ADDENDUM

to a

MEMORANDUM OF UNDERSTANDING

between the

INTERNATIONAL LINEAR COLLIDER
GLOBAL DESIGN EFFORT

and

Argonne National Laboratory

for the period

October 1, 2005 to September 30, 2006

1. Introduction

This Addendum constitutes the Statement of Work to be performed by Argonne National Laboratory (ANL) in support of the International Linear Collider (ILC) for the period of October 1, 2005 to September 30, 2007. It is expected that, under the auspices of the GDE, the baseline design for the ILC will be completed by December 2005, the reference design report and cost estimate by December 2006, and work on technical design will commence in 2007. ANL propose to participate in the preparation of and carry out R&D in support of these reports in areas specified in this Addendum.

The activities detailed in this document fall within the scope of the Memorandum of Understanding (MoU) between the GDE and ANL dated dd, 2005. The terms and conditions under which the work will be carried out are found within the MoU and are in force for the duration of time covered by this Addendum.

2. Statements of Work

This Section contains the Statements of Work to be done at ANL during the period of time covered by this Addendum.

Statements of costs and commitments incurred for each work package will be submitted at the end of each fiscal year quarter to the GDE-Americas Regional Office.

Semiannual technical progress reports for each work package will be submitted at the midpoint and close of the fiscal year to the GDE-Americas Regional Office. These reports will contain descriptions of technical progress, statements of goals for the next reporting period, and indications of long-range plans.

Within two months following the end of the fiscal year, a final technical report for each work package will be submitted, in which the actual work accomplished will be compared with the scope defined in the work package in this MoU.

2.1 Scope of Work

CATEGORIES:

1 PROGRAM DIRECTION AND ADMINISTRATION

- *1.3.1 Coordination of ILC Accelerator Effort at ANL*

2 ACCELERATOR DESIGN, INCLUDING REFERENCE DESIGN REPORT

- *2.2.2 Control System Design*
- *2.4 POSITRON SOURCES*
  - *2.4.2 End-to-End Simulations of the Undulator-based Positron Sources from the Undulator to the Damping Ring*
- *2.5 DAMPING RING*
  - *2.5.6 Damping Ring Characterization and Optimization*

3 RESEARCH AND DEVELOPMENT

- *3.2 RESEARCH & DEVELOPMENT: GLOBAL SYSTEMS*
  - *3.2.3 Diagnostic Processor for Power Supplies*
  - *3.2.4 High Availability Control System & Standard Instrument Modules*
    - *3.2.4.1 High Availability Controls System*
    - *3.2.4.2 High Availability Standard Modules for Instrumentation Systems*
  - *3.2.6 Control Systems*
    - *3.2.6.1 High Stability RF Phase Distribution System Development*
    - *3.2.6.2 Control System Framework*
  - *3.2.7 Development of Time-Resolved Photon Diagnostics for the ILC Multi-GeV Beams*
  - *3.2.8 Survey and Alignment*
    - *3.2.8.1 Implementation of a New X-ray Alignment Technology for the ILC*
- *3.4 POSITRON SOURCES*

3.4.4 Gamma-ray Undulator

3.5 DAMPING RING

3.5.4 Development of Time-Resolved Photon Diagnostics for the ILC Damping Ring

3.5.7 Damping Ring Beam Dynamics

3.5.8 Damping Ring Magnets

3.9 MAIN LINACS, INCLUDING RF SYSTEMS

3.9.3.4 Electropolishing System for the ILC at the ANL-FNAL Joint Facility

5 INFRASTRUCTURE AND TEST FACILITIES

5.2 Infrastructure and Test Facilities: Global Systems

5.2.2 Control System Design for ILCTA

5.2.2.1 Control Systems Support for ILCTA

2.2 Definition of Work

CATEGORY 1—PROGRAM DIRECTION AND ADMINISTRATION

1.3.1 Coordination of ILC Accelerator Effort at ANL:

Description:

ANL is pursuing a number of topics in ILC design and R&D. This workpackage is for coordination of this effort within ANL and with ILC Americas and the GDE.

