University-based Accelerator R&D for a Linear Collider
Project Description

1 Introduction

1.1 Preamble

There is a now a worldwide consensus that the next large facility in particle physics should be an international high energy electron-positron collider. This consensus recognizes the central importance of the physics to be studied, as well as the maturity of accelerator designs being simultaneously advanced (and proposed) at laboratories in the United States, Germany, and Japan. In January, 2002 the U.S. High Energy Physics Advisory Panel (HEPAP) called[6] for vigorous U.S. participation in a Linear Collider effort:

> We recommend that the highest priority of the U.S. program be a high-energy, high- luminosity, electron-positron linear collider, wherever it is built in the world. This facility is the next major step in the field and should be designed, built and operated as a fully international effort.
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> We also recommend that the United States take a leadership position in forming the international collaboration needed to develop a final design, build and operate this machine. The U.S. participation should be undertaken as a partnership between DOE and NSF, with the full involvement of the entire particle physics community.

Response to this consensus has been swift. In early 2002, physicists from U.S. universities and laboratories organized a series of workshops at Chicago, Fermilab, Cornell, SLAC, and U.C. Santa Cruz aimed at understanding fruitful directions for research and collaboration towards the Linear Collider. The hundreds of technical issues involved in the design and construction of the accelerator and detector emerged as an organizing theme. UCLC organized itself to consider these issues in the context of NSF support, and the Linear Collider Research and Development Working Group (LCRD)[2] did likewise in the context of DOE support. The two groups are naturally intermingled with each other. All concerned are working together within the American Linear Collider Physics Group (ALCPG)[11] to coordinate their activities to the single task of building the linear collider.

Taken together, the LCRD and UCLC proposals mark a fundamental change in the level of engagement of U.S. universities in the Linear Collider. In the year 2001, Linear Collider work was supported at fifteen U.S. universities, and the work was largely confined to physics and detector simulation studies. Almost all of the accelerator related work was performed at national laboratories. This proposal, together with the UCLC detector R&D proposal, and that of LCRD, together nearly quadruple the number of institutions, with most participants having had no prior affiliation with the Linear Collider effort. In a significant broadening of focus, this proposal is devoted to work on accelerator issues at universities. The increase in numbers and breadth of focus follows on the Snowmass consensus, and the excitement and commitment of the U.S. university physics community toward making the Linear Collider a reality.

1.2 Physics Goals of the Linear Collider

The physics goals of the Linear Collider are ambitious and compelling. The Linear Collider is needed to address the central issue in particle physics today, the origin of mass and electroweak symmetry breaking.

Over the past decade, a wide variety of experiments has shown that elementary particle interactions at the TeV scale are dictated by an $SU(3) \times SU(2) \times U(1)$ gauge symmetry. The non-zero masses of the W and Z particles imply, however, that the electroweak $SU(2) \times U(1)$ symmetry is broken spontaneously. We do not know how the symmetry is broken, and we will not know until the agents of electroweak symmetry are produced directly in the laboratory and, also, are studied in precise detail. But we have every reason to believe that whatever is responsible for electroweak symmetry breaking will be accessible at the Linear Collider.

Although we do not know the mechanism of electroweak symmetry breaking, we have some good hypotheses. In the so-called Standard Model, one doublet of scalar fields breaks the symmetry. This model has one physical Higgs particle, which is the window to electroweak symmetry breaking. The global consistency of precision electroweak measurements gives this model credence, and suggests that the Higgs boson is relatively light, $m_H \leq 200$ GeV. However, we know this model works poorly beyond TeV energies. A theoretically preferable scenario is based on supersymmetry (SUSY) at the expense of a whole new spectrum of fundamental particles and at least five Higgs states. But the lightest of these states looks much like the Standard Model Higgs, with nearly standard model couplings and a mass less than 200 GeV or so. Nature may break electroweak symmetry through some other mechanism, of course, but most realistic mechanisms we have imagined result in a Higgs boson or some related phenomena accessible to the Linear Collider.

