issues

- For the warm technology, major subsystems were built to study actual performance.
  - The KEK damping ring was constructed to demonstrate the generation and damping of a high-intensity bunch train at the required emittance, together with its extraction with sufficient stability.
Experimental Test Facility - KEK

- Prototype Damping Ring for X-band Linear Collider
- Development of Beam Instrumentation and Control

<table>
<thead>
<tr>
<th></th>
<th>ATF</th>
<th>GLC/NLC-DR</th>
</tr>
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<tbody>
<tr>
<td>$E_b$</td>
<td>1.28 (1.54 max)</td>
<td>1.98 GeV</td>
</tr>
<tr>
<td>$N_e$</td>
<td>$\sim 10^{10}$</td>
<td>0.75 $10^{10}$ e-/bunch</td>
</tr>
<tr>
<td>$S_b$</td>
<td>2.8</td>
<td>1.4 ns</td>
</tr>
<tr>
<td>$N_b$</td>
<td>20</td>
<td>192 /pulse</td>
</tr>
<tr>
<td>$\gamma \varepsilon_X$</td>
<td>$\sim 4$</td>
<td>3 $\mu$m.rad</td>
</tr>
<tr>
<td>$\gamma \varepsilon_Y$</td>
<td>$\sim 0.015$</td>
<td>0.02 $\mu$m.rad</td>
</tr>
</tbody>
</table>
Evaluation: Technical Issues

- For the warm technology, major subsystems were built to study actual performance.
  - The KEK damping ring was constructed to demonstrate the generation and damping of a high-intensity bunch train at the required emittance, together with its extraction with sufficient stability.
  - The Final Focus Test Beam at SLAC was constructed to demonstrate demagnification of a beam accelerated in the linac.
Evaluation: Technical Issues

Final Focus Test Beam Collaboration

BINP (Novosibirsk)
DESY
Fermilab
IBM
Kawasaki
KEK
LAL (Orsay)
MPI (Munich)
Rochester
SLAC

Vertical beam size of 60-70 nm
... the needed demagnification.
Evaluation: Technical Issues

• For the warm technology, major subsystems were built to study actual performance.
  – The KEK damping ring was constructed to demonstrate the generation and damping of a high-intensity bunch train at the required emittance, together with its extraction with sufficient stability.
  – The Final Focus Test Beam at SLAC was constructed to demonstrate demagnification of a beam accelerated in the linac.
  – As a result, the subsystem designs are more advanced for the warm technology.
Evaluation: Technical Issues

• In general, the cold technology carries higher risk in the accelerator subsystems other than the linacs, while the warm technology has higher risk in the main linacs and their individual components.

• The accelerating structures have risks that were deemed to be comparable in the two technologies.
  – The warm X-band structures require demonstration of their ability to run safely at high gradients for long periods of time.
  – The cold superconducting cryomodules need to show that they can manage field emission at high gradients.

• For the cold, industrialization of the main linac components and rf systems is now well advanced.
Evaluation: Technical Issues

• Superconducting RF Linac Concept demonstrated in TESLA Test Facility
TESLA Test Facility Linac

- Laser driven electron gun
- Photon beam diagnostics
- Pre-accelerator
- Beam position monitor
- Quadrupole package
- He gas return pipe
- Module length 12.2 m
- Input coupler

Electron gun:
- 240 MeV
- 120 MeV
- 16 MeV
- 4 MeV

Components:
- bunch compressor
- superconducting accelerator modules
- undulator
- electron gun
- diagnostics
Evaluation: Technical Issues

- Superconducting RF Linac Concept demonstrated in TESLA Test Facility

- Many cold technology components will be tested over the coming few years in a reasonably large-scale prototype through construction of the superconducting XFEL at DESY.
Evaluation: Technical Issues

- Superconducting RF Linac Concept demonstrated in TESLA Test Facility
- Many cold technology components will be tested over the coming few years in a reasonably large-scale prototype through construction of the superconducting XFEL at DESY.
- A superconducting linac has high intrinsic efficiency for beam acceleration, which leads to lower power consumption.
Site power: **140 MW**

- **Linac:** 97MW
- **RF:** 76MW
- **Cryogenics:** 21MW
- **Beam:** 22.6MW
- **Sub-systems:** 43MW

**Power Usage TESLA Design**

- Injectors
- Damping rings
- Water, ventilation, …
Evaluation: Technical Issues

- The lower accelerating gradient in the superconducting cavities implies that the length of the main linac in a cold machine is greater than it would be in a warm machine of the same energy.

