SB2009 Proposal Document

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1 Introduction

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The Technical Design (TD) Phase of the ILC Global Design Effort will produce a technical design of the ILC in sufficient detail that project approval from all involved governments can be sought. The TD phase will culminate with the publication of a Technical Design Report (TDR) at the end of 2012. The key elements of the TDR will be:

- A complete and updated technical description of the ILC in sufficient detail to justify the associated VALUE estimate.
- Results from critical R&D programmes and test facilities which either demonstrate or support the choice of key parameters in the machine design.
- One or more models for a Project Implementation Plan, including scenarios for globally distributed mass-production of high-technology components as "in-kind" contributions.
- An updated and robust VALUE estimate and construction schedule consistent with the scope of the machine and the proposed Project Implementation Plan.

The TD plan is divided into two phases:

- **TD Phase 1** will conclude in mid-2010. The emphasis of TD Phase 1 is on high-priority risk-mitigating R&D – most notably the Superconducting RF linac technology – and quantifying the scope for potential cost reduction of the current Reference Design (Accelerator Design and Integration, or ADI, activities). The end of TD Phase 1 will also see a re-baseline of the conceptual machine design, in preparation for further technical design work in TD Phase 2. The end of TD Phase 1 is an appropriate time to propose a new baseline reference design because:

    1) The proposal builds on three years of Accelerator Design and Integration work accomplished since the publication of the Reference Design Report (RDR) in early 2007,

    2) the establishment of a new baseline in 2010 enables specific, more detailed, design work and costing to be completed by the end of 2012,

    3) the new baseline will include updates devised in accordance with results from three years of R & D effort, notably on SCRF technology and,

    4) the new baseline will also include updates intended to be consistent with proposed Project Implementation Plans, which were not available prior to the publication of the RD Report.

- **TD Phase 2** (2010-2012) is intended to consolidate the new baseline reference design with further technical design studies leading to an updated VALUE estimate and construction schedule. In parallel remaining critical R&D and technology demonstration milestones will be concluded. A further critical component of TD Phase 2 will be the detailed development of the Project Implementation Plan.

This document is the Proposal for the new baseline reference design. Section 1, the Introduction, outlines the purpose of this important project milestone. Section 2 explains the motivation for the proposal and the philosophy and thought process behind it. It also gives summaries of specific items in the proposal. Section 3 gives a description of the proposed new layout of the accelerator complex. Section 4 gives specific descriptions of the design changes proposed for each of the accelerator subsystems. Section 5 discusses cost implications and summarizes the cost increments. Section 6 outlines how risk-mitigating R & D in support of the new baseline will be accounted against the original Reference Design Risk Register.

An important step is to confirm the proposed baseline accelerator system configuration, on which the design, costing and R&D efforts are based. It is for this purpose that the Proposal document for the new baseline will be submitted to the Project Director for analysis and review in early 2010, before launching the TDP2. In due course, reviews, high-level approval, and possible refinements are expected before the establishment of the new baseline configuration.

2 SB2009 Overview

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2.1 Rationale and Methodology

The ILC Reference Design Report, published in early 2007, included a VALUE estimate of the cost for the project of roughly 6.6 B ILC units. The new baseline is intended to be a better design, with a reduced value estimate and acceptable or, perhaps reduced, risk. It should also be better adapted to emerging project implementation strategies and recent R & D results.

The motivation for subsystem cost reduction in the TDP is based on a commitment to balance progress in one area or system against a concern for possible cost increase in another. Broadly, there are two types of cost reductions, 1) those resulting from engineering evaluation and detailed design and 2), those resulting from changing basic parameters or applying results from ongoing R & D. The overall maturity level of the 2007 Reference Design indicates most project cost reduction will come from the former, rather than the latter, but the engineering resources needed to accomplish the needed 'value engineering' activity are not available at present. With a few exceptions, this Proposal is based on relatively large changes intended primarily to reduce the Conventional Facilities & Siting criteria.