The TeV scale is the natural place to look for the agents of electroweak symmetry breaking. Thus, the ongoing Run 2 at Fermilab's Tevatron has a chance of getting the first glimpses of these phenomena. Starting later in the decade, CERN's LHC, with seven times the energy, will almost certainly observe the Higgs boson, and has a very good chance of discovering something else. Most high-energy physicists believe, however, that the LHC will not unravel the mysteries of symmetry breaking on its own. Experimentation at a linear e^+e^- collider (LC) provides information that cannot be obtained by other means. Let us just cite two examples. First, a series of cross section and branching ratio measurements will trace out a detailed profile of the Higgs boson, in a model-independent way, and incisively test whether its couplings are proportional to mass. Second, if SUSY is at play, the LC can determine the lightest superpartners' masses with exquisite precision. Since the LHC measures mass differences more precisely than the masses themselves, one sees that a single LC measurement will significantly improve and extend the whole program of SUSY measurements at the LHC. In both these cases, the Linear Collider adds critical information to what will be learned at the LHC. The Linear Collider is the right next step for experimental high energy physics, and now is the time to take it in order to maximize the interplay of its results with those of the LHC.

The full scientific case for the Linear Collider can be found in the Resource Book[7] prepared for Snowmass 2001 or the physics chapter of the TESLA Technical Design Report[8]. We believe the essential elements of the physics case have been made persuasively, and we are responding by banding together to meet the technical challenges that remain, so that the instrument can be built in a timely and cost-effective fashion.

1.3 The Need for Accelerator R&D for the Linear Collider

The physics goals of the Linear Collider require[4] a starting center-of-mass energy of 500 GeV, upgradeable to approximately 1 TeV or more, and a luminosity of approximately $2{\times}10^{34}\text{cm}^{-2}\text{s}^{-1}$, an ambitious four orders of magnitude larger than the luminosity achieved by the first linear collider, the SLC. Achieving the high energy and ultra-low emittance of the Linear Collider requires significant advances in accelerator physics and technology: end-to-end simulation of the entire accelerator complex; mastery of the consequences of strong wakes; ultra-fast beam manipulation; nanometer stability of the beams at the crossing point; extreme stability in beam energy, luminosity and polarization; handling unprecedented beam power;

and the development of instrumentation to monitor the beam on a bunch-by-bunch basis. A construction start in 2009 requires that the basic R&D required for a full technical design be complete by 2006. Much R&D remains to be done, and is urgently needed. The International Linear Collider Technical Review Committee (ILC-TRC)[5] concluded its 2003 report with a list of high priority R&D items in the areas of: accelerator simulation and design; accelerator experiments; the development and test of radio-frequency (RF) systems, instrumentation, and other hardware; and operational issues.

Many of the R&D tasks identified by the laboratories and the ILC-TRC are ideally matched to the experience and talents of both elementary particle physicists and accelerator physicists at U.S. universities. These physicists have invaluable expertise in: large-scale computer simulations; data acquisition and control system architecture; innovative instrumentation; accelerator theory, design, and experiments; and accelerator RF systems. The U.S. university community, through the UCLC and LCRD consortia, is taking up the challenge of completing the necessary R&D in collaboration with the laboratories and affiliated institutions worldwide that are developing the Linear Collider designs.

1.4 Broader Impact of the Work described in this Proposal

The design, construction, and utilization of the Linear Collider offers profound opportunities for the engagement of university based physics and engineering groups, and will pay back large dividends of intellectual stimulation and scientific discovery. In its January, 2002, report[6], the U.S. High Energy Physics Advisory Panel provided some perspective on the broad impact of a Linear Collider:

> The linear collider would be an exciting opportunity for the United States, and a flagship facility for the 21st century. It could be a centerpiece of a national effort to boost the physical sciences. In partnership with the broader scientific community, an X-ray free electron laser facility could be included in the project, providing a brilliant, coherent fourth-generation light source with femtosecond time resolution. Such a facility could open important new areas of research across many sciences, including the life and environmental sciences, as well as physics and chemistry.

The study and control of dense beams of electrons requires a scientific and engineering infrastructure that starts in electrodynamics and beam physics, but spills into many other fields, including lasers, optics, interferometry, motion stabilization, superconductivity, materials science, acoustics, plasma physics, microwaves, and power and control systems. Problems in these areas are ideal foci for interdisciplinary collaborations with other university departments beyond physics, which can build a support base for the Linear Collider, and fulfill its potential as a broad stimulant for all science and technology. Some of this collaboration-across-boundaries has already been realized in the research projects presented here, and we expect to see more of it arise as the work progresses.

This proposal will open new doors for graduate student training in accelerator physics. Most accelerator work is carried out in national labs, which do not have the strong training mission of a university. The national shortage of accelerator physicists is related to the relatively poor representation of this discipline in the university community. This shortage will affect not only high energy physics, but also many other fields, such as solid state physics, materials science, biophysics, and medical science, which have come to depend on accelerators as their front-line research tools. This proposal will begin to reverse this trend, and consequently can have a broad impact on all these fields.

