Activity Report
on the
Second International Linear Collider
Technical Review Committee

Gregory A. Loew

Chicago Workshop
On Physics and Dectectors at Linear Colliders

January 9, 2002

SECOND ILC-TRC CHARGE

- To assess the present technical status of the four LC designs at hand, and their potentials for meeting the advertised parameters at 500 GeV c.m. Use common criteria, definitions, computer codes, etc., for the assessments

- To establish, for each design, the R&D work that remains to be done in the next years to prepare a Conceptual Design Report from which final costs can be calculated and construction can proceed

- To assess the potential of each design for reaching higher energies above 500 GeV c.m., and the R&D work needed to reach this potential

- To suggest futures areas of collaboration

TRC Original Charge

"The Technical Review Committee is to consider the goal to design, build, and operate a TeV-scale linear electron-positron collider capable of satisfying the need to explore the particle physics of this energy range. Specifically, the Committee is to examine accelerator designs and technologies suitable for a collider that will initially have center-of-mass energy of 500 GeV and luminosity in excess of 10^{33} $cm^{-2}s^{-1}$, and be built so that it can be expanded in energy and luminosity to reach 1 TeV center-of-mass energy with luminosity of 10^{34} $cm^{-2}s^{-1}$. The Committee should consider construction and operation of both the initial facility and the upgrade path to 1 TeV. The Committee is also asked to comment on the potential of technologies to reach higher energies and luminosities, and to provide alternative physics capabilities, for example gamma-gamma collisions.

The Technical Review Committee is to identify the accelerator physics and technological requirements for each approach to provide particle physics opportunities at the energy and luminosity goals stated above. The report of the Committee should contain a brief commentary of the status of and expected progress toward understanding and achieving the most important of these requirements. The Committee should attempt to identify areas of possible further collaboration in the world-wide linear collider R&D program.

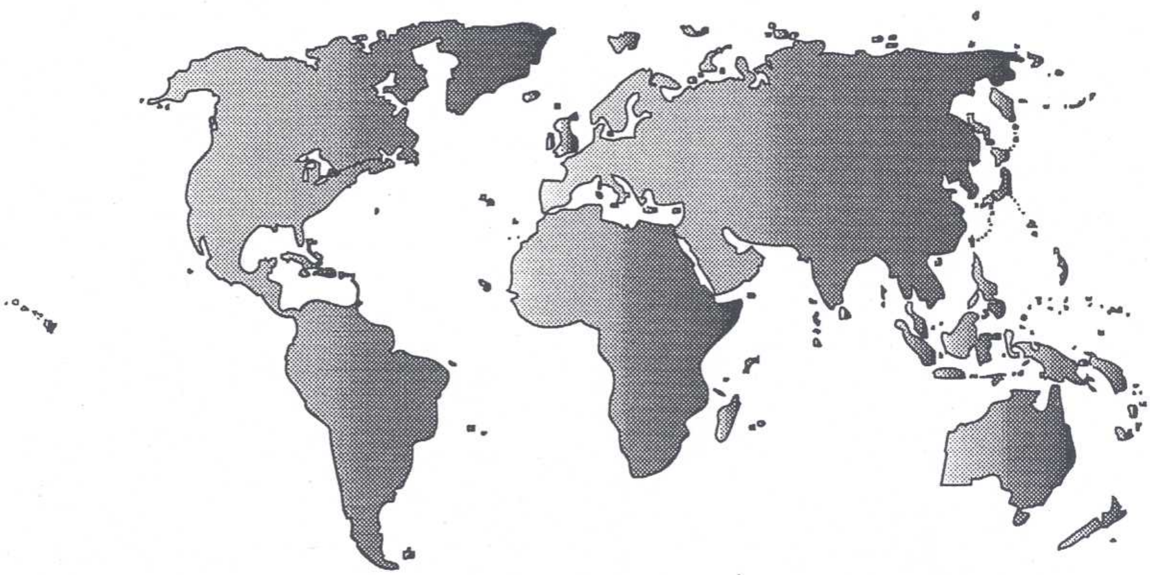
A draft of the Committee report should be submitted to the Collaboration Council shortly after the LC 95 meeting scheduled for March 1995 in Japan."