Thus, simple cost reduction is not achieved by imposing a uniform cut of the allocated construction budget across the entire system. In this proposal 'cost containment' is pursued with several specific and simultaneous goals in mind. Each such goal, their guiding principles, and implications are here:

- Overall cost reduction - Any opportunities for cost reduction should be taken, in as much as they do not pose a major threat to the system's performance.
- Improved understanding of system functionality - Understanding of any performance threat forces a careful analysis of systems' functionality, strength or vulnerabilities, which has a critical value on its own.
- Improved cost balancing - Cost margins, which are created in some subsystems through this exercise, can be made available for some other subsystems which are found to require an increased construction cost.
- More robust design - These efforts, if done appropriately, are expected to improve the overall robustness of the ILC systems design.
- More complete design - These efforts would force the team to revisit many of the design and implementation details which might not have been completely thoroughly covered during the RDR era.
- Reoptimised R&D plans - Improved understanding of the system functionalities and performance issues would help us produce a reoptimized and more effective global R&D plans to pursue in TDP2, for the technologies required for the ILC.

Our re-baselining proposal has been developed in this spirit through an associated review process which involved a series of internal meetings, some of which were done remotely via internet and some others which were done in the framework of face-to-face meetings.

The iterative work for development of this re-baselining proposal was carried out by the a team which consists of:

- a set of key leaders around the Project Managers who organized the efforts and led the overall discussion and direction,
- individual "area groups" and "global groups" who are responsible for specific accelerator subsystems or accelerator-wide facility systems,
- the costing group who are responsible for collecting and organizing the cost implications
- ad-hoc groups formed under the leadership of the Project Managers to address the risks in terms of technical development toward construction of the ILC and the systems availability.

The documents which help interested leaders to trace this design development process are available at XXXXX.

2.2 Summary of Proposed Changes

Figures 2-1 shows an approximate comparison of the overall ILC layout as documented in RDR and as put forth in the proposed new baseline.

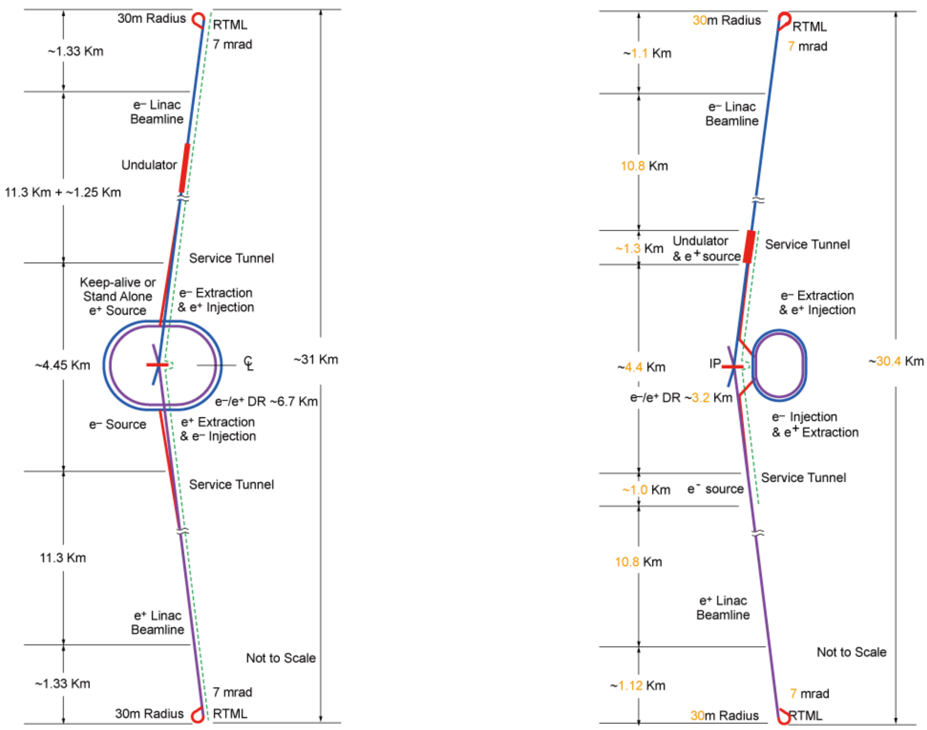

Figure 2-1: RDR layout (left) and the re-baseline layout in proposal (right).

