5 Cost Studies

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5.1 Purpose

This section describes the studies that have been made so far on the cost differentials that would result from the changes of the design baseline that are presented in an earlier part of this proposal document. The primary focus of this costing exercise, at this stage, is to understand and support the cost changes in the context of overall evaluation of the design changes. Therefore, no re-evaluations are considered for the costing numbers that were already presented in the RDR. The results presented here, together with those from risk assessment, after due review process, would then form the basis for the baseline assumptions in TDP2, where the full technical design and cost estimating work will be built upon.

5.2 Methodology

Unit costs of individual components: The same unit cost numbers as RDR are used, whenever the same components are used in the proposed new baseline scheme. Exceptions are the Klystron Clusters and Disributed RF Systems (DRFS) for the main linacs where radically new components which did not appear in RDR are introduced. For these, the unit cost numbers were evaluated for each of the new components and are used to estimate the relevant system cost. Otherwise, no new unit costs are generated, and relatively straightforward updates from the RDR estimate are made, whenever possible. Parts of this study include some scaling or parameterization from RDR unit costs or summary costs.

Technical systems and conventional facilities: The ILC RDR estimate had a single design and a single cost estimate for the technical elements, such as power supplies, magnets, RF components, vacuum systems, control systems and others. However, for the conventional facilities and civil construciton, the RDR studies were made on the three regional sample sites, separately, to account for effects of differing geologies and geographies and differing conventional construction and facilities designs. However, since they were more complete than for the Asian and European Conventional Facility Estimates, only the Amercicas CFS estimates were used for these cost studis for SB2009.

The estimates for the SB2009 studies address two technical approaches and configurations for the RF power source systems for the main linacs, i.e. the Klystron Clusters and DRFS. They are both considered for each of the three regional sample sites. It is noted, however, that for these considerations, there are some known inter-dependence between a particular site and a preferred technical approach or configuration.

Evolution of the ILC Estimate:

Starting with the published Reference Design Report, the evolution through corrections and modification of the RDR estimate is illustrated. This includes the Sendai 2008 decisions to change to a 6.4 km racetrack Damping Ring and to a single-stage Bunch Compressor for the RTMLs and the various combinations of options under consideration under SB2009 for the new baseline design. The estimates quoted are intended to allow examination and comparison of various elements within the proposed design changes in a more coherent fashion. In many cases, the design changes can be said to have cost impacts in an "orthogonal manner" which can be factored. For instance, adopting a

single tunnel and Klystron Cluster/DRFS for the Main Linac does not affect the DR configuration or associated cost differencials. However, exceptions also exist. For example, the choice of a 3.4 km Damping Ring may make it difficult to adopt the Full Power (2625 bunches/train) option for the ML.

5.3 Scenarios Being Estimated

Due to cost confidentiality concerns, this section will not quote the estimates beyond the corrections or adjustments to the RDR estimate, but will contain a short description on each. Members of the ILC-GDE Cost Management Group may access the password protected version including cost numbers at
https://www-ilcdcb.fnal.gov/estimates/SB2009/SB2009-Ch-5-Cost-Studies-with-Costs.doc

Note that 1 ILCU = $ 1 (2007)

6,618 M ILCUs – RDR estimate – average of 3 regional estimates

6,677 M ILCUs – RDR with Americas Regional CFS estimate

X,XXX M ILCUs (-66 M ILCUs) – RDR with Correction to Americas Regional CFS estimate,
corrected shaft base cavern volumes and outsourced civil engineering,
and added RTML invert floor.

X,XXX M ILCUs (-72 M ILCUs) – add Value Engineering for higher ΔT Cooling Water sys for ML only.

X,XXX M ILCUs (+X M ILCUs) – at Sendai, March 2008 –
changed DR from 6.7 km hexagonal => 6.4 km racetrack (need updated magnet # and costs):
Wigglers 80 => 88 per ring, RF remained at 18 per ring, other DR magnets remained same,
RTML and e+ Source transfer lines are extended to mate with racetrack DR (long axis ⊥ ML).