International Collaboration for R&D Toward TeV-Scale e^+e^- Linear Colliders

A Brief History of the First TRC Report

October 18, 1993 (LC93, SLAC)	First informal MOU drafts (DESY, KEK, SLAC) to organize International Collaboration
July, 1994 (EPAC, London)	First formal meeting of the Collaboration Council and creation of the TRC
Fall of 1994	Selection of first TRC membership and agreement on Table of Contents of Report
December 1995	Publication of Report

INTERNATIONAL LINEAR COLLIDER TECHNICAL REVIEW COMMITTEE REPORT 1995



Prepared for the Interlaboratory Collaboration for R&D Towards TeV-scale Electron-Positron Linear Colliders

Structure and Members of the Technical Review Committee

Steering Group:

G. Loew, Chairman
T. Weiland, Secretariat

Reading Committee:

B. Aune, V. Balakin, H. Edwards, K. Hübner, E. Paterson,
A. Sessler, K. Takata, G. Vignola, G. Voss, B. Wiik

Working Groups:

1) Injection Systems and Pre-Accelerators

M. Yoshioka, Chair
A. Mikhailichenko, Deputy Chair
H. Braun, J.P. Delahaye (CLIC), K. Flöttmann, J. Frisch, R. Miller, C. Pagani, L. Rinolfi,
J. Rosenzweig, H. Tang, C. Travier, D.A. Yeremian

2) Damping and Compression Systems

J. Rossbach (SBLC), Chair
J. Urakawa,Deputy Chair
S. Chattopadyhay, A. Mikhailichenko, J.P. Potier, T. Raubenheimer

3) Linac Technology

P. Wilson (NLC),Chair
D. Proch, Deputy Chair
N. Holtkamp, Deputy Chair
G. Caryotakis, T. Higo, H. Mizuno, W. Namkung, H. Padamsee, R. Palmer,
N. Solyak (VLEPP), G. Westenskow, I. Wilson

4) Beam Dynamics

K. Yokoya (JLC), Chair
A. Mosnier, Deputy Chair
G. Guignard, R. Ruth, R. Wanzenberg

5) Beam Delivery

R. Brinkmann (TESLA),Chair
V. Telnov, Deputy Chair
A. Dragt, J. Irwin, O. Napoly, K. Oide, A. Sery, B. Zotter

6) Experimentation

R. Settles, Chair
T. Markiewicz, Deputy Chair
S. Bertolucci, S. Kawabata, D. Miller, R. Orava, F. Richard, T. Tauchi, A. Wagner

Table 1.1
Linear Colliders: Overall and Final Focus Parameters – 500 GeV (c.m.)

	TESLA*	SBLC	JLC (S)	JLC (C)	JLC (X)	NLC	VLEPP	CLIC
Initial energy (c.of .m.) (GeV)	500	500	500	500	500	500	500	500
RF frequency of main linac (GHz)	1.3	3	2.8	5.7	11.4	11.4	14	30
Nominal Luminosity (10^{33} $cm^{-2}s^{-2}$)†	2.6	2.2	5.2	7.3	5.1	5.3	12.3	0.7-3.4
Actual luminosity (10^{33} $cm^{-2}s^{-2}$)†	6.1	3.75	4.3	6.1	5.2	7.1	9.3	1.07-4.8
Linac repetition rate (Hz)	10	50	50	100	150	180	300	2530-1210
No. of particles/bunch at IP (10^{10})	5.15	2.9	1.44	1.0	.63	.65	20	.8
No. of bunches/pulse	800	125	50	72	85	90	1	1-10
Bunch separation (nsec)	1000	16.0	5.6	2.8	1.4	1.4	–	.67
Beam power/beam (MW)	16.5	7.26	1.3	2.9	3.2	4.2	2.4	.8-3.9
Damping ring energy (GeV)	4.0	3.15	2.0	2.0	2.0	2.0	3.0	2.15
Main linac gradient, unloaded/loaded†† (MV/m)	25/25	21/17	31/–	40/32	73/58	50/37	100/91	80/78
Total two-linac length (km)	29	33	22.1	18.8	10.4	15.6	7	8.8
Total beam delivery length (km)	3	3	3.6	3.6	3.6	4.4	3	2.4