The high energy physics groups participating in UCLC have historically been active in outreach to undergraduates, through REU programs and employment of undergraduates in their research. To augment this effort, we propose a new program of UCLC Fellows and UCLC Scholars. UCLC Fellowships will bring high school teachers to Linear Collider research, by providing funding for up to 8 weeks of summer research with UCLC groups. UCLC Scholarships will do the same for high school students. This program will bring to high school classrooms a taste of the exciting energy frontier physics to be studied by the Linear Collider, and the state-of-the-art technologies required for its implementation. Details of these outreach efforts are presented in Section 6 below.

In engaging our graduates and undergraduates in accelerator R&D, we serve to train the next generation of scientists and engineers in all of the fields described above. Our students participate as more than just a skilled and enthusiastic labor pool: when the facility is operating, many of these student "builders" will have become members of the next generation of high energy physicists. Their research will be conducted simultaneously at the Collider facility and in the academic departments of every collaborating institution, carrying forth the excitement and stimulation of science and technology into the larger community.

1.5 Structure of this project description

The accelerator projects can be broadly categorized into four general areas of study. In the sections below, we describe these categories, outline the critical R&D issues associated with each, and explain how the proposal addresses these issues. The total budget, project leaders, and senior personnel are also listed. More detailed descriptions of proposed individual UCLC projects, including detailed budgets, statements of work, and deliverables, may be found at the following web site: `http://www.lns.cornell.edu/public/LC/UCLC/projects.html`, and are provided in the Appendix.

In Section 6, the education and outreach program of UCLC is presented. Section 7 outlines the plan by which the projects will be managed.

2 Beam dynamics calculations and experiments, and accelerator design

The Linear Collider must produce and maintain beams with unprecedented low emittance, low jitter, low losses, and few halo particles. To proceed to a site-independent design in 2006, we need timely solutions to a number of unsolved problems in beam dynamics and accelerator design. Beam dynamics simulations, calculations, and experiments are needed to determine how to control the effects that cause emittance growth, jitter, particle loss, and halo production. The beam in the sources and damping rings is susceptible to space charge effects. The damping rings are susceptible to dynamic aperture limitations from damping wigglers; emittance growth from misalignment and intrabeam scattering (IBS); and instabilities from electron clouds and ions. The TESLA damping ring design requires the development of very fast injection and extraction kickers. In the main linac the emittance must be preserved in the presence of wake fields and misalignments. The transport and collimation of the beam halo must be understood and very well controlled for successful detector operation.

The NLC and JLC projects, the TESLA collaboration, and others around the world have made progress on each of these critical and challenging issues, ranging from estimates of the magnitude of the effects to simulation studies and beam experiments. However, for each issue much more new work must be done before proceeding to the site-independent design phase.

With DESY, KEK, LBNL, and SLAC, a Cornell/Minnesota group **[Project leader: J. Rogers; Other Senior Personnel: G. Dugan, D. Rubin, R. Poling (Minnesota); Budget: $238K over 3 years]** plans to fully model the effect of space charge in the damping rings in a particle tracking simulation; to benchmark dynamic aperture calculations for wiggler-dominated damping rings against experiments in CESR-c, a wiggler-dominated machine; and to experimentally study electron cloud and ion effects in CESR-c with damping ring-like parameters. In collaboration with KEK, the North Carolina A&T State University group **[Project leader: S. Mtingwa; Budget: $153K over 3 years]** plans to study the IBS growth rate at the KEK Accelerator Test Facility (ATF) and in CESR-c to resolve the discrepancy between theory and previous IBS experiments at the ATF. This group will also study the feasibility of using the disrupted beams for Compton backscattered photoproduction. **[Budget: 39K over one year]**

With DESY, Fermilab, and U. Illinois, another Cornell group **[Project leader: G. Dugan; Other Senior Personnel: J. Rogers, D. Rubin; Budget: $278K over 3 years]** plans to investigate fast damping ring kicker options and prototype a kicker. In collaboration with SLAC, a third Cornell group **[Project leader: D. Rubin; Other Senior Personnel: G. Dugan, J. Rogers, L. Gibbons, R. Patterson; Budget: $70K over 3 years]** plans to develop the pre-linac collimation system; study the formation and transport of the beam halo; develop an end-to-end particle tracking simulation; and develop modeling tools for commissioning and operation. Each of the proposed activities goes well beyond previous work, and will be done in coordination with the TESLA collaboration and the NLC and JLC projects.

We have set milestones and deliverables for each of the three years of this effort. The major milestones and deliverables are summarized here.

