## Impact Statement – February 8, 2008

Given the likelihood that there will be little or no support for ILC damping ring R&D in the US at institutions other than Cornell, it is necessary to assess the likely impact of this scenario on the CesrTA program. We had anticipated that our collaborators would provide hardware, in the form of instrumented wiggler chambers, help with simulation of electron cloud effects, and experimenters who would participate in our program of measurements at CESR. We expected a significant portion of the simulation effort to be carried out by our collaborators from SLAC, LBNL, KEK, ANL and Fermilab and that physicists from those institutions would participate in running the experiments with CESR. There will be no change in the simulation program activities at KEK but the limited effort that may be provided at SLAC, LBNL, ANL and Fermilab will have to be supported by their base programs and those base programs are under severe financial pressure. LBNL, with support from SLAC, was to provide the instrumented wiggler vacuum chambers as part of their ILC R&D funded program that has now been terminated. KEK may be able to carry out most of the fabrication of these critical chambers with some delay compared with the original schedule. The limited remaining final design work for the chambers will be carried out here at Cornell. Every effort will be made to limit the impact of these changes on our schedule but it is likely that the first tests with an instrumented wiggler vacuum chamber will be delayed from the originally planned tests in June 2008 until late 2008 or early 2009. The fast X-ray beam size monitor for the positron beam depends on adequate funding for CHESS to achieve the present installation schedule targeted for September 2008. It could be delayed if CHESS funding is constrained.

The program to use beam based alignment and other techniques to achieve ultra low emittance with the CESR lattice is likely to be limited by the number of experienced accelerator physicists involved in the process and the length of time that is devoted to the effort. With the reduced number of visitors and the reduced length of the experimental program, achieving a vertical emittance in the 5 to10 picometer range will represent a significant challenge. We believe that, with our available resources, a vertical emittance of less than 20 picometers will be achieved. This will provide a very sensitive probe of the emittance dependence of the electron cloud effects on the beam dynamics in this very low emittance regime. It is very unlikely that there will be any surprises in extrapolating these results to the few picometer vertical emittances of the ILC damping rings.

We are making every effort to garner as much support as we can from our collaborators who were previously supported by the ILC damping ring R&D program. We are also exploring the possibility of borrowing equipment that was designed and built as part of the electron cloud experimental program at SLAC. This would replace some of the effort required to incorporate additional beam diagnostics and mitigation techniques in modified CESR vacuum chambers. The recovered effort from this part of the project would help offset the additional design effort required to complete the design of the instrumented wiggler vacuum chambers.

Overall, the largest effect on the CesrTA research program by the rescoping of the ILC damping ring R&D will likely be some schedule slippage and a somewhat reduced capability in understanding the experimental results using calibrated simulation models for the beam dynamics effects due to the electron cloud. This may affect the milestones as enumerated in the CesrTA Project Description. Nevertheless, CesrTA remains a rich scientific program that retains all of the core elements of the original proposal.

**CesrTA De-scoped Plan for 2 Years of Damping Rings R&D**

**Outline of the Revised Plan that is consistent with a suggested 2 year funding profile**

**(The changes with respect to the proposal that was jointly reviewed by DOE and NSF in July are summarized in the table below.)**

The elements of the CesrTA proposal that will be preserved in the revised plan include:

1. Electron cloud growth and instability studies:
    a. Measure cloud growth in wiggler, dipole, quadrupole fields
    b. Test effectiveness of electron cloud suppression techniques
    c. Measure instability thresholds and emittance growth at the lowest achievable emittance.
    d. Test instrumented wiggler vacuum chamber at 5GeV
2. Development of low emittance tuning techniques with a goal of achieving 5-10pm vertical emittance
    a. Implement high resolution single turn BPM electronics for precision measurement of orbit and dispersion
    b. Upgrade survey equipment to improve the efficiency and accuracy of alignment of guide field magnets
    c. Analysis of beam based measurements to identify sources of emittance dilution
    d. Implementation of corrective measures based on findings (c)
    e. Test and refinement of low emittance tuning algorithms
3. X-ray beam size monitor

    Development of 1-dimensional x-ray beam size monitor with the capability of measuring variations of beam size at the lowest attainable emittance for both electrons and positrons.

The elements of the CesrTA proposal that will be deemphasized or eliminated include:

1. Study of ion related instabilities and emittance dilution
2. 2-dimensional x-ray beam size camera upgrade
3. Contingency for
    a. Follow-up tests of alternative mitigation techniques
    b. Tests of ILC prototype hardware
    c. Further reductions in beam emittance, and further refinement of low emittance tuning methodology.

**Low Emittance Tuning**

Perhaps the most challenging and uncertain aspect of the CesrTA program is the achievement of ultra-low vertical emittance. Low emittance tuning depends on implementation of new instrumentation, upgraded beam position monitors for precision measurement of orbits, upgraded survey equipment for magnet alignment, and x-ray beam size monitor to measure the ultra- low emittance. Beam based measurements will be used to identify sources of emittance blowup. In the proposed funding scenario, acquisition and installation of digital beam position monitor electronics can be completed during the third major shutdown. Upgraded survey equipment is available during the second shutdown. Both permit an accelerated start of the low emittance tuning program. However, subsequent machine operating time for beam based measurement, and down time for amelioration of emittance diluting sources, is significantly reduced in the proposed scenario, thus increasing risk that we will be unable to achieve our ultra-low emittance target of ~5-10pm.