Key Personnel:

K.-J. Kim - Scientific (20%)
K. Jaje - Administrative (30%)

Effort in FY06 was funded by ANL internal funding.

Proposed Work and Milestone (FY07):

Cost Summary:

The following level of funding is required for FY07 and beyond.

FTE	Labor (K$)	M&S (K$)	Indirect(K$)	Total (K$)
	57	15 (travel)	25	97

2.2.2 Control System Design:

Abstract:

This category includes coordination and level of effort to define global requirements for controls system architecture for hardware and software to support the RDR and TDR. This effort requires coordination of management level and technical experts from several laboratories.

Project Definition:

Provide level of effort to develop specifications, research applications requirements from all Area and Technical Systems, construct the WBS, coordinate cost modeling and estimating, document systems and cost books; write descriptions for RDR and TDR, and archive all backup information.

Initial work in FY07 will focus on the completion of the RDR and costing by November 2006. Beginning in January 2007, work on the Technical Design Report will begin. Although the pace, focus, and milestones of the TDR process will be determined by the GDE, it is anticipated that work beginning in FY07 will consist of two major efforts:

1. Starting from the BCD and RDR, perform a more detailed investigation and definition of the requirements of the Integrated Controls System, and interfaces with the technical systems. This will include:
   - Refining interfaces between the integrated control system and the technical systems.
   - Developing an understanding of unique or special control system requirements.
   - Develop integrated views of the Machine Protection System, Global Timing System, and beam-based feedback systems.

2. Begin work on those areas of the Integrated Control System which must be defined early in the technical design phase so as to provide appropriate information and guidance to the Technical System Groups. Early definition of these globally used resources will help avoid duplication of effort and ensure a smooth integration phase of the entire machine, including:
   - *Definition of site-wide infrastructure and interfaces,* such as networks, timing, real-time video distribution, real-time machine status, computing and storage capabilities.
   - *Definition of the control system "service tier."*
   - *Standardization of the integrating protocol(s) and tools*, to allow easier (and less costly) integration of the technical systems, and to help minimize duplication of effort.

- *Standardization of control hardware/software where applicable,* to reduce cost, and increase reliability, maintainability and operability.
- *Definition of Technical System requirements from the control system,* to ensure compatibility and to ensure global requirements are met for data collection, fault analysis, and operations.

Motivation:

This work is necessary in order to provide appropriate costing, reference design, and technical design for the ILC Integrated Control System.

Collaboration with Other Institutions:

This work will leverage the strong collaboration between SLAC, FNAL, and ANL (in the Americas), and institutions in Europe and Asia, including DESY, KEK, University of Oxford, and Daresbury.

It is anticipated that John Carwardine will continue in his leadership role as the America's Region Coordinator for the Controls Global Group.

Deliverables and Milestones for FY07:

- Complete first-cut WBS, cost estimate, Reference Design Report, and supporting documentation by November 2006.
- Begin developing the Technical Design Report.

Key Personnel:

ANL: John Carwardine + staff
FNAL: Margaret Votava + staff
SLAC: Ray Larsen + staff

Cost Summary:

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL	1.7	250	85	30	9	374
FNAL						
SLAC						

Expectation for FY08 and Beyond:

This work will continue throughout FY08 and beyond, with the team developing an increasing level of detail and technical certainty, and completing the Technical Design Report and supporting materials.

2.4 POSITRON SOURCES

2.4.2 End-to-End Simulations of the Undulator-based Positron Sources from the Undulator to the Damping Ring

Description:

During the proposed period, we will perform detailed end-to-end simulations in order to optimize the ILC positron source. The simulated components include: incident-drive electron beam, undulator (photon production), photon collimators, conversion target, positron collection system (mainly the adiabatic matching device, AMD), normal conducting preaccelerator, positron separator and selection optics, and superconducting accelerator-to-damping rings. We will use well-documented and proven accelerator codes (EGS4, GEANT, FLUKA, and PARMELA) to simulate the positron dynamics throughout all the components listed above and provide realistic particle distributions to the damping ring design team. Throughout the simulation, we will provide systematic lists of the positron source parameters to help the GDE team make decisions on the positron design. We will also design a conventional adiabatic matching solenoid that potentially can be operated in a radiation-hard environment; this is a backup scheme for the superconducting solenoid currently being considered. In addition, we will design and simulate the keep-alive conventional positron source, which is essential for availability of ILC operations. Along the way, we will investigate and solve physics problems associated with the positron source design.