In FY04 we will deliver reports: on a design for the pre-linac collimation for NLC and TESLA; on an independent evaluation of the robustness of the NLC and TESLA damping ring lattices; on simulation studies of space charge in damping rings; on a design algorithm to maximize dynamic aperture in damping rings with wigglers; on the feasibility of fast kicker schemes for the TESLA damping ring and alternative damping ring solutions for TESLA; on analysis of beam dynamics studies at ATF, CESR-c, and ALS; and on the feasibility of using the disrupted beams for Compton backscattered photoproduction.

In FY05 we will produce codes to do beam halo transport and report on halo transport studies. We will deliver reports on theoretical studies of IBS in the presence of coupling, and on an evaluation of the utility of superferric wigglers for NLC and TESLA. We will produce a prototype fast kicker magnet for the TESLA damping ring. We will benchmark the dynamic aperture algorithm through experiments with CESR-c wigglers.

In FY06 we will produce reports on beam transport issues, including halo source and transport studies and modeling tools developed for studies of commissioning; on the combined effects of IBS and other sources of emittance growth on damping ring emittance; and on the results of the prototype fast kicker tests. We will apply the dynamic aperture design algorithm to NLC and TESLA designs; and will produce a report on measurements of the electron cloud and fast ion instabilities in CESR-c.

The International Linear Collider Technical Review Committee[5] concluded its 2003 report with a list of high-priority R&D items. Rank 2 items are R&D needed to finalize design choices and ensure reliability of the machine. Rank 3 items are R&D needed before starting production of systems and components. The projects described above directly address seven of the most critical Rank 2 issues, and five of the Rank 3 concerns.

3 Beam diagnostic monitors and electron sources

The electron and positron beams in linear colliders require close monitoring and tight controls to keep their phase-space volumes small. Associated beam diagnostics must surpass the performance of contemporary instruments. As just one example, linear-collider applications call for a time-resolution of about one-tenth the rms bunch length, which for the NLC works out to be $\sim$10 μm. In recognition of their importance, the ILC-TRC Report lists beam diagnostics as a Rank 3 activity, stating: "A vigorous R&D program is mandatory for beam instrumentation in general; it would be appropriate for a collaborative effort between laboratories."

Herein, we propose an innovative program to develop instrumentation that is both highly synergistic and collaborative. The instrumentation is intended for use in measuring properties of the source beam and beams in the damping rings. Concerning the source beam, our goal is to develop instruments that are capable of resolving features in the three-dimensional density distribution to within a few μm. The damping-ring beams are flat and span only a few μm in the narrow dimension; our goal is to develop instrumentation that will image a single bunch in a damping ring and measure its size, shape, and position.

In addition to this instrumentation work, we will also develop new simulation techniques for the modeling of high-brightness photoinjectors, based on the application of wavelets to develop a space-charge algorithm.

The Northern Illinois University (NIU) group **[Project leader: C. Bohn; Budget: $182K over 3 years]** will develop new interferometric and electro-optic (EO) instrumentation, and will also develop improved simulation codes for high-brightness photoinjectors. These diagnostics will be used to measure the electron beam at Fermilab's photoinjector (FNPL) to cross-correlate the results and as part of benchmarking the improved simulation codes. The ultimate goal for both techniques is to enable high-resolution measurements of the longitudinal density profile of a single bunch, as opposed to a profile that is averaged over many bunches. The single-shot interferometer will extract this information from coherent transition radiation (CTR) that is emitted as the beam passes through a thin foil. It is thus an invasive technique; however, it will provide high resolution of the longitudinal density profile. The EO crystal will be housed in a low-impedance vacuum chamber to facilitate measurement of the beam's field by reducing the chamber wakefield. The laser that will be used to probe the crystal is the same used to generate beam from the photocathode. Thus, in the absence of a shorter-pulse laser probe, only the bunch length will likely be accessible; fine structure in the beam will remain unresolved.

A Vanderbilt University group **[Project leader: B. Feng; Other senior personnel: S. Csorna, B. Gabella; Budget: $200K over 3 years]** will carry out a program that is synergistic with that of NIU. One facet of this program is to develop diagnostics based on the measurement of coherent diffraction radiation (CDR) to extract information about both the longitudinal and transverse phase spaces of the beam. A Martin-Puplitt interferometer will be used to measure the CDR spectrum from one or more slits in a metal foil. The instrument will be tested at the Vanderbilt FEL linear accelerator. It then will be taken to CESR, where the beam energy is much higher, and used in experiments there. If the efforts involving Vanderbilt and NIU prove successful, the possibility presents itself to combine their products in the future. The single-shot interferometer that NIU will develop, combined with the CDR technique that Vanderbilt will perfect, can potentially result in a diagnostic capable of noninvasive single-shot (i.e., single-bunch) measurements that will provide high-resolution data on the overall phase space.