	TESLA*	SBLC	JLC (S)	JLC (C)	JLC (X)	NLC	VLEPP	CLIC
$\gamma\epsilon_x/\gamma\epsilon_y$ ($m\text{-}rad \times 10^{-8}$)	2000/100	1000/50	330/4.8	330/4.8	330/4.8	500/5	2000/7.5	300/15
β^*_x/β^*_y (mm)	25/2	22/0.8	10/0.1	10/0.1	10/0.1	10/0.1	100/0.1	10/0.18
σ^*_x/σ^*_y (nm) before pinch	1000/64	670/28	260/3.0	260/3.0	260/3.0	320/3.2	2000/4	247/7.4
σ^*_z (μm)	1000	500	120	120	90	100	750	200
Crossing Angle at IP (mrad)	0	3	6.4	6.0	6.1	20	6	1
Disruptions D_x/D_y	0.56/8.7	.36/8.5	.29/25	.20/18	.096/8.3	.07/7.3	.4/215	0.29/9.8
H_D	2.3	1.8	1.6	1.4	1.4	1.34	2.0	1.42
Upsilon sub-zero	.02	.037	.20	.14	.12	.089	.059	0.07
Upsilon effective	.03	.042	.22	.144	.12	.090	.074	.075
δ_B (%)	3.3	3.2	12.7	6.5	3.5	2.4	13.3	3.6
n_γ (no. of γ's per e)	2.7	1.9	2.2	1.5	.94	.8	5.0	1.35
N_{pairs}(p_T^{min}=20 MeV/c,θ_{min}=0.15)	19.0	8.8	31.6	10.3	2.9	2.0	1700	3.0
$N_{hadrons}$/crossing	0.17	0.10	0.98	0.23	0.05	0.03	45.9	0.05
$N_{jets} \times 10^{-2}$ (p_T^{min}=3.2 GeV/c)	0.16	0.14	3.4	0.66	0.14	0.08	56.4	0.10

* Refer to Section 1.1 regarding possible TESLA parameter changes.

† For the sake of uniformity, the nominal luminosity is simply defined as $N^2/4\pi\,\sigma^*_x\,\sigma^*_y$ times the number of crossings per second, and in all cases assumes head-on collisions, no hour-glass effect and no pinch. The actual luminosity incorporates all these effects, including crossing angle where applicable. NLC calculations assume crab-crossing.

†† The loaded gradient includes the effect of single-bunch (all modes) and multibunch beam loading, assuming that the bunches ride on crest. Beam loading is based on bunch charges in the linacs, which are slightly higher than at the IP.

Table 1.2

Pre-linacs, Damping Rings and Main Linac Parameters – 500 GeV (c.m.)