**X-ray Beam Size Monitor**

The ability to measure vertical emittance at the 5-10pm level of both electron and positron beams is essential to the CesrTA program and we plan to accelerate the purchase of the x-ray optics and installation of the x-ray beam lines. We had originally proposed to enhance the functionality of the beam size monitor with a 2 dimensional camera upgrade. However, the 2-d capability is not critical to the low emittance tuning effort or the e-cloud research plan. In view of the limited running time, we do not expect to pursue the 2-d upgrade.

**Ions**

Because the available experimental time is limited, we will de-emphasize the fast ion studies.

**Running Time**

The greatest impact of the reduced running time is the loss of contingency for investigating unexpected discoveries, and testing ILC prototypes, and the increased risk associated with the low emittance part of the program. We are likely to find that the rate of progress in reducing emittance is set by the finite intellectual resources that can be brought to bear. We are exploring the possibility of involving physicists at SLAC (Cai), LBNL, Daresbury (Wolski) and BNL (NSLSII) as active participants in the low emittance tuning program as a way of leveraging the expertise at Cornell.

**Equipment**

According to the budget outlined by DOE/NSF, we are about $600k short on capital equipment. We save ~$250k with elimination of the 2D xray camera and hydrostatic level system. We will recover some of that shortfall, (about $160k), using existing UCLC grants (for general damping ring R&D, and CesrTA development). If we are unable to realize savings in the existing budget, or to persuade collaborators to contribute hardware to the CesrTA effort, we will necessarily reduce the number of tests of alternative e-cloud mitigation techniques.

**Collaboration**

We are exploring the possibility of collaboration with university research groups. In particular we are preparing descriptions of several components (eg, fast readout electronics for the electron cloud retarding field analyzers) which have a scope that is well-matched to work by university groups. We are negotiating with Alfred University to provide hardware as well as manpower resources for the development of the x-ray beam size monitor. We are pursuing expanded collaborations with Daresbury, LBNL and SLAC which may be able to provide hardware needed for the electron cloud experimental program. Indeed collaboration is essential to insure that the CesrTA R&D is integrated and consistent with the overall ILC damping rings program.

**Time Line with Tasks and Milestones**

The table of tasks and milestones below is an annotated version of the table that we presented at the review in July. An overstrike indicates an item that was in the original version and that we propose to excise. Items that we are able to move earlier in the program, thanks to the availability of equipment capital up front, are indicated in red. Other changes to the plan are indicated in blue.

| Period | Date | Duration | Tasks and Milestones |
|---|---|---|---|
| Down 1 | ~~4/1/08~~<br>5/19/08 | 15 days | ~~1) Install first instrumented wiggler chambers~~<br>~~a. One with diagnostics (control)~~<br>~~b. One with diagnostics and TiN coating*~~<br>1) Install first instrumented dipole chamber along with additional instrumented drift chambers in CESR |
| CesrTA Run 1 | 6/3/08 | 28 days | ~~1) Beam tests of wiggler chambers at 2-2.5 GeV~~<br>1) Electron cloud growth studies in instrumented chambers at 2-2.5 GeV<br>2) Low emittance operation and alignment studies in CESR-c configuration |
| Down 2 | 7/1/08 | 92 days | 1) Reconfigure CESR for low emittance<br>a. Wiggler moves (from arcs to L0)<br>b. Vertical separator removal (L3)<br>~~2) Instrumented copper vacuum chambers (RFAs)~~<br>~~a. Wiggler chambers with additional EC mitigation techniques* (L0 installation) and adjacent drift chambers.~~<br>~~b. Dipole and drift chambers in arcs (regions where wigglers removed). At least one dipole control and one coated chamber (likely NEG)*~~<br>2) Instrumented vacuum chambers (RFAs)<br>a. Install first wiggler chambers with EC instrumentation and mitigation hardware (L0 installation) and adjacent drift chambers..<br>b.Dipole and drift chambers in arcs (regions where wigglers removed). Mitigation hardware dependent on collaborator support<br>c. Drift chambers (or possibly dipole chicane if available from SLAC) in L3<br>3) Optics line for X-ray beam size monitor (positrons)<br>~~4) Deploy upgraded BPM system around ~25% of ring (half of vertical quadrupole locations)~~<br>4) Deploy upgraded BPM system around part of ring<br>5) Upgraded leveling and adjustment system on quadrupole stands |

