NSF/DOE Review of the Cesr Conversion Proposal (July 2007)

A combined NSF/DOE review of Cornell University's **Cesr Conversion** proposal, henceforth referred to as **CesrTA**, was held at NSF Headquarters on the 16th and 17th of July 2007. The proposal requests new funding to create ultra-low-emittance positron beams in Cornell's Cesr accelerator and use them to explore electron-cloud (e-cloud) effects. The intent of these experiments is to show that the e-cloud effects can be mitigated, thereby lowering the risk associated with the current single-damping-ring baseline design of the International Linear Collider (ILC).

The review panelists were: Susanna Guiducci (INFN-Italy), Janos Kirz (Stony Brook/ ALS), Katsunobu Oide (KEK-Japan), Claudio Pellegrini (UCLA), Marion White (Chair, ANL), and Frank Zimmermann (CERN). There were three consultants to the Panel: Andy Wolski (Cockcroft Institute - UK), Bill Willis (Columbia), and Mike Harrison (BNL). Funding agency representatives participating in this review included Gerald Blazey (DOE), Phil Debenham (DOE), Marvin Goldberg (NSF), Paul Grannis (DOE), Lance W. Haworth (NSF), Jack Lightbody (NSF), Moishe Pripstein (NSF), Guebre X. Tessema (NSF), and Jim Whitmore (NSF).

The following elements constituted the Charge to the review panel: 1) an assessment of the technical approaches and feasibility of the proposal; 2) an assessment of the likely duration of the proposed work; 3) identification of the technical metrics against which progress can be measured; 4) an assessment of costs by scrutinizing key cost drivers; 5) where appropriate, noting opportunities for cost reductions consistent with meeting the goals; 6) an assessment of the completeness of the effort, by noting possible items omitted, and the associated cost and schedule impacts; 7) noting the consequences of increased or decreased funding levels; 8) a discussion of important collaboration, personnel, and management issues; 9) a discussion of the proposal's flexibility in response to unanticipated risks; 10) a discussion of GDE/ART integration issues; 11) a comparison of this proposal with possible competitive efforts worldwide; and 12) an assessment of broader impacts such as Education, Training and Outreach; benefits to other accelerator activities.

Presentations can be found at:
https://wiki.lepp.cornell.edu/ilc/bin/view/Public/CesrTA/Proposal/

Panelists and consultants were impressed by the excellent quality of the proposal. Presentations by Cornell staff members were clear and informative.

Information in this report is drawn from and organized around the Panel's written comments on issues related to the Charge.

Executive Summary

The Panel believes that the R&D described in the CesrTA Proposal is important to mitigate risk in the ILC positron damping ring design and should be carried out.

The Panel feels that Cornell's proposal is the only one consistent with gaining the necessary information on a timescale compatible with the ILC schedule for production of an Engineering Design Report (EDR) in 2010. CesrTA also appears to be the most cost-effective option available to obtain the required data.

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Acronym	Definition www.web.address (if applicable)
ALS	Advanced Light Source [at LBNL] http://www-als.lbl.gov/
ANL	Argonne National Laboratory http://www.anl.gov
APS	Advanced Photon Source [at ANL] http://www.aps.anl.gov
ART	Americas Regional Team [for ILC]
ATF	Accelerator Test Facility at KEK, Japan http://www-atf.kek.jp/atf/
ATF-II	At KEK, a scaled model of the ILC Beam Delivery System to transport, focus, and control the low emittance beam at an interaction point. http://lcdev.kek.jp/ATF2/
BNL	Brookhaven National Laboratory http://www.bnl.gov
BPM	beam position monitor
CERN	European Organization for Nuclear Research (French: Centre Européen pour la Recherche Nucleaire) http://www.cern.ch
Cesr	Cornell electron storage ring http://www.lepp.cornell.edu/accelphys/cesr.shtml http://www.lepp.cornell.edu/Research/AP/CESR/WebHome.html
CesrTA	Cesr Conversion Proposal to make a Cesr test accelerator
CLASSE	Cornell Laboratory for Accelerator Sciences and Education http://www.news.cornell.edu/stories/July06/CLASSE.ws.html http://www.lnf.infn.it/esperimenti/sr_dafne_light/
DAΦNE	Synchrotron Radiation Facility at the Laboratori Nazionali di Frascati http://www.lnf.infn.it/esperimenti/sr_dafne_light/
DESY	Deutsches Elektronen-Synchrotron [German Electron Synchrotron Lab] http://www.desy.de
e-cloud	electron-cloud
ECI	e-cloud instability
EDR	Engineering Design Report
ERL	Energy Recovery Linac
FNAL	http://www.fnal.gov Fermi National Accelerator Laboratory
FP7	Seventh Framework Programme of the European Community for research, technological development and demonstration activities. http://esgard.lal.in2p3.fr/Project/LoIFP7/ http://cordis.europa.eu/fp7/home_en.html
FTE	full time equivalent
FY	fiscal year
GADGET	Generation And Diagnostics Gear for tiny EmiTtance http://esgard.lal.in2p3.fr/Project/LoIFP7/ http://esgard.lal.in2p3.fr/Project/LoIFP7/ESGARD-LoI-CERN-CLIC-GADGET.doc
GDE	Global Design Effort [for ILC] http://www.linearcollider.org/cms/?pid=1000014
HERA	Hadron Electron Ring Accelerator Facility [at DESY] http://adweb.desy.de/mpy/hera/
IBS	intra-beam scattering