	TESLA*	SBLC	JLC (S)	JLC (C)	JLC (X)	NLC	VLEPP	CLIC
Pre-linacs								
First stage $e\pm$ energy (GeV)	4	3.15	1.98	1.98	1.98	2	3.0	2.15
Second stage $e\pm$ energy (GeV)	-	-	-	20	10-20	10	–	9.0
Beam energy to make e^+ (GeV)	250	250	10	10	10	3-6	150	2.15
Damping Rings								
e^+ pre-damping ring energy (GeV)	-	-	1.98	1.98	1.98	2.0	–	2.15
$e\pm$ damping ring energy (GeV)	4	3.15	1.98	1.98	1.98	2.0	3.0	2.15
Ring circumference (m)	20,000	650	222	321	277	223	160	283
Damping times (ms) (τ_x/τ_y)	20/20	3.8/3.8	6.1/8.0	3.5/4.3	4.0/5.2	4.1/4.6	1.8/2.9	10.5/10.5
Number of bunches per ring	800	125	100	288	340	360	3	48×10
Bunch length (mm)	10	3.6	4.8	5.0	5.0	4.1	9.8	1.8
Extr. beam emittance, $\gamma\epsilon_x/\gamma\epsilon_y$ 10^{-6}	20/1	10/.5	3/0.03	3/0.03	3/0.03	2.5/0.03	45.5/0.45	2.5/0.04
Main Linacs								
RF frequency (GHz)	1.3	3.0	2.8	5.7	11.4	11.4	14	30
Unloaded/loaded†† gradient (MV/m)	25/25	21/17	31/–	40/32	73/58	50/37	100/91	80/78
Active two-linac length (km)	20	30.2	19.8	15.7	8.7	14.2	5.8	6.3
Total two-linac length (km)	29	33	22.1	18.8	10.4	15.6	7.0	8.8
Total number of klystrons	604	2517	2560	4356	3320	3936	1400	2
Total number of modulators	604	2517	2560	2178	3320	1970	140	NA
Klystron peak power (MW)	8	150	135	48	135	50	150	NA
Klystron repetition rate (Hz)	10	50	50	100	150	180	300	2530/1210
Klystron pulse length (μsec)	1315	2.8	4.5	2.4	.5	1.2	.5	.0116/.00176
Pulse compression ratio	-	-	3.75	5	2	5	4.55	-
Pulse compression gain	-	-	~2	3.5	1.96	3.83	3.2	-
RF pulse length at linac (μsec)	1315	2.8	1.2	.480	.230	.240	.110	.0116/.00176
Number of sections	19328	5034	5120	8712	6640	7872	5600	22466
Section length (m)	1.04	6	3.6	1.8	1.31	1.8	1.0	0.280
a/λ (range if applicable)	.15	.16/.11	.14/.10	.16/.12	.20/.14	.22/.15	.14	.20
Total AC power to make rf (MW)	164	139	118	139	114	103	57	100
Wall plug → beam efficiency (%)	20	10.4	3.0	4.6	5.6	8.2	8.4	1.6/7.8

* Refer to Section 1.1 regarding possible TESLA parameter changes.

†† The loaded gradient includes the effect of single-bunch (all modes) and multibunch beam loading, assuming that the bunches ride on crest.

Second ILC-TRC Report
Major Milestones and Timetable

February 8-9, 2001	ICFA at its DESY meeting requests second ILC-TRC study and report
July 27, 2001	After several months of work and discussions, ILC-TRC Steering Committee is formed, and new proposal is submitted to ICFA in Rome. ICFA accepts proposal.
August-October 2001	Constitution of the Working Groups/ Assignments
November 2001	Working Groups begin their assignments
December 14, 2001	Completion by Steering Committee of first overall megatables listing machine parameters

Membership of the Steering Committee

Chair: Gregory Loew

Members:
1) Reinhard Brinkmann (DESY)
2) Kaoru Yokoya (KEK)
3) Tor Raubenheimer (SLAC)
4) Gilbert Guignard (CERN)

The Four Technical LC Approaches to be Assessed

1) TESLA
2) JLC (C-band)
3) JLC (X-band)/NLC (X-band)
4) CLIC

Technology, RF Power and Energy Performance Subgroups

- Structures
- Power Sources
- Power Distribution
- Injectors and Beam Delivery Technologies
- Reliability

ILC-TRC Working Group Members

Luminosity Performance Working Group
Gerry Dugan - Chair
Ralph Assmann - CERN
Peter Tennenbaum - SLAC
Jacques Gareyte – CERN
Witold Kozanecki - Saclay
Kiyoshi Kubo - KEK
Nan Phinney - SLAC
Daniel Schulte - CERN
Nick Walker - DESY
Andy Wolski - LBL
Ron Settles - MPI
Joe Rodgers - Cornell
Andrei Seryi - SLAC
Winifried Decking - DESY

This group will play a role similar to the first TRC Beam Dynamics group, but will broaden its scope to analyze all those factors which affect the ultimate luminosity performance (both peak and integrated) of all four machines, including but not limited to, emittance dilution, beam jitter, tunability, and reliability. It will look at all phenomena which can reduce the luminosity at each machine sub-system, so as to predict the final emittances and luminosity reachable at the interaction point. Wherever possible, the members of this group (including a few dectector representatives) should set common standards and use common computer codes to predict emittances, jitters, etc. Calculations should take into account mechanical and electrical tolerances, ground motions at various sites, etc. The standards and assumptions should be clearly spelled out.