Both the RDR layout and the proposed new layout require a site footprint of approximately 31km length. Both layouts support a single detector hall which can accommodate two detector systems that alternately share the beamtime.

The following changes are proposed for the ILC design baseline configuration.

1. A main linac length to be consistent with an **optimal choice of average accelerating gradient**. It was set to be 31.5MV/m in the specification RDR cryomodule operational gradient, and the ILC

ML operational gradient is to be re-evaluated and to be settled including reasonably sufficient, RF operational margin.

2. **Single-tunnel solution** for the main linacs and RTML, with two possible variants for the HLRF - Klystron cluster scheme and Distributed RF System scheme.
3. **Undulator-based e+ source** located at the end of the electron main linac (i.e. 250GeV) - capture device based on quarter-wave transformer, remaining conservative with continued R&D on alternatives.
4. **Reduced beam parameter set** with respect to RDR - nb = 1312 so-called "low power" as the baseline with provision for upgradeability later.
5. Approximately **3.2km circumference damping rings** at 5GeV - 6mm bunch length for either 3 or 6 km rings.
6. **Single-stage bunch compressor** -- compression factor of 1/20.
7. **Central Region Integration** off the e+ and e- sources into a common "central region beam tunnel", together with the BDS.

2.3 System Tables

		RDR	SB2009
Beam and RF Parameters			
No. of bunches		2625	1312
Bunch spacing	ns	370	740
beam current	mA	9	4.5
Avg. beam power (250 GeV)	MW	10.8	5.4
Accelerating gradient	MV/m	31.5	31.5 >> TBD
Pfwd / cavity (matched)	kW	294	147
Qext (matched)		3.00E+06	3.00E+06
Tfill	ms	0.62	1.13
RF pulse length	ms	1.6	2
RF to beam efficiency	%	61	44

IP Parameters				
Norm. horizontal emittance	mm.mrad	10	10	
Norm. vertical emittance	mm.mrad	0.040	0.035	
bunch length	mm	0.3	0.3	
horizontal β*	mm	20	11	
horizontal beam size	nm	640	470	
			no trav. focus	with trav. focus
vertical β*	mm	0.4	0.48	0.2
vertical beam size	nm	5.7	5.8	3.8 (?)
Dy		19	25	21
δEBS/E	%	2	4	3.6
Avg. PBS	kW	260	200	194
Luminosity	$cm^{-2} s^{-1}$	2.00E+34	1.50E+34	2.00E+34

2.4 Summary of Proposed Changes

2.4.1. Main linac – SCRF operational field gradient in beam acceleratrion

Apart from the R&D goal to reach the 9-cell cavity maximum field gradient ot 35 MV/m in vertical test, and to reach an averaged field gradient of 31.5 MV/m in the cavity-string test in cryomodule, we would propose an averaged field gradient of xx MV/m in the beam acceleration gradient with the ML cryomodule string. It shall be required to allow RF operational margin (for tuning, and dynamic variation of the power distribution (such as in case of a quench). The FLASH beam test with a prototype cromodule operation will give us further detail evaluation,

2.4.2. Main linac –Single tunnel configuration

Foremost among the proposed changes is the adaptation of the main linac tunnel configuration to one with only a single, accelerator-enclosure tunnel, which does not have the support equipment tunnel proposed in the Reference Design. Several key studies and strategic initiatives make it advisable to propose this change for the new baseline:

1. The single tunnel configuration is a simpler underground construction
2. Safety studies commissioned in each region (Asia /Japan, Americas/US and Europe / CERN) indicate valid single-tunnel life safety egress strategies may be realized in some variations according to each regional features/constraints,
3. R & D on High Level RF power sources and distribution indicate that quite different, much more flexible, schemes from that outlined in the Reference Design may be feasible,
4. Availability studies that are adapted to the proposed new HLRF systems and linac tunnel configuration changes show an acceptable performance change can be expected with appropriate adaptation of sub-system designs and
5. The new configuration has an intrinsic flexibility that will allow parties with a potential 'bid-to-host' the confidence that a technically viable, safe, design solution exists and is well suited for their site.