Another Vanderbilt effort **[Project leader: B. Gabella; Other senior personnel: B. Feng; Budget: $204K over 3 years]** will also pursue EO diagnostics with 30 fs time resolution. This effort involves acquiring a Ti:sapphire laser with time resolution of a few fs and then synchronizing it to the electron beam with sub-100 fs accuracy. This instrument likewise will be developed on the Vanderbilt linac. The first step will involve using the Ti:sapphire laser as a probe to measure the longitudinal profile of the FEL laser pulse which is $\sim$1 ps long. An essential by-product will be a procedure for synchronizing the two beams that can then be applied to electron-beam measurements. For the latter, Vanderbilt plans to incorporate a low-impedance chamber, and their chamber design will be aided by NIU's effort. Moreover, because the probe laser offers high temporal resolution, Vanderbilt plans to do similar measurements at FNPL where high bunch charge is routinely generated and, as previously noted, a comparable laser probe is unavailable.

A group from SUNY, Albany, in collaboration with Cornell, **[Project leaders: J. Alexander, Cornell; J. Ernst, SUNY, Albany; Budget: $89K over 3 years]** will develop techniques to image directly 1-10 keV X-rays from incoherent synchrotron radiation emitted as a beam traverses a damping ring. The desired diagnostic combines a point-to-point imaging system, a high-resolution detector that is fast enough to separate closely spaced bunches, and a high-speed data-acquisition system to analyze the signal and pass the information to accelerator control systems in real time. This effort will culminate in a design report for such a system. The imaging system will be designed, software tools will be developed for simulating signal acquisition with solid-state detectors and signal-processing electronics, and by combining these tools with empirical data from existing detectors, they will be applied to design an imaging and detector system with optimal response time.

We have set milestones and deliverables for each of the three years of this effort. The major milestones and deliverables are summarized here.

In FY04 we will deliver reports: on initial CDR experiments; on studies that are preliminary to building EO diagnostics; on the X-ray imaging system; and on wavelet-based space-charge computational techniques for electron sources. We will build a Martin-Puplett interferometer and a CDR screen, and we will develop software to simulate x-ray detection and signal processing. We will produce designs for a single-shot interferometer bunch length diagnostic and the low-impedance chamber for an electro-optic bunch length diagnostic.

In FY05 we will complete the Ti:sapphire laser and related hardware and do first measurements of Vanderbilt's FEL laser pulse. We will deliver reports: on CDR and incoherent DR experiments with the Vanderbilt linac; on the Ti:sapphire laser; and on simulations and measurements of candidate hardware for the X-ray diagnostics. We will produce a single-shot interferometer bunch length diagnostic; a low-impedance chamber for an electro-optic bunch length diagnostic; and a wavelet-based simulation code for sources.

In FY06 we will build and install the EO diagnostic on Vanderbilt's linac. We will deliver reports: on CDR and incoherent DR experiments with the CESR beam; on single-bunch EO measurements of the Vanderbilt electron beam and results; on the final design of the X-ray diagnostic; on the benchmarking of the wavelet-based simulation code for electron sources; and on experiments with the interferometric and electro-optic beam diagnostics.

4 RF structure R&D

The International Linear Collider Technical Review Committee has identified the need for a reliable demonstration of high gradients in normal-conducting structures as a Rank One issue for the NLC/JLC and CLIC approaches for the 500 GeV Linear Collider, as well as the one TeV upgrade. Design gradients are 65 MV/m (unloaded) for J/NLC and and 172 MV/m (unloaded) for CLIC. For the TESLA- 800 GeV upgrade, the gradient issue was called out as Rank One. Here the design that needs adequate demonstration is 35 MV/m. Gradients above 35 MV/m would increase the upgrade energy. Techniques to lower the production costs of 20,000 structures will also be important toward the eventual realization of a linear collider.