11/29/01

Luminosity Performance Subgroups

1. Sources
   Photocathode and conventional electronic sources
   Conventional and undulator-based positron sources and pre-accelerators
   Charge and polarization production and preservation, technical risks

2. Damping rings
   Emittance in/out, polarization, technical risks

3. Beam transport from damping rings and bunch compressors through main linacs, beam delivery, beam-beam effects, dumps, technical risks

4. Collimators, backgrounds, detector interface, technical risks

5. Reliability and operability (% luminosity delivered in given energy band), MTBF of components, technical risks.

Major Milestones and Timetable
(Continued)

January 2002	Project Descriptions ready
February 4-8, 2002	First review and discussion of Working Group reports at LC 2002 at SLAC Freeze of parameters for 500 GeV c.m. energy designs
April 2002	Second Review of Working Group reports, location to be determined
June 2002	First draft of Report, meeting at EPAC, Paris
October 2002	Report ready

LC02 Workshop Schedule

Sunday 3-Feb-02	Time	Monday 4-Feb-02	Tuesday 5-Feb-02	Wednesday 6-Feb-02	Thursday 7-Feb-02	Friday 8-Feb-02
	8:00	Coffee and Registration	Coffee	Coffee	Coffee	Coffee
	9:00	Welcome Physics Goals - TBD TLC "Loew Panel" - G. Loew TESLA (45 mins)	Working Groups	Working Groups	Working Groups	Plenary Summaries WG1 (30 mins) WG2 (30 mins) WG3 (30 mins)
	10:30	Coffee Break	Coffee Break	Coffee Break	Coffee Break	Coffee Break
	11:00	NLC/JLC (45 mins) C-Band RF (15 mins) CLIC (30 mins)	Working Groups	Working Groups	Working Groups	WG4 (30 mins) WG5 (30 Mins) Closing
	12:30	Lunch	Lunch	Lunch	Lunch	ADJOURN
Registration Auditorium Breezeway	13:30	Working Groups	Working Groups	Working Groups	Working Groups	
		Coffee Break (15:30 on Monday)				
	16:00	Plenary Seminar "Free Electron Lasers" J. Rossbach (DESY)	Coffee Break	Coffee Break	Coffee Break	
			Plenary Seminar "The LC - a Smarter Machine" T. Himel (SLAC)	Plenary Seminar "Bkdwn and Gradients in Normal and SuperC" H. Padamsee (Cornell)	Plenary Seminar "The Importance of Test Facilities" TBD	
		Reception (17:30)				
		Cantor Arts Center Stanford Campus		Banquet (19:00)		
				Faculty Club Stanford Campus		

Outcomes and Conclusions

1) An international group that knows how to work together

2) Agreement on what still needs to be done on all projects, when and how, 500 GeV and up

3) Criteria for site selection(s)

4) Road maps toward the CRDs and foundations for final cost estimates

5) Possible recommendation(s) or preference(s) tainted by the energy reach, available R&D funding and corresponding schedules, confidence levels, risk assessments, and politics

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11/29/01

Table 1.1 Overall Parameters

	TESLA		JLC (C)		JLC/NLC* (X)		CLIC	
Center of mass energy	500 GeV	800 GeV	500 GeV	1000 GeV	500 GeV	1000 GeV	500 GeV	3000 GeV
RF frequency of main linac (GHz)	1.3		5.7		11.4		30	
Peak luminosity ($10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	34	58	7.95	8.41	25.0 (20.0)	25.0 (30.0)	14.2	103
Linac repetition rate (Hz)	5	4	100		150 (120)	100 (120)	200	100
No. of particles/bunch at IP (10^{10})	2	1.4	1.1	1.4	0.75		0.4	
No. of bunches/pulse	2820	4886	72		192		154	
Bunch separation (nsec)	337	176	2.8		1.4		0.67	
Beam power/beam (MW)	11.3	17	3.2	4.0	8.6 (6.9)	11.5 (13.8)	4.9	14.8
Unloaded/loaded gradient† (MV/m)	23.4 / 23.4	35 / 35	42 / 33.9	59.5 / 49.2	70 / 55		172 / 150	
Total two-linac length (km)	30	30	17.7	24.9	12.6	25.8	5.0	27.5
Total beam delivery length (km)	3		XX		3.7		7	
Proposed site length (km)	33		XX		32		40	
Tunnel configuration	Single		Double		Double		Single	

* Numbers in ( ) correspond to US site with 120 Hz repetition rate.