X,XXX M ILCUs (-XX MILCUs) – at Sendai, March 2008, adopted Single-stage Bunch Compressor for RTML. This change was enabled by the shorter bunch length from the racetrack DR.

X,XXX MILCUs (-XX M ILCUs) – removed 4*394 m of empty tunnel for expansion for energy margin,
including e- beam tunnel, e- service tunnel, e+ beam tunnel, and e- tunnel.
This was done to allow more direct comparison with the SB2009 estimates and drawings.

X,XXX M ILCUs – "modified RDR estimates without SB2009 considerations": 250x250 GeV, 2 tunnels,
4.5 meter diameter, full # bunches, full complement of klystrons and modulators,
6.4 km hexagonal DR: 88 wigglers, 18 RF per ring, single-stage Bunch Compressor for RTML,
e+ flux concentrator, dE(undulator) = 3 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel for drift for e+ timing.

X,XXX M ILCUs - SB2009 Updates to RDR (2 tunnels – 4.5 m dia.):
3.2 km DR, low Power, traveling focus, full complement of klystrons, Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – SB2009 Updates to RDR (2 tunnels – 4.5 m dia.) with 3.5 % Energy Margin:
3.2 km DR, low Power, traveling focus, full complement of klystrons, Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no extra tunnel or drift for e+ timing.

X,XXX M ILCUs– RDR - Low Power: ½ klystrons and modulators (longer pulse), with traveling focus,
2 tunnels – 4.5 meter diameter,
6.4 km DR, e- flux concentrator, dE(undulator) = 3.0 GeV compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – RDR – Low Power – with 3.5 % Energy Margin: 2 tunnels – 4.5 meter diameter,
with ½ klystrons and modulators (longer pulse), with traveling focus,
6.4 km DR, e- flux concentrator, dE (modulator) = 3.0 GeV compensated in e- ML,
no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – RDR – Low Power with SB2009 Updates: 2 tunnels – 4.5 meter diameter,
with ½ klystrons and modulators (longer pulse), with traveling focus,
3.2 km DR: 88=>32 wigglers, 18=>8 RF per ring, Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – RDR – Low Power with SB2009 Updates – with 3.5 % Energy Margin:
2 tunnels – 4.5 meter diameter,
remove ½ klystrons and modulators (longer pulse), with traveling focus,
3.2 km DR: 88=>32 wigglers, 18=>8 RF per ring, Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – Klystron Cluster – 1 tunnel – 4.5 m dia. – full Power: 6.4 km DR,
no Central Complex, e+ flux concentrator, dE(undulator)=3 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – Klystron Cluster – 1 tunnel - 4.5 m dia. – full Power – with SB2009 Updates:
3.4 km DR: 88=>32 wigglers, 18=>8 RF per ring, traveling focus, with Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – Klystron Cluster – 1 tunnel – 4.5 m dia.– full Power
– with SB2009 Updates and 3.5 % Energy Margin
3.4 km DR: 88 =>32 wigglers, 18=> 8 RF per ring, traveling focus,
with Central Complex, no extra tunnel or drift for e+ timing,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML.

X,XXX M ILCUs – Klystron Cluster – 1 tunnel - 4.5 m dia . – Low Power:
½ klystrons and modulators, travelling focus,
6.4 km DR, no Central Complex,
e+ flux concentrator, dE(undulator)=3 Gev, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – Klystron Cluster – 1 tunnel – 4.5 m dia. - Low Power – with SB2009 updates:
½ klystrons and modulators, traveling focus,
3.4 km DR: 88 =>32 wigglers, 18=> 8 RF per ring, traveling focus, with Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – Klystron Cluster – 1 tunnel – 4.5 m dia. – Low Power