2.4.3. Reduced beam parameter set

The proposed the new baseline change with largest anticipated cost saving is the reduced beam parameter option, in which the beam power is reduced by halving the number of bunches, *nb*, keeping the single bunch intensity the same as that of the 2007 Reference Design. Since the luminosity scales as $L \cdot N^2\, nb$, it is advantageous to reduce the number of bunches. In general the luminosity is restored by pushing the beam-beam parameters, which – although an increase in performance risk – are not considered a major cost driver.

In this option, there has been a conscious decision to not lower (below the Reference Design) the power handling capability of beam dumps, positron target and capture, etc, and other systems which might be difficult to upgrade later and after some time in operation. Thus technical risk is reduced for these complex, high-radiation components. This strategy allows studies of several possible future upgrade paths to be studied in TDP phase 2, while leaving the SB2009 as the ILC starting configuration.

2.4.4. Central Region Integration

The motivation for the Central Region Integration component of the proposed baseline is the simplification of the central region tunneling and civil engineering. By combining functions within a single underground enclosure, the complexity of the underground excavation in the central region can be substantially reduced. Thus a total reduction in tunnel length of xxx is realized and the number of tunnel intersections is reduced by nnn. (Section 3)

2.4.5. Optimal Choice of Average Accelerating Gradient (duplication with 2.4.1)

The most highly leveraged R & D, that has the greatest potential return, is the development of cavity gradient. The cost impact is seen primarily in the linac length required to achieve 500 GeV in the center of mass. The Reference Design gradient specification was adopted within the paradigm of developing a forward-looking design; hence a definitive demonstration of nominal performance 35 MV/m in low power, vertical test was left for the Design Phase of the project. It shall be required to allow RF operational margin (for tuning, and dynamic variation of the power distribution (such as in case of a quench)**.** The FLASH beam test with a prototype cromodule operation will give us further detail evaluation, The R & D Plan requires a re-evaluation of the Reference Design gradient specification at the end of TDP-1, a major milestone.

2.4.6. Undulator-based e+ source change

The motivation for moving the undulator – based positron source to the end of the e-linac is to simplify the operation of the source and to consolidate technical systems: 1) machine protection of the undulator is combined with machine protection of the Beam Delivery system, resulting in a net beamline length reduction of about 400 m, 2) the backup 'auxiliary' positron source is integrated with the main high-power source, and 3) the low energy un-damped positron transport system is shortened several kilometres. With this move, the positron source moves within +/- 2.5 km of the center of the accelerator complex, a feature which may be advantageous for a given potential site.

The new baseline proposal includes a description of a possible low energy operational scheme. The scheme is consistent with the RDR: "Physics runs are possible for every energy above sqrt_s = 200 GeV and calibration runs with limited luminosity are possible at sqrt_s = 91 GeV".

An additional change is the adoption of a simpler capture magnet (Quarter Wave Transformer, QWT) immediately after the pair-production target. This simpler magnet is clearly feasible and so adopting this magnet reduces the risk for this item in comparison with the previously assumed flux concentrator which has not yet been shown to be feasible, although studies continue on this important R&D topic.

2.4.7. 3.2km Circumference Damping Rings

The reduced beam parameter set, with *nb* half of the RDR value, allows the reduction of the circumference of the damping ring, while maintaining the same inter-bunch distance. The rings are simpler, having roughly half the number of components, and less expensive.

2.4.8. Single Stage bunch compressor

The single stage bunch compressor is made feasible by the reduction incoming bunch length from 9 mm (Reference Design) to 6 mm. The overall compression, from 6 mm to 300 microns, is thus reduced from the RDR factor of 45 to a factor of 20.