Our work falls into the categories:

IN_e+, target and AMD, very high
IN_e+, e+ source simulation, high
IN_e+, e+ capture, high

Motivation:

Our work will support the baseline decision and technical design for the ILC positron source. Although the GDE team has selected the undulator-based positron scheme for the ILC, it is critical to perform systematic and detailed end-to-end simulations. Also, a conventional-based keep-alive source is needed for the ILC operation and is yet to be designed.

Collaboration with Other Institutions:

We collaborate closely with the SLAC positron team (John Sheppard and Vinod Bharadwaj), and perform simulations and optimizations as requested by them. We will also work with the DESY positron team on the detailed simulation studies at the intellectual information exchange level.

<u>**Milestones and Deliverables**</u>**:**

We will approach the positron source studies on both the numerical simulation and engineering design fronts. To produce the gamma rays, we will follow the TESLA design for the gamma-ray-based positron source, but with the electron beam energy lowered from 250 GeV to 150 GeV. The initial distribution of the charged particles (positron and electron) emerging from the conversion target is simulated using the electromagnetic shower simulation codes EGS4 and GEANT. Next, the generated positrons and electrons go into the positron capture optics, which consists of the adiabatic matching device (AMD) and the preaccelerator. The AMD (a tapered solenoid starting with a high initial field and tapering adiabatically down to the constant end field) is used to match the initially large divergence of the positrons into the preaccelerator, and then the preaccelerator accelerates particles to ~ 250 MeV. Finally, the positrons satisfying the constraint of the damping ring acceptance are captured, passed through a quadrupole focusing system, and continuously accelerated up to 5 GeV before being transported to the damping ring. The beam dynamics, from the conversion target to the entrance of the damping ring, will be performed using the particle tracking code PARMELA.

<u>**Proposed Work and Milestones (FY06)**</u>

During FY2006, the following tasks will be performed:

1. Conduct detailed end-to-end beam dynamic simulations and multivariate optimization from the photon production and collimation at the undulator to the polarized positron production at the target and to the damping ring for different ILC positron designs. Provide the necessary input parameters to the ILC positron source collaboration for baseline considerations and provide particle phase space to the damping ring design teams.
2. Conduct detailed studies on the positron separation and collimation at 250 MeV before injecting into a 5-GeV linac. Detailed magnets requirements and beamline design will be given. We will also investigate phase manipulation schemes that compress and collimate the positron beam for the damping ring input.
3. Perform initial design of the keep-alive positron source. Determine the drive beam energy and intensity based on the requirement from the GDE.
4. Investigate various schemes for the AMD solenoid, such as Bitter magnet, conventional, and superconducting coils. Examine the capturing efficiency as a function of the AMD magnetic field parameters. Produce a final design of the tapered solenoid, and perform a detailed engineering study, including cooling implementation and a power supply.

In summary, through the work outlined above, we will contribute to the ILC design by making a detailed study of the positron source and its associated issues.

<u>**Key Personnel**</u>**:**

Wei Gai, 35%; Wanming Liu, 80%; Haitao Wang, 80%; Kwang-Je Kim, 5%

Cost Summary (06):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
143	7		150

Additional support will be provided by ANL internal funding to cover the actual spending.

Proposed Work and Milestones (FY07 and Beyond):

The work outlined in FY06 is a multi-year effort and is expected to continue into FY07 and beyond. It is anticipated that more detailed simulation effort is required for the ILC positron source studies to determine detailed hardware components and accelerator designs, e.g., the collimator design for the photon beam; engineering layout for the positron separation region; beamline magnet design for the positron transport; and the keep-alive source target and positron accumulation design.