ILC	International Linear Collider http://www.linearcollider.org/cms/
ILC-DR	ILC Damping Ring
INFN	National Institute of Nuclear Physics in Italy (Istituto Nazionale di Fisica Nucleare) http://www.infn.it/indexen.php
KEK	Japanese High Energy Accelerator Research Organization http://www.kek.jp/intra-e/
KEKB	B-factory at KEK, Japan http://www-acc.kek.jp/kekb/
LANL	Los Alamos National Laboratory http://www.lanl.gov
LBNL	Lawrence Berkeley National Laboratory http://www.lbl.gov
LHC	The Large Hadron Collider at CERN http://lhc.web.cern.ch/lhc/
LiCAS	Linear Collider Alignment and Survey http://www-pnp.physics.ox.ac.uk/~licas/
NEG	non-evaporable getter
PEP-II	B-factory facility at SLAC http://www.slac.stanford.edu/grp/ad/ADPEPII/ADPEPII.html
pm	picometer
ps	picosecond
PS	Proton Synchrotron – refers specifically to the CERN-PS http://ab-dep-op-ps.web.cern.ch/ab-dep-op-ps/ http://documents.cern.ch/cgi-bin/setlink?base=cernrep&categ=Yellow_Report&id=2004-003-v3
RF	radiofrequency
RFA	Retarding Field Analyzers
SEY	secondary electron yield
SLAC	Stanford Linear Accelerator Center http://www.slac.stanford.edu/
SLC	SLAC linear collider http://www-sldnt.slac.stanford.edu/alr/slc.htm
SPS	Super Proton Synchrotron – refers specifically to the CERN-SPS http://documents.cern.ch/cgi-bin/setlink?base=cernrep&categ=Yellow_Report&id=2004-003-v3 http://sl-div.web.cern.ch/sl-div/spspage.html
SPS+	proposed upgrade to SPS for LHC luminosity upgrade http://paf-spsu.web.cern.ch/paf-spsu/
TiN	titanium nitride
UCLA	University of California at Los Angeles http://www.ucla.edu/
UK	United Kingdom

Electron and positron damping rings are critical elements in the design of a linear collider. Collider luminosity is directly determined by the beam characteristics, namely: charge per bunch, horizontal and vertical emittance, and average current. Large amounts of data have been obtained from B-factories and from the ATF collider damping ring model on physical limitations for these parameters due to collective effects. A great deal of analysis and theoretical work has been done to analyze and understand the effects producing the limitations. Using these results and the current models, it is possible to design damping rings that allow the ILC luminosity goal to be achieved.

However, optimization of the damping ring design is still limited by our incomplete understanding of one effect, the e-cloud instability (ECI), that mostly affects the positron beam. A complete knowledge of the physics of the e-cloud effect would allow us to estimate the feasibility of decreasing the longitudinal separation between positron bunches, while still reaching the vertical emittance goal of the ILC positron damping ring. In practice, this would mean that a single 6.5-km-long positron damping ring, rather than two rings, would be needed to reach the ILC luminosity goal.

The CesrTA proposal is aimed at obtaining the detailed information that is necessary to put the decision of one positron damping ring versus two rings on a more sound basis. This extended knowledge would still be limited to a range of parameters different from those of the final ILC damping rings, and by an incomplete understanding of the e-cloud distribution around the ring. CesrTA's beam emittance is larger than that of the ILC damping rings, and the presently-achieved bunch separation is 4 ns instead of the 3-ns separation of the single damping ring ILC configuration (although there is no fundamental obstacle to achieving a bunch separation of 2ns in Cesr). Other effects, like intra-beam scattering (IBS), are important for CesrTA beams, but very much smaller in ILC damping rings.

Even with these limitations, the knowledge of the e-cloud effect obtained from the CesrTA project would be very important for the initial ILC damping ring design choice, and for the final detailed design of vacuum chamber elements and diagnostics that could be tested in the CESR ring. From this point of view, it is important that operation of the CesrTA ring as a test facility be able to extend beyond the presently-proposed period.