† The main linac loaded gradient includes the effect of single-bunch (all modes) and multibunch beam loading, assuming that the bunches ride on crest. Beam loading is based on bunch charges in the linacs, which are slightly higher than at the IP.

Table 1.4 Main Linac Parameters

	TESLA		JLC (C)		JLC/NLC* (X)		CLIC	
	500 GeV	800 GeV	500 GeV	1000 GeV	500 GeV	1000 GeV	500 GeV	3000 GeV
Initial Energy (GeV)	5		10		8		9	
RF frequency (GHz)	1.3		5.7		11.4		30	
Unloaded/loaded† gradient (MV/m)	23.4 / 23.4	35 / 35	44 / 34	59.5 / 49.2	70 / 55		172 / 150	
Overhead for fdbk & repair (%)	2		0	0	5		13	10
Overhead for off-crest operation (%)	0.4		0	0	5		XX	XX
Active two-linac length (km)	21.6	23	14.2	19.9	10.1	20.2	3.7	21.5
Total two-linac length (km)	30	30	17.7	24.9	12.6	25.8	5.0	27.5
Total number of klystrons	572	1212	3956	5562	3744 (1872)	7488 (3744)	332	364
Total number of modulators	572	1212	3956	5562	468 (234)	936 (468)	332	364
Klystron peak power (MW)	9.7		50	100	75		50	
Klystron repetition rate (Hz)	5	4	100	50	150 (120)	100 (120)	200	100
Klystron pulse length (μsec)	1370		2.5		1.6 (3.2)		18	100
Pulse compression ratio	1		5		4 (8)		32x4	32x22
Pulse compression gain	1		3.6		3.4 (6.8)		32x4	32x22
RF pulse length at linac (μsec)	1370		0.49		0.40		.13	.13
Number of sections	20592	21816	7912	11124	11232	22464	14544	42940
Section length (m)	1.04		1.8		0.9		0.5	0.5
a/λ (range if applicable)	0.15		0.165 – 0.130		0.210 – 0.148		0.212 – 0.199	
v_g/c (%)	–		3.1 – 1.3		5.1 – 1.1		10.4 – 5.2	
Filling time (ns)	4.2×10^5		296		120		30	
Q Unloaded	10^{10}		10036		9055 – 8093		3628 – 3621	
Shunt impedance (MΩ/m)	10^{13}		54.1		81.2		XX	
Total AC power for linacs‡ (MW)	95	160	145	146	150 (120)	200 (240)	100	300
Wall plug → Rf efficiency (%)	37.3		24.1	33.8	37.4		40.3	
Rf → beam efficiency (%)	62.4	56.5	17.6	15.9	26.7		21.3	

* Numbers in ( ) correspond to US site with 120 Hz repetition rate.

† The main linac loaded gradient includes the effect of single-bunch (all modes) and multibunch beam loading, assuming that the bunches ride on crest. Beam loading is based on bunch charges in the linacs, which are slightly higher than at the IP.

‡ Total AC power includes power for the cryo-plant in a superconducting facility and it includes power for cooling water in a normal conducting facility. It does not include power for distribution and it does not include power for magnets, movers, instrumentation or lighting.

ILC-TRC Working Group Members

Technology, RF Power & Energy Performance Working Group
Daniel Boussard - Chair
Chris Adolphsen - SLAC
Helen Edwards – FNAL
Kurt Hubner – CERN
Hans Weise - DESY
Marc Ross – SLAC
Nobu Toge – KEK
Tsumoru Shintake - KEK
Ralph Pasquinelli – FNAL
Lutz Lilje - DESY
Perry Wilson - SLAC
Pavel Logatchov - BINP
Hans H. Braun - CERN

This group will play a role similar to the first TRC Linac Technology working group, but will broaden its scope to analyze all those factors which affect the energy performance of all four machines. It will look at sources, injectors, magnets, cryogenics, klystrons, power supplies, modulators, rf pulse compression systems, rf amplitude and phase stability, and any other parts of the designs which determine whether the machines can reliably reach their operating energy, be tunable, and efficient in their use of electric power.