We will continue to study the positron beam parameter optimizations as outlined in tasks 1, 2, and 3 for FY2006. In addition, we will perform the following tasks:

1. Construct a prototype AMD solenoid to test cooling and power supply capabilities.
2. Perform radiation background calculations and determine the impact on accelerator components.
3. Other tasks as requested by the ILC positron source collaboration.

The expected number of FTEs for FY07 is two, the same as FY06: 1.2 FTE x $215K for ANL staff and 0.8 FTE x $40K for one student; total effort of $296K was rounded to $300K). The total cost expected in FY07 is about $340 K, and the same amount for subsequent years.

Cost Summary (07):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
222	30	88	340

2.5 Damping Ring

2.5.6 Damping Ring Characterization and Optimization

Description:

First Phase: Further characterize the performance of the seven reference damping ring lattices. This has been completed.

Second Phase: Produce one or more lattice designs for the 6-km baseline positron and electron damping rings. Add features to the accelerator simulation code `elegant`. Further apply principles of multi-objective optimization to damping ring lattice designs.

Motivation:

The first phase supports the Baseline Design Report for the damping ring that was finalized in January 2006. The second phase is required for the Reference Design Report.

Collaboration with Other Institutions:

We collaborate with a worker at FNAL, Bill Ng, who will use tracking code `elegant` for calculating space-charge effects.

Milestones and Deliverables (06):

First Phase: Provide performance data of the seven proposed optics designs from numerical simulations with the tracking code elegant. Several types of calculations are to be performed, including dynamic aperture boundary with typical magnet errors and determination of particle loss when injecting a beam with realistic initial coordinate distribution.

Second Phase: The lattices designed should meet specifications for damping time, equilibrium emittance, acceptance, etc. and should include all major subsystems, including injection/extraction sections, orbit, optics and coupling correction systems, rf cavities, etc. The circumference should be around 6 km and should allow for a variety of different fill patterns (different numbers of bunches) without changes in circumference or rf frequency.

We will add additional capabilities to `elegant` that are needed for damping ring assessment: i) effect of space charge, which tends to spoil the small vertical beam emittance; ii) various existing coupling formalisms to calculate the equilibrium vertical emittance and coupling angle around the ring lattice; and iii) singular-value-decomposition method for orbit correction.

Following this, we will determine optimization trade-off curves for the most promising designs using existing multiobjective evolutionary algorithms, a promising engineering approach only recently introduced into accelerator design. There are several fundamental parameters in each of the damping ring types that have been proposed; there are also several objectives to minimize or maximize in addition to the basic specifications of damping time, beam emittance, and bunch length. Possible objectives are lattice nonlinearity, beam instabilities, and the total costs. Since the objectives conflict with each other, a special sorting of feasible solutions is presented to the user as points on a surface in a multidimensional objective space (preferably limited to a 2-d or 3-d space). The actual work required is the coding of the objectives and design constraints as a function of decision variables for several or all of the ILC damping ring types.

A higher-level application of this optimization is that of the overall ILC cost relative to a subsystem specification taken as a variable. For example, damping rings have been given a (fixed) specification for the extracted beam bunch length. A change to a shorter bunch can be expensive to implement in a damping ring while making the bunch compressor beamline cheaper. A longer extracted bunch length reverses the respective costs. The global optimum is not known for certain since the costs of the damping ring and the bunch compressor as a function of bunch length have not been modeled as a function of bunch length. What would be useful to calculate is a trade-off curve with the bunch length as a decision variable, and the linear collider performance and global cost as objectives.

Key Personnel:

Aimin Xiao, 100%; Louis Emery, 20%; Yong-Chul Chae, 10%; Vadim Sajaev, 10%

Cost Summary (06):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
130	20		150

Additional support will be provided by ANL internal funding to cover the actual spending.

Proposed Work and Milestones (FY07):

Some aspects of the design process may continue (as refinements or adjustments) through 2007 as more engineering details are known. We estimate about 0.4 FTE required for the "maintenance" of the DR design and injector line.