The Cornell group's scientific and technical knowledge is well known, and their record of achievement in accelerator physics is outstanding. We believe they will achieve the main goals of the CesrTA project, thus making important contributions to the development of the ILC, and to the understanding of how the e-cloud and other effects limit positron storage ring performance.

The Panel's responses to the specific charge elements follow.

1. <u>Technical approaches and feasibility of the proposal</u>

There are three major components of the proposed CesrTA project: 1) measurement of e-cloud build-up and testing the efficiency of various e-cloud suppression techniques in an ILC-like wiggler under ILC-like beam conditions, 2) commissioning the ring with the new ultra-low-emittance optics, including the diagnostics required to measure the corresponding small beam size and ring focusing properties, and 3) studying the effect of the e-cloud on an ultra-low-emittance positron bunch train, plus associated comparative studies with electron beams under conditions similar to those of the ILC damping rings.

The new features of Cesr for this program are: 1) the e-cloud will be measured under conditions closely resembling those of the ILC, 2) the e-cloud build up in a wiggler will be studied experimentally for the first time, 3) important dependencies can be extracted by varying beam conditions - e.g., bunch spacing, beam energy, transverse beam size, swap between electron and positron beams - with the potential to answer long-standing questions and to disentangle the underlying processes, 4) various types of e-cloud mitigation techniques can be qualified and compared in a clean, dedicated environment, and 5) advanced e-cloud monitors will be employed that can resolve the e-cloud flux at the wiggler wall as a function of both transverse and longitudinal position.

The goal of the proposed CesrTA program is to demonstrate 5-10 pm vertical emittance for a positron beam with synchrotron radiation dominated by wigglers. CesrTA will be the closest thing to a prototype of the ILC Damping Ring (ILC-DR) that can be available during the EDR phase. The proposing team has rich and extensive experience with Cesr and Cesr-c in handling the beam orbit and optics, and they have the knowledge and skill needed for successful demonstration of the ultra-low-emittance ring configuration. The proposed upgrade of the beam position monitors (BPM), beam-size monitors, and feedback systems seems to be adequate to achieve the goals. Vertical emittance measurements have been made at KEK/ATF using a laser wire, but on a timescale of hours. The single-pass measurement, using synchrotron radiation in the x-ray region, will allow avoidance of effects that might be present in long-time-scale measurements without admixtures from orbit drifts, fluctuations, or beam oscillations. Fast optics tuning is also possible.

While IBS will greatly affect the CesrTA emittance, it should not have a major impact on the ILC-DR. IBS was properly estimated in this proposal, but might complicate the study of the e-cloud by distorting the beam distribution and causing beam tail formation. Similar effects can arise from beam-gas scattering and from beam loading of the RF system.

A wide variety of tuning methods can be used for ultra-low emittance. It may be worthwhile to consider additional methods beyond those proposed. For instance, active use of orbit offset in sextupoles to correct beta-beat/coupling/dispersion, and beam-based calibration of the BPM electrodes may have some merit.

The ultimate goal of CesrTA is to understand and evaluate the ECI in the very-low emittance regime; it is the crucial issue affecting the ILC-DR design. The ECI affects major design aspects of the ILC-DR, including the number of positron rings, the shape, material, and surface treatment of the beam pipes, and the overall cost.

As the specified vertical emittance of the ILC-DR is two orders of magnitude less than existing machines such as B-factories, extrapolation from results at existing machines could be dangerous, even though no explicit deviation from the conventional ECI model has been predicted. Development of mitigation techniques to suppress cloud formation is also proposed for CesrTA. By using beam pipes and wigglers that are nearly identical to the ILC-DR, the development at CesrTA may have advantages over similar tests elsewhere.

The majority of the e-cloud will be generated in existing beam pipes at CesrTA. It may be possible to measure the amount and distribution of the cloud in these beam pipes by adding Retarding Field Analyzers (RFA) in several locations, as proposed. It will still be necessary to extrapolate from these measurements in order to estimate the total amount of e-cloud in the ring. Measurement of the bunch-by-bunch tune shift will be a good method to obtain an integrated, beta-weighted, amount of e-cloud at the beam.

Since only the vertical tune shift was nonzero in the preliminary tune-shift measurement data at Cesr-c, the cloud in Cesr may be more or less uniformly distributed in the horizontal plane. Such a situation is conceivable if the cloud is mainly caused by photoelectrons generated at the sides of the beam pipes. At any rate, distribution of the cloud at Cesr might be very different from that in the ILC-DR and thus the validity of the evaluation using the tune shifts might be limited. This issue is the same for any machine except the real ILC-DR. Uncertainty in the distribution of e-cloud from existing beam pipes and its difference from the ILC-DR may complicate the understanding and evaluation of the ECI in the damping ring. Measurement of betatron sidebands could provide additional information on the ECI besides the tune shift and beam size measurements, and should be included in the plan. It will be possible to discriminate between ECI and other instabilities by using the electron beam.