- Future R&D must stress ways to extend the energy reach to 1 TeV, and even somewhat beyond.
Electro-polishing

(Improve surface quality -- pioneering work done at KEK)

BCP

- Several single cell cavities at $g > 40$ MV/m
- 4 nine-cell cavities at $\sim 35$ MV/m, one at 40 MV/m
- Theoretical Limit 50 MV/m

EP
New Cavity Shape for Higher Gradient?

- A new cavity shape with a small Hp/Eacc ratio around 350e/(MV/m) must be designed.
  - Hp is a surface peak magnetic field and Eacc is the electric field gradient on the beam axis.
  - For such a low field ratio, the volume occupied by magnetic field in the cell must be increased and the magnetic density must be reduced.
  - This generally means a smaller bore radius.
  - There are trade-offs (eg. Electropolishing, weak cell-to-cell coupling, etc)
Evaluation: Technical Issues

• In a superconducting rf structure, the rf pulse length, the length of the bunch train, and interbunch time interval are all large. This offers many advantages.

• The disadvantages are mainly related to the complex and very long damping rings, and the large heat load on the production target for a conventional positron source, which might require a novel source design.
  – Storage rings are among the best-understood accelerator subsystems today, and much of this knowledge can be transferred to the linear collider damping rings.
  – Beam dynamics issues such as instabilities, ion effects, and intrabeam scattering have been well studied in those machines.
Evaluation: Technical Issues

• Achieving design luminosity will be a critical measure of the collider’s success. A number of arguments indicate it will be easier with the cold technology.
  – The cold technology permits greater tolerance to beam misalignments and other wakefield-related effects.
  – Natural advantage in emittance preservation because the wakefields are orders of magnitude smaller.
  – The long bunch spacing eliminates multi-bunch effects and eases the application of feedback systems.
  – This feedback will facilitate the alignment of the nanometer beams at the collision point.

• For these reasons, we deem the cold machine to be more robust, even considering the inaccessibility of accelerating components within the cryogenic system.
Evaluation: Cost Issues

• The Panel spent considerable effort gathering and analyzing all information that is available regarding the total costs and the relative costs of the two options.

• At the present conceptual and pre-industrialized stage of the linear collider project, uncertainties in estimating the total costs are necessarily large.

• Although it might be thought that relative costing could be done with more certainty, there are additional complications in determining even the relative costs of the warm and cold technologies because of differences in design choices and differences in costing methods used in different regions.
Evaluation: Cost Issues

• Some of the important contributors to the uncertainties are:
  – Design and implementation plans for important technological components of each machine are in a preliminary state.
  – Differences in design philosophy by the proponents lead to differences in construction cost, as well as final performance. These cannot be resolved until a global and integrated design exists.
  – Assumptions about industrialization/learning curves for some key components have large uncertainties at this early stage in the design.
  – Present cost estimates have some regional philosophies or prejudices regarding how the project will be industrialized. Contingency accounting, management overheads, staff costs for construction and R&D costs for components are all treated differently; this adds uncertainty to cost comparisons.
Evaluation: Cost Issues

• Some of the important contributors to the uncertainties are: (continued)
  – In an international project, the procurement of substantial parts of the collider will be from outside the regions that prepared the present estimates, and this can considerably alter the costs.
  – The costs of operating the accelerator are also difficult to determine at this stage without a better definition of the reliability, access and staffing requirements, as well as the cost of power and component replacement.