Key Personnel: 0.4 FTE

Aimin Xiao, 30%; Louis Emery, 10%

Cost Summary (07):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
60	10	25	95

Similar level of effort will continue beyond FY07.

CATEGORY 3—RESEARCH AND DEVELOPMENT

3.2 RESEARCH & DEVELOPMENT: GLOBAL SYSTEMS

3.2.1 High Availability Power Supplies

Abstract:

Availability calculations show that the ILC cannot achieve its target availability without designing all subsystems for High Availability from the outset. This applies especially to the power systems including DC supplies and modulators. The DC supply subsystem alone cannot achieve better than 0.80 without HA design, and for the entire ILC to achieve 0.85 re-

quires that DC power and other subsystems achieve A~0.99. The project proposes to demonstrate technical feasibility with readily-available components and in parallel will develop additional features as needed to reach the availability goal. A demonstration system will be built in collaboration with KEK for ATF2. A second phase of study will demonstrate full HA features as well as cost viability by developing industrial sources.

This section is included for reference only. ANL is not requesting resources for this task.

Project Description:

The FY07 R&D program includes a component to provide engineering and coordination, supervision of construction and testing of an HA system of 40+ power supplies for ATF2. This system will be modular n/N but will not include redundant bulks or controllers. In parallel we propose to demonstrate a fully engineered HA power supply system capable of meeting the full ILC system availability goal. A detailed analysis by P. Bellomo shows that 4 of 5 redundant hot swappable modules alone can achieve a full ILC system A=0.88; adding the dual Bulk achieves A=0.92; and adding the dual controller yields A~0.99, the remaining limitation due to single-point failure components such as cables and transductors.

The proposed base unit will include n/N redundant hot-swappable switching power supplies, dual redundant bulk and controller, failure detection diagnostics, and auto-failover hardware/software. First a single unit and then a system consisting of four supplies fed from a common bulk will be demonstrated. The top end IOC (Input Output Controller) function with failover software will be built on the Telecom industry ATCA ("Advanced Telecom Computing Architecture") standard platform that is expected to be adopted for the main controls backbone and network systems.

Details of the imbedded diagnostic processor function are described in *3.2.3.*

Motivation:

Power supply systems are a major limitation to system availability unless designed with high availability performance from the outset. In addition to achieving unprecedented system performance the systems must remain cost-viable.

Collaborations with Other Institutions:

The power supply development is of interest to the ATF2 and a SLAC-KEK partnership has been proposed for a sizeable demonstration system to evaluate the approach in a real working environment. KEK has modestly supported an early successful prototype but as of this date has not yet committed to the larger system since technically it is not needed for the ATF2.

SLAC proposes a partnership with ANL on the Diagnostic Processor (see below) and has already benefited from a prototype development with Pohang Light Source in 2005-6.

Key Personnel:

SLAC:
KEK: TBD
ANL: John Carwardine (Point of Contact) + staff

FY07 Milestones and Deliverables:

Base Program:
- Design, build, test single unit of 4/5 5 KW supply, dual redundant bulk & controller.
- Incorporate diagnostic controller (see 3.2.3).
- Test failover modes with IOC

ATF2 Program:
- Support design, assembly, test, documentation of ATF2 40+ supply system.
- Procure modular supplies, racks, controllers

3.2.1 Cost Summary:

SLAC proposes 2 FTE's for Engineering and 85K M&S for the HA full feature system development program, and 0.75 FTE for Engineering and Coordination and 320K M&S for ATF2 development.

The ATF2 effort will occur in the last half of 07 after all purchased equipment is received.

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL						
FNAL						
SLAC						

Expectations for FY08 and beyond:

The Base HA program will continue with design, procurement, construction of a 4-unit HA 4/5 system (5KW supplies) with full features including failover software.

The ATF2 system will be tested at SLAC, delivered, installed, tested at KEK, and training conducted for KEK operations and maintenance staff.

Additional efforts will focus on developing vendors in the three ILC Regions for power systems designed to HA design criteria.