Some instabilities, such as longitudinal microwave, will prevent the study of ECI if they become important and competing effects. Changes planned for CesrTA should significantly reduce the vacuum chamber impedance compared to the existing machine. Estimation of instabilities driven by the chamber impedance should be done carefully. Experience with the SLC damping ring shows that lower chamber impedance does not always mean that instability thresholds are increased; sometimes, the opposite occurs.

For the first time, CesrTA will explore the interaction between a beam and an e-cloud for a positron beam of extremely low emittance. Preliminary tests at Cesr demonstrate that e-cloud effects are seen with both positron and electron beams and that the resulting tune shifts and beam-size blow up can be measured with excellent resolution for the present beam parameters.

The possible observation of an e-cloud-induced tune shift with an electron beam, if confirmed, may be the first such measurement ever. In the CesrTA and ILC parameter regimes the beam-cloud interaction is expected to depend strongly on the transverse beam size, since electrons perform multiple oscillations in the beam potential during a bunch passage, thereby giving rise to much higher local electron densities at the center of the bunch and to very non-uniform electron distributions. This highly-pinched e-cloud increases the effective single-bunch wake field, but also increases the tune spread and contributes to Landau damping. The strongly nonlinear field of the pinched e-cloud can also lead to a beam emittance blow-up.

Circumstantial evidence for such an effect may have been seen at KEKB while operating close to the half-integer resonance. CesrTA will be the ideal test-bed for studying the incoherent e-cloud effect, which may set the ultimate tolerance for the acceptable e-cloud density in the ILC damping ring. In particular, CesrTA will allow unique studies of the electron-beam interaction and beam-size blow-up as a function of the vertical beam size, which will help to explore different effects and their dependence on the initial vertical emittance. Studies for different horizontal emittances or at different beam energies may provide further insight.

2. Likely duration of the proposed work

The proposed project plan and duration seem basically adequate to obtain essential results in time for the ILC EDR in 2010. E-cloud monitoring and mitigation tests at other machines give confidence that the time allocated is adequate to reach this goal.

Optics correction and tuning methods for Cesr are well advanced, and significant emittance reduction should be achievable, as scheduled, in 2008. Reaching and measuring the positron vertical emittance goal of 10 pm can happen during 2009 after commissioning of the x-ray monitor, assuming all other components perform as required.

The schedule to gain enough confidence on e-cloud mitigation techniques to make a definitive decision on a single positron damping ring for ILC is tight. Advancing some of the capital funds forward to FY2008 would pull installation of essential diagnostic tools forward, thereby adding some schedule contingency. The panel strongly endorses that this option be explored by the funding agencies.

Preliminary results on the beam-cloud interaction and some of its parameter dependencies will be available by mid- to end- 2009 for the vertical beam emittance which has been obtained by that time. Complete characterization of the beam-cloud interaction and an agreement with modeling could take longer, based on e-cloud progress elsewhere.

The fate of existing positron storage rings in the world is unclear after 2008, so if CesrTA is not approved there are no other guaranteed alternatives. Once CesrTA is approved, it will be a unique facility that could be kept operational through the construction of the ILC-DR to answer many other important ILC questions and help with further ILC developments.

Possible uses include: testing and qualification of prototype vacuum chambers and other components such as kickers, BPMs, and RF cavities, etc. with an ILC-like beam, in advance of mass production. Development and testing of ILC beam diagnostics, optimization of low-emittance tuning procedures, and training of ILC accelerator physicists and operators could also be carried out. Another interesting test would be to extract the beam from CesrTA and demonstrate that the small emittance can be preserved in the extracted beam; for unknown reasons, this is not the case at KEK/ATF or the SLC damping rings.

The panel feels that the role of this project should not be limited to the proposed R&D, but should be considered with a larger scope toward the construction of the ILC. Extended use of CesrTA to support R&D needed for the ILC requires that no other plan for the ring be executed during this critical time period.

A potential conflict with plans in the longer-term (beyond the term of the present CesrTA proposal) for an Energy Recovery Linac (ERL) at Cornell must be resolved.

3. Discuss technical metrics against which progress can be measured

The first metric is qualification of wiggler vacuum chambers after application of various different mitigation techniques. This work includes measurement of the e-cloud density with RFAs in vacuum chambers with different mitigation techniques (TiN and NEG coating, grooved chambers, clearing electrodes), and then repeating the measurements in wiggler chambers at 5 GeV with ILC-like synchrotron radiation intensity. A comparison of these results with measurements at other machines (KEK, PEPII) and with simulations will enable the team to determine if RFAs are adequate.

The second metric is the creation of a low-emittance beam (vertical emittance 5-10 pm) with low-current single bunches and measurement with an x-ray beam-size monitor.