SLAC and CERN are making steady progress in understanding the extent of structure damage triggered by breakdown and the relationship to structure geometry, RF frequency and materials. For example while SLAC discovered that damage in 11.4 GHz copper structures can be limited by cavity designs with lower group velocity, CERN has shown benefits in their 30 GHz copper cavities by lining the iris with tungsten rings. However, to achieve high gradient reliably, much remains to be done to understand fundamental issues: what triggers breakdown, what controls the ensuing level of damage, and how these depend on the RF frequency. Breakdown experiments have led to development of models. Validation of these models requires experiments over a wide range of frequencies, especially between 11.4 and 34 GHz where linear collider designs exist. In particular it is important to use similar methods to power structures at different frequencies so results are comparable. SLAC has been driving 11.4 GHz structures with high power klystrons, while CERN decelerates a beam through their 30 GHz structures to proved the needed energy to reach high gradients.

In collaboration with CERN, the Yale group **[Project leader: J. Hirshfield; Budget: $95K over 3 years]** plans to address the above issues by powering 34 GHz structures by a 45 MW recently commissioned magnicon amplifier, rather than by the beam. CERN will provide the structures whereas Yale will provide the high power testing facility and diagnostics. Yale proposes to develop an accelerating structure design with low peak surface electric and magnetic field, and a group velocity of 0.05 c. Test results will help elucidate existing models or generate new ideas.

For the superconducting option, the TESLA collaboration has been making steady progress in developing cavity treatment procedures to regularly reach accelerating fields above 25 MV/m needed for 500 GeV. At higher gradients the Q begins to drop precipitously. New treatments such as electro-polishing and 100 C baking have been developed to delay the onset of the Q-drop to 30 - 35 MV/m. Missing is a good understanding of the cause of the Q-decline and the reason for the effectiveness of the empirical cures. Advances in these areas will open the door to higher gradients.

The Cornell SRF group **[Project leader: H. Padamsee; Other senior personnel: M. Tigner; Budget: $304K over 3 years]** plans to fabricate and test single cell cavities prepared by various treatments: standard chemical etching, electro-polishing and other chemical treatments on the horizon. Each cavity will be tested before and after 100 C baking, and higher baking temperatures will be explored. DESY will provide some of the cavities, especially those with electro-polished surfaces. Tests at Cornell will include a powerful thermometry diagnostic system which will identify regions of high RF losses. After dissection, these regions will be examined with Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray Analysis (EDX), Auger Electron Spectroscopy (AES) and Secondary Ion Mass Spectrometry (SIMS), surface analytic tools available at Cornell. Niobium samples prepared by the same methods as the cavities will be studied in parallel. Results from these tests will validate models under development for understanding the Q-slope mechanism.

Since RF losses in high magnetic field regions trigger the Q-drop, it will be important to develop new cavity designs that lower the surface magnetic field. After optimization, single cells will be fabricated and tested. At the same time, new treatment procedures will be investigated to lower costs for large scale production. Finally, multi-cell structures will be fabricated with the help of industry. This is also a good opportunity to fill an existing gap and train US industry in the sophisticated techniques of niobium cavity fabrication and surface preparation.

The milestones and deliverables for the normal conducting structure work are as follows:

In FY04 the 34 GHz accelerating test structure and test facility will be designed at Yale.

In FY05 we plan to fabricate the structure at CERN and carry out low power RF tests.

In FY06 high power tests will start at Yale. Using data from the tests together with on-going RF breakdown work at SLAC and CERN, we hope to further our understanding of breakdown. Annual reports will be presented every year, along with the final report at the end of three years.

The milestones and deliverables for the superconducting structure work are as follows:

In FY04 we will carry out tests on single cell cavities prepared by various treatments. Thermometry and surface analysis tests will help elucidate current models. We will also explore cavity designs with lower surface magnetic fields.

In FY05 we plan to fabricate single cell cavities with reduced magnetic field designs and prepare surfaces with the best chemical treatment, including exploration of options for treatments that will lower production costs.

In FY06 we will fabricate and test multi-cell structures of advanced designs with the help of industry.

Annual reports will be presented every year, along with the final report.

5 Accelerator control

The international nature of the Linear Collider collaboration lends itself to the possibility of a truly Global Accelerator Network (GAN) for operating such a facility. Exploration of the capabilities of this kind of network and its basic unit – the virtual control room – will help demonstrate the feasibility of this approach. Being one of the central building blocks for the virtual control room and the GAN idea in general, remote control and operation of a linear accelerator machine will be the focus of the Cornell/Ohio State University group project. It will be accomplished in close collaboration with DESY and its divison responsible for operating the TESLA Test Facility (TTF). This will be an excellent chance to demonstrate one of the concepts of GAN: sharing world-wide resources and competence by deploying collaborative technologies.