3.2.3 Diagnostic Processor for Power Supplies

Abstract:

The Diagnostic Processor is conceived as the key element in the development of the Diagnostic Interlock Layer referred to in the BCD Controls document. A generic diagnostic card designed to monitor internal functions of power devices such as large supplies and modulators was first undertaken in 2005 in collaboration with the Accelerator Department of the Pohang Light Source. This unit has waveform sampling and trigger/timing features for use in pulsed modulators and high power rectifier units in which waveforms are needed for troubleshooting. The card also has slow analog ADC's and DAC's for monitoring slow waveforms down to DC, such as the long pulse in ILC, temperatures, interlock trip signal levels and set-points. The full unit is still under evaluation at Pohang and a performance report is imminent. Meanwhile a second more specific version was undertaken for the Marx modulator under development and the first prototype unit is operational in the first Marx 12KV cell. Now another implementation is needed for the HA modular power supply under development. The goal is a small family of cards with a common communications interface to use in power applications, ultimately to get diagnostic data into the main control room, as well as available to service personnel in the field by a laptop connection to Ethernet.

Project Description:

1. Continue the support of the Pohang generic card program with M&S funds and matching personnel effort from PLS. Design, build and evaluate second prototype. This card has both fast and slow sampling capabilities and a very wide range of programmable time delays and widths, as well as DC multiplexed inputs for reading temperatures, DC interlock set-points etc. The unit will be tested in a practical application at Pohang and then evaluated in the 2-Pack solid state modulator at SLAC.
2. Continue support of the Marx development. The system consists of up to 16 Diagnostic Controllers, one per Marx cell floating at voltages up to 120KV, and a Ground Station communicating trigger and data information by fiber optic cables. The small 3 by 5 inch card provides local triggers with both a delay control, for output waveform optimization, and width control of the output current pulse to the klystron. Waveform digitizers monitor the charging waveforms as well as the output pulse and pulse rise and fall-times. The ground station link to a higher level applications program will be specified, built and tested. Design a second prototype in conjunction with Marx Design For Manufacture program starting in FY07.
3. Begin development of new Diagnostics Controller for HA Power Supply systems. This unit will provide information to Main Control via the Controls System to manage response to failed units as well as to possibly take action to avoid impending trips that would trip off the entire machine. The feature set will be optimized for modular units of typically a 5-module HA architecture and will have spare inputs for special functions.

Motivation:

The ILC will contain unprecedented number of modular units in power systems, and it is essential to incorporate an intelligent remote diagnostic system.

Collaborations with other institutions:

This effort is being led by SLAC.

Collaboration will continue with Pohang Light Source for a second-generation prototype. A new collaboration is proposed with Argonne National Laboratory, APS, for software development of the top level control system for the Marx unit, to start in 06 and complete in Q2 of FY07.

Further collaboration with APS is proposed for development of the Power Supply diagnostic controller software system, to begin in 07, and will strongly leverage on the work described in 3.2.4 ("High Availability Control Systems and Standard Instrumentation Modules"), with the diagnostic processor being a demonstration of a redundant EPICS IOC running on ATCA.

Key Personnel:

SLAC – D. McNair, P. Bellomo, J. Olsen
ANL – J. Carwardine (point of contact) + staff

Milestones and Deliverables (FY07):

1. PLS second generation DP prototype completed and tested Q407
2. ANL Completion of Marx DP controls software Q207
3. SLAC-ANL completion & test HAPS DP first prototype on 4/5 system.

Cost Summary:

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
SLAC						
ANL	0.25	37	12	35	10	94
PLS						

Expectations for FY08 and beyond:

- Assuming Marx system successful, build new full DP system for next generation DFM Marx design
- Explore feasibility of wireless connectivity to Marx cells to possible eliminate fiber connections to HV.
- Develop generic DP cards, hybrid circuits or low power custom chips suitable for major modular power system designs: Modulators, Power Supplies, and Chargers.
- Explore additional applications for DP's in high volume situations, e.g. Vacuum pumps, temperature monitoring of warm structures, etc.
- Major efforts will center on developing vendors to supply Diagnostic Processors for high volume applications.