The third metric is observation of e-cloud effects on an ILC-like beam for a well-characterized electron distribution around the ring. This part is the most complex, and details will depend on the findings and the problems encountered. Progress could be measured by comparing predictions and observations. Beam dynamics studies of e-cloud effects will be performed with witness-bunch measurements of bunch-by-bunch tune shifts and bunch-by-bunch beam sizes. The data obtained by RFA measurements will be inserted into the simulations to obtain a complete e-cloud model of the ring and to make predictions in agreement with the observations. Repeating the measurements at different energies and emittances (at different stages of the low emittance tuning process) will help in characterizing the e-cloud effects.

4. Assess the costs by scrutinizing key cost drivers

The major cost drivers are the resources for operation and maintenance of the Cesr machine, including salaries and indirect costs, and therefore they cannot be reduced without reducing the scope of the proposal. Reducing those costs would slow the program or limit its scope unacceptably. Other costs appear to be minimal by comparison.

5. Where appropriate, note opportunities for cost reductions consistent with meeting the goals

The main cost component appears to be salaries. Shortening the duration of the project would save money, but some time may be needed to understand and characterize the observed e-cloud phenomena. Another possibility would be to schedule shorter runs in each year, if that were possible and saved money. Unfortunately, shortened runs put achievement of the target emittance at risk. Stable operation and extended tuning periods will likely be necessary to achieve the low-emittance beam, as experience at many facilities has already shown. Exploiting and maintaining this unique facility for ILC R&D seems to be desirable in any event.

The proposed diagnostics for the beam (BPM upgrade, x-ray monitor) and for the e-cloud detectors (integral RFAs) appear to be the absolute minimum for reaching the objectives. The e-cloud diagnostics could rather be extended to include some other types of monitors developed at CERN and elsewhere, such as a variable-aperture strip detector, possibly (in-situ?) secondary electron yield (SEY) measurements for monitoring surface conditioning, and most importantly, microwave absorption studies to obtain an additional measure of the e-cloud density in various parts of the ring.

Extended collaborations could be helpful in meeting the goals. Similar tests of vacuum-chambers with different e-cloud mitigation techniques for the LHC proton beam are foreseen at CERN in the SPS and PS for 2008 and 2009 in view of the LHC injector upgrade. Earlier this year, a clearing electrode installed in an instrumented CERN PS vacuum chamber was shown to be effective in suppressing the build-up of e-cloud around the proton beam. At least the exchange of ideas and information between these two projects could be of mutual benefit, if not the joint design and preparation of electron-safe vacuum chambers or the collaborative development of advanced electron diagnostics. Some additional help could be expected from linear-collider related proposals presently being prepared for the European FP7 program (e.g., ILC-related proposals and GADGET). In addition, certain beam instrumentation or parts of it, such as turn-by-turn BPM electronics or x-ray optics components, could possibly be recuperated from PEP-II and HERA, both of which are in the process of shutting down.

6. <u>Assess the completeness of the effort by noting possible items omitted, and the associated cost and schedule impacts</u>

The CesrTA team presented a well-articulated plan to develop the new instrumentation that is required to carry out the program and help make timely decisions regarding the ILC positron damping ring. The plan includes improvement of existing diagnostic tools and deployment of new ones. The team presented a well-planned timeline for ring improvement, new instrumentation installation, and beam measurements.

The Cornell team plans to improve and extend the instrumentation on the CesrTA ring to be able to diagnose e-cloud formation in ring components such as dipoles and wigglers, and to measure the positron bunch emittance and tune change. E-cloud formation will be diagnosed using RFAs; they are already being tested. The RFAs will be developed to the level needed for insertion in wiggler vacuum chambers and other ring components. The use of RFAs in all ring components is critical to the understanding of e-cloud formation and to the ability to model the e-cloud distribution around the ring.

The emittance of a single positron bunch will be measured in a single shot, thus giving detailed information on the effect. The emittance measurement will be made using an x-ray beam size monitor that can measure the vertical beam emittance with a resolution of about 10 µm using synchrotron radiation from a dipole.

The improved instrumentation is critical to the effort of lowering the vertical emittance to the required 5- to 10-pm. The new single-pass x-ray monitor for measuring the vertical bunch-by-bunch beam size with ~10-µm resolution is an important step forward in the measurement of beam properties in low-emittance rings. This type of device may become a crucial diagnostic tool not only for CesrTA, but for the ILC itself.

The instrumentation for alignment of ring components will also be improved with the acquisition of a new laser-based alignment system. This is important to establish the low emittance configuration.