– with SB2009 updates and 3.5% Energy Margin:
½ klystrons and modulators, traveling focus,
3.4 km DR: 88 =>32 wigglers, 18=> 8 RF per ring, traveling focus, with Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – DRFS – 1 tunnel – 5.2 m dia. – full Power: 6.4 km DR,
no Central Complex, e+ flux concentrator, dE(undulator)=3 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.
X,XXX M ILCUs – DRFS – 1 tunnel – 5.2 m dia. - full Power – with SB2009 Updates:
3.4 km DR: 88=> 32 wigglers, 18=> 8 RF per ring traveling focus, with Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.
X,XXX M ILCUs – DRFS – 1 tunnel – 5.2 m dia. – full Power – w SB2009 Updates & 5 % Energy Margin
3.4 km DR: 88=> 32 wigglers, 18=> 8 RF per ring, traveling focus, with Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no extra tunnel or drift for e+ timing.

X,XXX M ILCUs – DRFS – 1 tunnel – 5.2 m dia. - Low Power: ½ klystrons and modulators,
travelling focus, 6.4 km DR, no Central Complex,
e+ flux concentrator, dE(undulator)=3 Gev, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.
X,XXX M ILCUs – DRFS – 1 tunnel – 5.2 m dia. – Low Power – with SB2009 updates:
½ klystrons and modulators, traveling focus,
3.2 km DR: 88 => 32 wigglers, 18=>8 RF, including Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no allowance for energy margin, no extra tunnel or drift for e+ timing.
X,XXX M ILCUs – DRFS – 1 tunnel – 5.2 m dia. - Low Power – w SB2009 updates & 3.5% Energy Margin: ½ klystrons and modulators, traveling focus,
3.2 km DR: 88 => 32 wigglers, 18=>8 RF, including Central Complex,
e- flux concentrator replaced by QWT, dE(undulator) = 4.1 GeV, compensated in e- ML,
no extra tunnel or drift for e+ timing.

5.4 Issues with the Cost Study

Some elements of this cost study have not yet been completed. Updated quanties, parameters, and costs for conventional magnets for the hexagonal Damping Rings were not available – the RDR estimates were used. There is still some uncertainty on the extent and cost of the pulse distribution system for the DRFS. The positron timing drift for self-replacing positron bunches in the DR is quoted as 416 meters for the Central Injector Complex with 3.2 km DR. However, subsequent calculation has shown the drift length should be corrected to 462 meters. The cost impacts have not yet been updated to account for this small correction. It is also noted that the positron timing drift of 462 meters (or even 416 meters) would cover the 401 meters needed for the 3.5 % energy margin for the Klystron Cluster approach. However, the similar positron timing drifts for 5% energy margin for the DRFS and for 3.5% energy margin for the RDR would be approximately 2.07 km and 1.35 km, respectively. This is because the 5% energy margin for DRFS passes the boundary for another orbit in

the 3.2 km DR and the positron timing drift length is driven by quantized units of ½ of the circumference of the larger 6.7 km DR. Rather than adding such long tunnels with mostly empty drift space (FODO quads, trim magnets, instrumentation, and vacuum pipe, plus the cryomodules to produce the energy margin), it is hoped that a 4.0 % energy margin, which fits within the 462 m positron timing drift, will be within the uncertainty in machine performance to the recommended 5% energy margin for the DRFS. Otherwise, we would expect that another more active solution could be found to produce the self-replacing feature for the positron bunches in the DR, rather than just long drifts. Although these evaluations were not completed in time for the deadline for this written document, we will continue to study them and post updated versions when available.

New Electrical Power estimates have not being done completely. There has not been an electrical engineer assigned to the ILC-GDE CFS team over the last two years. An electrical engineer has recently been assigned at Fermilab. Only the impact on the electrical power equipment cost estimate for the Low Power option for the Klystron Cluster has been evaluated at this time. Similarly, due to lack of available personnel, the impacts on the Cryogenics estimates have only been evaluated in a parametric scaling manner for these new scenarios. It is unlikely that the impact in these areas will be fully evaluated for consideration by the SB2009 studies. However, it is necessary that adequate support in all Area, Techncial, and Global Systems, including electrical and cryogenic engineering, will be available for the Technical Design Phase.