| **Period** | **Date** | **Duration** | **Tasks and Milestones** |
|---|---|---|---|
| CesrTA Run 2 | 11/18/08 | 42 days | 1) Tests of EC growth in vacuum chambers at 2-2.5 GeV. Characterize growth as a function of bunch spacing, intensity, train configuration, emittance.<br>2) Continue beam-based and instrumental alignment program to achieve ultra low emittance<br>3) Experiments at low emittance to explore instability thresholds and emittance dilution due to the ECI and FII<br>~~4) Begin commissioning of positron X-ray BSM~~<br>4) Commission positron X-ray BSM |
| Down 3 | 1/6/09 | 43 days | ~~1) Install photon stop for 5 GeV wiggler operation in L0~~<br>~~2) Complete a large fraction of alignment/survey upgrade~~<br>2)Complete alignment/survey upgrade<br>3) Install 2 additional instrumented dipole chambers with EC mitigation*<br>4) Install 3 instrumented quad chambers (L3) with EC mitigation*<br>~~5) Install upgraded BPM readout at remainder of vertically focusing quadrupole locations~~<br>5) Complete BPM system upgrade<br>6) Install solenoid windings in drift regions |
| CesrTA Run 3 | 4/7/09 | 42 days | ~~1)Complete commissioning of  positron X-ray BSM~~<br>2) EC growth measurements in chambers in 2-5 GeV range<br>3) Continued work to achieve ultra low emittance<br>4) Instability and emittance dilution experiments |
| Down 4 | 7/7/09 | 49 days | 1) Install optics line for electron X-ray beam size monitor<br>2) Complete longitudinal feedback upgrade<br>3) Installation of additional vacuum chambers with EC diagnostics and mitigation as determined by results of CesrTA runs 1-3, perhaps at a reduced level, depending on funding.<br>4) Install photon stop for 5 GeV wiggler operation in L0 |
| CesrTA Run 4 | ~~8/25/09~~<br>9/21/09 (delayed start due to funding profile) | 42 days | 1) Complete evaluation of electron cloud growth in wiggler, dipole and quadrupole chambers.  Compare with simulation and prepare evaluations for ILC EDR<br>2) Continue program to achieve ultra low emittance<br>3) Detailed experiments at the lowest achieved emittance to characterize EC ~~and FII~~ instability thresholds and emittance dilution<br>4) Commission electron X-ray beam size monitor<br>5) Measure electron cloud growth and mitigation in wigglers at 5GeV |

| Period | Date | Duration | Tasks and Milestones |
|---|---|---|---|
| CesrTA Run 5 | ~~11/24/09~~<br>12/21/09 | ~~49 days~~<br>42 days | 1) Continue program to achieve ultra low emittance<br>2) Experiments to characterize instability thresholds and emittance dilution and prepare evaluations for the ILC EDR<br>~~3) Start commissioning of electron x-ray beam size monitor~~ |
| Down 5 | ~~1/18/10~~<br>2/1/10 | ~~51 days~~<br>21 days | ~~1) Install BPM upgrade at all horizontally focusing quads~~ (already complete)<br>2) Install additional vacuum chambers with EC diagnostics and mitigation as determined by results of CesrTA and other ILC experimental programs, perhaps at a reduced level depending on funding |
| CesrTA Run 6 | ~~5/4/10~~<br>2/23/10 | 42 days | 1) Complete program to achieve ultra low emittance<br>2) Characterize electron and positron instability thresholds and emittance-diluting effects at the lowest achievable vertical emittance for both electrons and positrons |
| ~~Down 6~~ | ~~6/15/10~~ | ~~15 days~~ | ~~1) Install wiggler with ILC prototype vacuum chamber~~ |
| ~~CesrTA Run 7~~ | ~~8/17/10~~ | ~~42 days~~ | ~~1) Experimental studies at ultra low emittance (ECI, FII, IBS,…)~~<br>~~2) Test ILC prototype wiggler vacuum chamber (2-5 GeV)~~ |
| ~~Down 7~~ | ~~9/28/10~~ | ~~15 days~~ | ~~1) CesrTA available for installation and testing of ILC prototypes~~<br>~~2) Ongoing experimental program at ultra low emittance~~<br>~~3) unexpected discoveries from 2008-2010 program~~ |
| ~~CesrTA Run 8~~ | ~~11/30/10~~ | ~~49 days~~ | ~~1) CesrTA available for installation and testing of ILC prototypes~~<br>~~2) Ongoing experimental program at ultra low emittance~~<br>~~3) unexpected discoveries from 2008-2010 program~~ |
| ~~Down 8~~ | ~~1/18/11~~ | ~~49 days~~ | ~~1) CesrTA available for installation and testing of ILC prototypes~~<br>~~2) Ongoing experimental program at ultra low emittance~~<br>~~3) unexpected discoveries from 2008-2010 program~~ |
| ~~CesrTA Run 9~~ | ~~4/26/11~~ | ~~42 days~~ | ~~1) CesrTA available for installation and testing of ILC prototypes~~<br>~~2) Ongoing experimental program at ultra low emittance~~<br>~~3) unexpected discoveries from 2008-2010 program~~ |
| ~~Down 10~~ | ~~6/7/11~~ | ~~15 days~~ | ~~1) CesrTA available for installation and testing of ILC prototypes~~<br>~~2) Ongoing experimental program at ultra low emittance~~<br>~~3) unexpected discoveries from 2008-2010 program~~ |