Additional e-cloud detectors would perhaps be helpful, such as microwave absorption measurements, and an in-situ measurement of the SEY and its evolution with time. The team might want to consider development of an independent procedure, e.g. a scan of beam lifetime vs. aperture, or, even better, a complementary or improved synchrotron-light monitor to measure the horizontal emittance of a single bunch and provide a complete beam characterization. Measuring the horizontal emittance would help to extract the vertical emittance from the observed Touschek lifetime and it would also confirm an important beam parameter needed for modeling the electron-beam interaction. In the much longer term, after 2011, extraction experiments could be of interest.

The BPM data acquisition system will be improved to allow turn-by-turn measurement of individual bunch positions. The improved instrumentation is important to gain a full understanding of beam optics in the ring, including non-linear effects, and to enable the vertical beam emittance to be reduced to the 5- to 10-pm goal.

7. Discuss the consequences of increased or decreased funding levels

Increased funding in FY08 would allow for timely purchase of the high-priority equipment required for e-cloud characterization and mitigation. Materials purchases should not be compromised. The panel recommends that the funding requested for FY08 be increased by $1M for this reason. The budgets for FY09 and FY10 are appropriate.

Significant reduction in the requested funds would put the entire proposed program at risk. If the consequence of a decreased funding level is the shut down of Cesr, the CesrTA project cannot go ahead. The Cornell team indicated, and the Panel basically agreed, that it would be appropriate to also add about 7.5 FTE to the FY 08 budget to reduce the risk of schedule slippage.

Plans for FY11 depend on development of the ILC-DR R&D program and any issues that may come up as the work progresses. While the budget seems at the right level to continue to support ongoing activities, it may require updating in light of later developments.

It is difficult to judge whether salary costs can be reduced and if so by how much. Shortening the run time would have an adverse impact on the scope of the program, and is not desirable.

8. Discuss important collaboration, personnel, and management issues

The proposal involves important and extensive collaborations with other groups involved in ILC-DR R&D. In particular, beam pipes to be tested will be fabricated by LBNL, and RFA electronics will be based on developments at LANL.

The team should consider greater collaboration with European and Asian partners and with synchrotron light sources. E-cloud efforts and chamber tests for the LHC and for the LHC injector upgrade (in particular SPS+) appear to be comparable in scope and they address similar questions, although the work is done for protons and not positrons. The relevant LHC and B-factory beam parameters are not dramatically different. Goals of the SPS+ studies with proton beams are synergistic with positron studies at CesrTA: 1) understand the effect of the e-cloud on the beam, particularly its scaling with transverse beam size and beam energy, and 2) suppress electron build-up locally with appropriate mitigation schemes. Different test chambers will be installed at the SPS in 2008 and/or 2009. An electron clearing electrode is operating successfully in an instrumented PS chamber since spring of 2007. One could think of sharing the design of e-cloud diagnostics and/or of jointly developing those parts of the mitigation hardware that could possibly be common to proton systems as well as positron systems. Collaboration within the next European Framework Program (FP7) may be an additional possibility. To preserve this option, it could be prudent for CLASSE to appear as an associated institute in the relevant EU proposals now in preparation. There was an early intention to collaborate with the Linear Collider Alignment and Survey (LiCAS) group at University of Oxford/John Adams Institute. Unfortunately, this collaboration is no longer feasible due to cuts in the LiCAS program.

Highly-qualified personnel will become available with the completion of the Cesr-c program. The size of the proposed team is well matched to the proposed program. The proposed management system appears to be appropriate to the task.

CesrTA may become a joint project between the two funding agencies, NSF and DOE. The safety policies of one agency may not satisfy the other. The subject of safety and how it will be handled in a jointly-funded project requires further attention by all of the relevant parties.

9. Discuss the proposal's flexibility in response to unanticipated risks

The CesrTA proposal is solid and its key components can, in our opinion, be reached in a timely manner. The required performance of the instrumentation needed to reach these goals is perhaps one of the main risks. Fast, reliable BPMs and beam-size monitors are essential. The committee was assured that they would be available. RFAs have already been used at many machines and should perform as specified from the beginning.

CesrTA has adequate flexibility in its beam optics to control the energy and emittance almost freely, so the study of the low emittance beams and ECI can be done with a wide range of options. Versatility in the bunch-filling pattern will bring more information on ECI; it will be perfect if the 2-ns bunch spacing is achieved. There is no fundamental obstacle at Cesr to prevent 2-ns spacing.