Using existing technological solutions that allow remote control, monitoring as well as operation of a distant accelerator have been demonstrated at DESY, Cornell, SLAC and elsewhere; but an accelerator control and data acquisition system design using the GAN approach has not yet been carried out.

The Cornell/Ohio State University group **[Project leader: D. Hartill; Other senior personnel: K. Honschied (Ohio State); Budget: $173K over 3 years]** proposes to work out a control system design with DESY which will emphasize remote operation and control capabilities. Among the goals of this project are evaluation and creation of new collaborative tools, to support the development process of various system components, and to foster the knowledge exchange between HEP experienced University groups and accelerator sites.

A program for upgrading and enhancing the control and data acquisition (DAQ) system for the TESLA Test Facility will be performed which includes remote access and remote online diagnostics. With reliable distant access to online information and data, remote operation can be effectively and safely conducted. With the upgraded data acquisition system in place, the goal will be to carry out beam emittance measurements at TTF with remote operation and measurements from Cornell. Tools that allow collaborative document sharing and archiving as well as distributed code development are critical for these activities. Affordable video conferencing tools that work reliably in many different countries to exchange ideas across these geographical boundaries are key to the success of such a collaboration. The effectiveness of these collaborative tools will be evaluated as part of this project.

The **FY 2004** year will be dedicated to the evaluation of possible extensions to the existing prototype of the TTF data acquisition system. The main focus will be on global accelerator network specific enhancements like remote control and monitoring capabilities. Data storage concepts which will allow for easy access to the recorded data by off–site collaborators, experts and technicians, will be developed. A first concept design will be carried out and a prototype system will be developed. Collaboration with scientists at the NLCTA and the ATF at KEK will be actively pursued to provide assistance on similar problems that these facilities face. In addition, the first stage of collaborative tools will be deployed including video conferencing tools and development environments. Deliverables for the first year will be a prototype data acquisition system and a data storage concept for a linear accelerator control system as well as a report on the effectiveness of deploying collaborative tools in an early project design and development stage.

The main focus for **FY 2005** will be further development of the data storage parts and developing GAN tools needed for retrieval, visualization and analysis of data taken with an accelerator control system. Active collaboration with DESY, the NLCTA and/or the KEK ATF groups should be underway. Deployment of collaborative tools especially for code management and documentation will be necessary for this part of the project and an enhanced report on these activities will be provided. Deliverable items will be a usable data acquisition including data storage and remote access to the data as well as a documentation system covering the design and development phase to date. Remote operation of the TTF to start beam emittance measurements will be attempted from Cornell.

In **FY 2006** year we will focus on the development of visualization and analysis tools for accelerator controls and physics data. We will investigate standard HEP software packages, *e.g.* ROOT, to see if they are suitable for this purpose and if they can be used in parallel or even replace commercial products like MatLab. Collaboration with the NLCTA and/or the KEK ATF groups will continue. A technical report on the use and exploration of collaborative tools during the three years of developing and implementing the software will be provided.

6 Education and Outreach

The physics of the Linear Collider (LC) is exciting, and we hope to share the excitement beyond the walls of the labs and universities.

To bring a glimpse of LC physics and technology to high schools, we propose a new program of UCLC Fellows and UCLC Scholars. UCLC Fellowships will bring high school teachers to LC research, by providing funding for up to 8 weeks of summer research with UCLC groups. UCLC Scholarships will do the same for high school students. Fellows and Scholars will help carry out beam simulations, develop fast kickers, prototype beam diagnostic monitors, study RF breakdown or develop strategies for remote accelerator control, working side-by-side with university physicists. For classroom transfer, teachers could take, for example, cosmic ray detectors in the form of component parts back so that their students could assemble and operate them.

Fellows and Scholars would be viewed as members of UCLC. We would expect Fellows to attend the workshop of the American Linear Collider Physics Group during the summer of their Fellowship. In addition to attending the regular sessions of the Workshop, we envisage a special session at that workshop in which science teachers participating in LC research would present their results to one another. This session would include all UCLC Fellows, both from this accelerator program and from the partner UCLC detector program, as well as teachers participating in LC research through other programs such as Quarknet or RET. The UCLC Scholars from the detector and accelerator programs will also present their results to one another through a video forum near the end of the summer.

UCLC Fellows and Scholars will be selected competitively. Individual UCLC university groups will identify candidate Fellows through their contacts with local schools, or using contacts developed through Quarknet and RET programs. Fellows will be selected from among these candidates based on their qualifications and the appropriateness of the project proposed for them by the sponsoring university group. We expect that some UCLC Fellows will have participated in the very successful Quarknet or Research Experience for Teachers programs, but past participation in those programs is not a requirement. Similarly, UCLC Scholars will be drawn from the communities neighboring UCLC universities, and will be selected on the basis of recommendations by their teachers.