• As a result of these considerations, the Panel concluded that comparable warm and cold machines, in terms of energy and luminosity, have total construction and lifetime operations costs that are within the present margin of errors of each other.
Evaluation: Schedule Issues

• In accordance with our charge, we assumed that LC construction would start before 2010, and that it would be preceded by a coordinated, globally collaborative effort of research, development, and engineering design.

• Based on our assessment of the technical readiness of both designs, we concluded that the technology choice will not significantly affect the likelihood of meeting the construction start milestone.

• We believe that the issues that will drive the schedule are primarily of a non-technical nature.
Evaluation: Physics Operations Issues

• Several factors favor the cold machine:
  – The long separation between bunches in a cold machine allows full integration of detector signals after each bunch crossing. In a warm machine, the pileup of energy from multiple bunch crossings is a potential problem, particularly in forward directions.
  – The energy spread is somewhat smaller for the cold machine, which leads to better precision for measuring particle masses.
  – If desired, in a cold machine the beams can be collided head-on in one of the interaction regions. Zero crossing angle might simplify shielding from background.
  – a nonzero crossing angle permits the measurement of beam properties before and after the collision, giving added constraints on the determination of energy and polarization at the crossing point.
Evaluation: General Considerations

• Linear collider R&D affects other scientific areas
  – the development of high-gradient superconducting cavities is a breakthrough that will find applications in light sources and X-ray free electron lasers, as well as in accelerators for intense neutrino sources, nuclear physics, and materials science.
  – New light sources and XFELs will open new opportunities in biology and material sciences.
  – The superconducting XFEL to be constructed at DESY is a direct spin-off from linear collider R&D.
  – the R&D work done for the X-band rf technology is of great interest for accelerators used as radiation sources in medical applications, as well as for radar sources used in aircraft, ships and satellites, and other applications.
We recommend that the linear collider be based on superconducting rf technology.

- This recommendation is made with the understanding that we are recommending a technology, not a design. We expect the final design to be developed by a team drawn from the combined warm and cold linear collider communities, taking full advantage of the experience and expertise of both (from the Executive Summary).

- The superconducting technology has several very nice features for application to a linear collider. They follow in part from the low rf frequency.
Some of the Features of SC Technology

• The large cavity aperture and long bunch interval reduce the complexity of operations, reduce the sensitivity to ground motion, permit inter-bunch feedback and may enable increased beam current.

• The main linac rf systems, the single largest technical cost elements, are of comparatively lower risk.
TESLA Cost estimate 500 GeV LC, one e+e- IP

3,136 M€ (no contingency, year 2000) + ~7000 person years

Machine cost distribution
Some of the Features of SC Technology

- The large cavity aperture and long bunch interval reduce the complexity of operations, reduce the sensitivity to ground motion, permit inter-bunch feedback and may enable increased beam current.

- The main linac rf systems, the single largest technical cost elements, are of comparatively lower risk.

- The construction of the superconducting XFEL free electron laser will provide prototypes and test many aspects of the linac.

- The industrialization of most major components of the linac is underway.

- The use of superconducting cavities significantly reduces power consumption.
The ITRP Recommendation

- The ITRP recommendation was presented to ILCSC & ICFA on August 19 in a joint meeting in Beijing.

- ICFA unanimously endorsed the ITRP’s recommendation on August 20 and J. Dorfan announced the result at the IHEP Conference.
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• The ITRP recommendation was discussed and endorsed at FALC (Funding Agencies for the Linear Collider) on September 17 at CERN.
Attendees: Son (Korea); Yamauchi (Japan); Koepke (Germany); Aymar (CERN); Iarocci (CERN Council); Ogawa (Japan); Kim (Korea); Turner (NSF - US); Trischuk (Canada); Halliday (PPARC); Staffin (DoE – US); Gurtu (India)

Guests: Barish (ITRP); Witherell (Fermilab Director,)

“The Funding Agencies praise the clear choice by ICFA. This recommendation will lead to focusing of the global R&D effort for the linear collider and the Funding Agencies look forward to assisting in this process.