Other possible risks and complications can be envisioned, although one hopes they will not arise: 1) The RFAs may not give the full picture of the e-cloud evolution and distribution inside the wiggler, e.g., there are magnetic bottles between subsequent poles where electrons are trapped and survive for a long time without being recorded by the RFAs. Or the electrons hit at a location where no RFA is placed. In such cases more diagnostics, e.g. microwave measurements, may be needed. 2) The e-cloud may not be suppressed by any of the applied coatings and surface modifications, e.g. since both secondary emission and photo-emission are important contributors. Clearing electrodes may be the only efficient cure. If the first generation fails, construction and testing of chambers with additional countermeasures may take more time than anticipated. Enamel-based clearing electrodes presently under development at CERN in collaboration with German industry could be tried. A proper evaluation of clearing-electrode impedances with beam may be difficult, but could be attempted. Impedance changes due to NEG coatings of single insertions have been reported by several light sources. It might also be of interest to try to measure the impedance changes more generally, whenever newly modified wiggler chambers are installed. 3) The target vertical emittance may not be reached easily. In that case, e-cloud effects and their sensitivity to beam size can still be studied at the larger emittance. But it will then be important for ILC to understand and overcome the limitations. The change of the beam shape due to IBS, in particular the generation of long tails, could affect the beam-size diagnostics. 4) Some of the observed e-cloud effects may not be understood quickly. For example, at KEKB it is not known where the remaining electrons are located. Solving a problem of this type may require additional electron diagnostics. Winding solenoids over a significant part of the small field-free regions and observing their effect on the tune shift would quantify the fraction of the e-cloud in field-free regions and support the modeling.

The ability to slice the x-ray monitor signal longitudinally along the bunch may help to disentangle head-tail motion from incoherent blow up.

10. <u>Discuss GDE/ART integration issues</u>

ILC Damping Ring R&D requirements were explicitly identified and prioritized by the S3 (Damping Rings) working group of the ILC R&D Board.

The CesrTA proposal directly addresses 7 of the 11 “very high priority” objectives, including: e-cloud effects, generation of very-low-emittance beams, and ion effects. Other “high-priority” R&D items, such as the development of advanced instrumentation, are also addressed by the proposal.

The CesrTA proposal is very well aligned technically with the ILC global R&D planning. This project, if funded, would be the major R&D test facility for the Damping Rings. CesrTA work would be in close collaboration with other key ILC-ART players, including SLAC, LBNL, FNAL, and ANL-APS.

Schedule and the availability of resources are larger issues than the technical alignment with the R&D program appears to be. The ILC global planning is aimed at producing an Engineering Design by 2010. This design will rely on input from the CesrTA program to finalize the damping ring complex and determine whether e-cloud problems necessitate two positron rings rather than one.

The proposed schedule for the CesrTA program, while consistent with the goal of producing an Engineering Design by 2010, appears to have very little schedule contingency in the event that R&D results require more machine time than projected.

Although not the focus of this review, it should be noted that the resources needed to accomplish the CesrTA program are significant on the scale of the total ART program.

11. <u>Compare this proposal with possible competitive efforts worldwide</u>

KEKB, HERA, and ATF have been considered at a global level as possible test facilities for low-emittance e-cloud studies.

The KEKB low-energy positron ring is a well-understood machine with advanced diagnostic instrumentation and software, and an expert staff. They can store high current (~1.6 A) with flexible bunch patterns, and they can operate with a 2-ns bunch spacing. The optics can be reconfigured for low emittance at ~2.3GeV (the beam energy for physics operation is 3.5 GeV). The study of low-emittance tuning and the dimension-diluting effects of e-cloud both depend on implementation of an x-ray beam-size monitor. KEKB has long drift spaces wrapped with solenoids that provide a means to control the e-cloud density, but there are no ILC-like high-field wigglers. KEKB would be a good candidate, but it is not available for dedicated operation as test accelerator until at least 2009. After that, it may be used in a dedicated mode for a maximum of 1 or 2 months but even that is not certain, because of availability issues and the need to provide running costs for those periods.

The circumference of the HERA electron/positron ring matches the baseline ILC-DR design. It is possible to achieve the ILC-DR emittance at 5 GeV with a modified lattice, and with some modifications, HERA could be a full-scale demonstration of the ILC-DR. DESY does not plan to pursue this proposal.

The ATF ring is used as a damping ring test facility and it achieves an extremely low vertical emittance (twice the ILC-DR nominal value). ATF cannot be used for e-cloud studies with positron beams since it lacks positrons; moreover, future ILC-DR activities would be in direct competition with the extracted beam for ATF II.

Specific tests and measurements can be done at other facilities to demonstrate ultra-low emittance (ANL-APS, ALS, KEKB, ATF) and to perform e-cloud studies (PEP-II, KEKB, DAΦNE, LHC, SPS). For example, measurements of e-cloud growth in different vacuum chambers with various mitigation techniques (TiN and NEG coating, grooved chambers, clearing electrodes) are in progress at PEPII and KEKB. These measurements are performed at a much higher emittance than ILC-DR. Studies of mitigation techniques with the LHC proton beam are ongoing at SPS and PS for the SPS upgrade. They plan to install several instrumented vacuum chambers at the SPS in 2008 and 2009. These chambers will be equipped to test various mitigation techniques (TiN coating, NEG Coating, enamel clearing electrodes, grooves). An instrumented chamber with clearing electrodes was installed at the PS earlier this year and demonstrated the efficiency of this mitigation method. High-priority studies of scaling of the ECI with transverse beam size and beam energy are in progress at the SPS for the injector upgrade.