UCLC Fellows and Scholars would receive a stipend of $5000 and $1500 respectively and modest travel support on a case-by-case basis. In addition, teachers would receive $1000 support for classroom transfer materials and support for travel to the ALCPG workshop. We plan to support two Fellows and two Scholars in accelerator research in the first year of this program and four of each in the second and third years.

In addition to mentoring UCLC Fellows and Scholars, UCLC groups would continue with their many ongoing education and outreach activities. UCLC groups will engage numerous undergraduates in their research. Each year, at least three undergraduates will contribute to UCLC accelerator projects, either independently or through Research Experience for Undergraduates (REU) programs. Minnesota plans to develop Linear Collider web resources, link them to class web sites, and advertise them to their students and other UCLC groups. Wherever possible, the LC will be introduced into outreach activities aimed at K-12 students and the general public.

This proposal opens new territory for graduate education in accelerator physics. Traditionally, accelerator research has been largely confined to the labs and a handful of universities closely connected with them. With this proposal, a number of new university groups will begin accelerator research, and for the first time, will offer accelerator research to their graduate students.

7 Project Management Plan

Cornell University will be responsible for overall management of the activities of UCLC. Maury Tigner will serve as PI, with Gerry Dugan serving as co-PI and Project Manager for this proposal. Each project external to Cornell will be funded by a subcontract award from Cornell to the project leader's institution. In cases in which the project involves more than one university, the project leader's institution will award a "second tier" subcontract to the other institution.

Financial reports for each project will be assembled from the subcontracting universities and Cornell quarterly. The funding of each project will be tracked against the project's budget.

Each project leader will be expected to submit a written progress report to the Project Manager every six months. In addition, the project leader or his or her delegate will give an oral report at the summer meeting of the ALCPG. The progress will be tracked against the deliverables promised in the project description.

Annually, the work of UCLC and LCRD will be jointly reviewed by independent review panels under the auspices of the U.S. Linear Collider Steering Group. The continuation of funding for each project at its nominal level will depend on the evaluation of the review panel, the completion of the promised deliverables, and the availability of funds.

The project leaders and UCLC management will meet annually at the summer ALCPG meeting to discuss matters of consortium-wide interest and policy. There will also be a meeting of UCLC and LCRD coordinators in conjunction with the ALCPG workshop.

References

[1] http://w4.lns.cornell.edu/public/LC/UCLC/

[2] http://www.hep.uiuc.edu/LCRD/html_files/index.html

[3] T. Himel *et al*, "The Accelerator List", http://www-conf.slac.stanford.edu/lcprojectlist/asp/projectlistbyanything.asp.

[4] American Linear Collider Physics Group Executive Committee, "Design Considerations for an International Linear Collider" (2003), http://blueox.uoregon.edu/~jimbrau/LC/scope.ps

[5] G. Loew *et al*, "International Linear Collider Technical Review Committee: Second Report", SLAC-R-606 (2003), http://www.slac.stanford.edu/xorg/ilc-trc/2002/2002/report/03rep.htm

[6] DOE/NSF High Energy Physics Advisory Sub-panel on Long Range Planning for U.S. High Energy Physics, Jan. 2002, http://doe-hep.hep.net/lrp_panel/

[7] "Linear Collider Physics Resource Book for Snowmass 2001", American Linear Collider Working Group, BNL-52627, CLNS 01/1729, FERMILAB-Pub-01/058-E, LBNL-47813, SLAC-R-570, UCRL-ID-143810-DR, LC-REV-2001-074-US, http://www-sldnt.slac.stanford.edu/snowmass/OrangeBook/index.html

[8] "Physics at an e+e- collider", R. D. Heuer, D. Miller, F. Richard, P. Zerwas, TESLA Technical Design Report, Part III, http://tesla.desy.de/new_pages/TDR_CD/PartIII/physic.html

[9] http://w4.lns.cornell.edu/public/LCCOM/

[10] http://w4.lns.cornell.edu/public/LCCOM2/

[11] http://blueox.uoregon.edu/~jimbrau/LC/ALCPG/

[12] http://www-conf.slac.stanford.edu/lcprojectlist/projectlist/intro.htm

[13] M.G. Bardeen, R. M. Barnett, and R. Ruchti, eds, "Particle Physics, Education and Outreach 2001" available at http://www-ed.fnal.gov/hep/home.html.