The Funding Agencies see this recommendation to use superconducting rf technology as a critical step in moving forward to the design of a linear collider.”

FALC is setting up a working group to keep a close liaison with the Global Design Initiative with regard to funding resources.

The cooperative engagement of the Funding Agencies on organization, technology choice, timetable is a very strong signal and encouragement.
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- The ITRP recommendation was presented to ILCSC & ICFA on August 19 in a joint meeting in Beijing.
- ICFA unanimously endorsed the ITRP’s recommendation on August 20 and J. Dorfan announced the result at the IHEP Conference.
- The ITRP recommendation was discussed and endorsed at FALC (Funding Agencies for the Linear Collider) on September 17 at CERN.
- The final report of ITRP was submitted to ILCSC on September 20 and is now available.
  http://www.ligo.caltech.edu/~skammer/ITRP_Home.htm
What Comes Next?

- ICFA declared that the old names NLC, GLC, TESLA are now retired, and the project will be called ILC.

- ILCSC is now setting up the “Global Design Initiative” (GDI), comprised of two parts (GDE [Effort] for up to agency approval and funding; GDO [Organization] when agencies take ownership.

The plan:

- A Central Team located at a National Laboratory Site, with Director, Chief Accelerator Scientist, Chief Engineer and staff initially of 10-15.

- Three regional teams sited in Asia, Europe and North America as determined by the regions. Each to have a Regional Director who join with the Central Team Director, Accel. Scientist and Engineer to form an overall directorate.

- Central Team to direct the work and design choices.

- Actual design of subsystems to be done in the Regional Teams.
ILC machine design:

• First ILC workshop to be held in KEK Nov. 13-15 -- invite ~120 accelerator physicists from around the world to review systems designs for cold LC; discuss which aspects of the TESLA proposal should be kept, and which need more thought, R&D; start to work on dividing R&D effort among regions and labs. US workshop at SLAC Oct. 14-16.

• KEK and SLAC have embraced the new design effort and are re-organizing to play critical roles.

• Fermilab will lead a consortium to build a superconducting rf test facility (in Meson East) with ANL, J-Lab, Cornell. They will build capability to fabricate and test superconducting cavities, cryomodules outside DESY.

• DESY, CERN and others won ‘EuroTeV’ grant from EU to study beam delivery systems, damping rings, polarized positron sources, beam diagnostics, integrated luminosity performance systems, metrology and global accelerator network (remote operation).

• CERN role is critical – its main foci are launching LHC (and its upgrades) and assuring its own future. R&D on CLIC will continue. However, in recent months, CERN has increasingly engaged in and supported the move toward the TeV scale ILC.
Fall 2002: ICFA created the International Linear Collider Steering Committee (ILCSC) to guide the process for building a Linear Collider. Asia, Europe and North America each formed their own regional Steering Groups (Jonathan Dorfan chairs the North America steering group).

**International Linear Collider Steering Committee**
Maury Tigner, chair

- **Physics and Detectors Subcommittee** (AKA WWS) Jim Brau, David Miller, Hitoshi Yamamoto, co-chairs (est. 1998 by ICFA as free standing group)
- **Accelerator Subcommittee** Greg Loew, chair
- **Parameters Subcommittee** Rolf Heuer, chair (finished)
- **Technology Recommendation Panel** Barry Barish, chair (finished)
- **Global Design Initiative organization** Satoshi Ozaki, chair (finished)
- **GDI central team site evaluation** Ralph Eichler, chair
- **GDI central team director search committee** Paul Grannis, chair
- **Communications and Outreach** Neil Calder et al
Conclusion

Remarkable progress in the past two years toward realizing an international linear collider:

- important R&D on accelerator systems
- definition of parameters for physics
- choice of technology
- start the global organization
- funding agencies are engaged

- Many major hurdles remain before the ILC becomes a reality (funding, site, international organization, detailed design, …), but there is increasing momentum toward the ultimate goal --- An International Linear Collider.