All of these tests complement the CesrTA program and improve our understanding of e-cloud effects. No other facility can operate simultaneously with positron and electron beams in the same beam pipe, an important factor in being able to make the distinction between e-cloud effects and regular impedance effects. Electron and positron operation also allows for a parallel exploration of fast-ion effects on the electron beam.

CesrTA is the only available facility that can provide important e-cloud information on a timescale consistent with obtaining critical input for the EDR.

12. **Provide an assessment of broader impacts such as Education, Training and Outreach; benefits to other accelerator activities**

The crucial role played by accelerators in today’s society is widely acknowledged. Cornell has a long and outstanding tradition in the area of educating and training scientists in accelerator physics and engineering. A large number of graduate and undergraduate students are already part of the CESR program, and have made contributions to CesrTA. The participation of students will continue to be an important part of the program. The training of new PhD’s in the accelerator physics area will be a very important product of the CesrTA program. It will help provide the scientific and technical effort that will be needed for the design, construction and operation of the ILC and other particle-accelerator based projects and facilities. The number of universities in the US with accelerator physics PhD programs, and where undergraduate students can be involved in accelerator physics projects, is very limited. Cornell is an important member of this small group of universities.

An operating in-house accelerator provides an invaluable training environment for students and junior staff members. While it is possible to carry out active and focused R&D projects with small accelerators, a project like CesrTA that is based at a university gives the possibility for students to experience the full complexity and integrated nature of a fully-functional accelerator with all of its inter-related and interacting components. This aspect is made more important by the unfortunate fact that today’s “factory” machines, with 95% availability requirements and 5500+ hours of scheduled user beam per year, have almost no time available for accelerator physics R&D and training. These types of tasks can best be accomplished in projects where accelerator physics research and the exploration of new physics and technology are primary goals. Substantial studies time periods need to be dedicated to these activities.

E-cloud efforts and chamber tests for LHC and SPS+ appear somewhat comparable in scope and address similar but not identical questions. The goals of SPS+ studies with proton beams are similar to those of CesrTA with positrons, thus, designs of e-cloud diagnostics for one facility could possibly help the other. Joint efforts could also be undertaken with a view toward development of e-cloud mitigation techniques. Positrons and protons are both positively charged particles, but what works in one case may not work in the other; verification must be done for both types of beams.

In the longer term, the benefits of CesrTA to society are likely to include better performing proton accelerators, e.g. for cancer therapy, and light sources with much higher brilliance. Conceivably, a next generation of satellites could be less prone to failure thanks to improved understanding of the spacecraft charging that can result from photoemission and secondary emission.

U.S. Department of Energy
and the
National Science Foundation

June 12, 2007
Marvin Goldberg
Program Officer,
Experimental Particle Physics
Division of Physics
Directorate of Mathematical
and Physical Sciences

Dear Colleagues,

We wish to extend our appreciation for your agreeing to serve on the joint DOE/NSF CESR TA Review Panel. The panel will meet on July 16-17 in Room 1020 of the National Science Foundation, 4201 Wilson Blvd. Arlington, Virginia. Marion White has agreed to serve as chair. Paul Grannis and I will be the agency representatives.

The U.S. funding agencies are in the process of defining R&D for the International Linear Collider, with increased specificity. The role of the Cornell Laboratory in this R&D needs to be evaluated. To this end, we request that you review the CESR CONVERSION proposal, as submitted to both agencies. This review should evaluate the cost, schedule, scope, technical, and management components of this proposal.

Please include in your report:

1. an assessment of the technical approaches and feasibility of the proposal.
2. an assessment of the likely duration of the proposed work.
3. identification of the technical metrics against which progress can be measured.
4. an assessment of costs by scrutinizing key cost drivers.
5. where appropriate, noting opportunities for cost reductions consistent with meeting the goals.
6. an assessment of the completeness of the effort, by noting possible items omitted, and the associated cost and schedule impacts.
7. noting the consequences of increased or decreased funding levels.
8. a discussion of important collaboration, personnel, and management issues.
9. a discussion of the proposal's flexibility in response to unanticipated risks.
10. a discussion of GDE/ART integration issues.
11. a comparison of this proposal with possible competitive efforts worldwide.
12. an assessment of broader impacts such as Education, Training and Outreach; benefits to other accelerator activities.

We ask that you provide a final report describing your findings, assessment, and recommendations by August 1, 2007. We will be happy to answer any questions you may have.

Marvin Goldberg

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