3.2.4 <u>High Availability Control System & Standard Instrument Modules</u>

3.2.4.1 High Availability Controls System

Abstract:

The Baseline Conceptual Design (BCD) for controls recommends that Controls adopt a High Availability design philosophy in order to achieve overall integrated luminosity goals for ILC. This leads to extensions of classic architectures to eliminate single-point failures of both hardware and software. This work evaluates the cost-benefit of applying various High Availability techniques to address the failure modes. The High Availability techniques will be prototyped across the Applications, Services (middleware), and Real-time tiers of the ILC accelerator control system. This work will require strong interaction with the ILC Commissioning, Operations, and Reliability Group.

Project Description:

Evaluation of high availability techniques must be informed by a process of identifying potential control system failure modes and their effect on machine performance & luminosity. The work would begin by determining the likelihood, duration, and impact of a variety of failures in the control system and other operational systems, based on experience at existing facilities. Part of the project would involve identifying a useful methodology for doing the failure modes & effects analysis.

High availability techniques for addressing identified failure modes, both administrative and technical, will then be identified. The adoption of a platform such as ATCA ("Advanced Telecom Computing Architecture") (the subject of another proposal) provides one part of a system of highly available hardware and software components. A wide variety of techniques are yet to be identified which can provide high availability through the entire architectural "vertical" of the control system. We will identify options, including administrative controls, software development methodologies, off-the-shelf, and custom frameworks, etc.

In order to ground the above analysis in a concrete implementation, a prototype "vertical" software demonstration will be implemented applying a representative set of techniques to the applications, services, and real-time tiers. This could be done in conjunction with ILCTA specific projects, or on a stand alone demonstration test stand. The performance of the system will be tested through real and/or simulated failures.

Through the above failure mode characterization, solution space analysis, and prototype test stand, a cost-benefit evaluation of the identified high availability techniques and products will be conducted.

This work is coupled with the work described under 3.2.4.2, "High Availability Standard Modules for Instrumentation Systems."

Motivation:

The technical and geographic scale of the ILC places unprecedented demands on the control system hardware and software for availability and remote diagnosis and troubleshooting. To accomplish the ILC goals of integrated luminosity, the ILC control system must be highly available. High availability is not an easily quantifiable term. Both the bounds of a system that is called highly available and the degree to which its availability is extraordinary must be clearly understood on a case-by-case basis.

Performing this work in FY07 will ensure that decisions about future control system development and control system implementation can be made in a timeframe consistent with the overall ILC schedule.

Collaborations with other institutions:

A collective understanding of high availability in the context of accelerator control systems has been growing through discussions across many institutions, including SLAC, ANL, FNAL, KEK, and DESY. Efforts and interests amongst the member Laboratories are considered complementary. Discussions with outside organizations such as SAF (Service Availability Forum) and NASA are being pursued as well.

Lead roles amongst the partner Labs are currently being developed, based in part on the availability of specific individuals at each site.

Key Personnel:

ANL: Claude Saunders + staff
FNAL: Margaret Votava + staff
SLAC: Ray Larsen, Bob Downing (Downing Inc) + staff

Milestones and Deliverables for FY07:

- Identify a methodology and/or supporting tools for conducting and documenting a failure mode analysis of typical accelerator control systems.
- Conduct and document failure modes & effects analysis.
- Identify and document potential high availability techniques and products, and how they would address failure modes.
- Procure hardware and software necessary to prototype selected techniques, either forming an independent test stand (ANL lead), or integrating equipment with some portion of ILCTA.
- Leveraging off the work performed under 3.2.4.2 to port EPICS to the ATCA platform, extend EPICS to support redundant IOC databases running on two ATCA processors.

- Develop complete "vertical" demonstration of selected high availability techniques.

3.2.4.1 Cost Summary (07):

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL	1.0	147	50	60	18	275
FNAL						
SLAC						

Expectations for FY08 and beyond:

It is anticipated this effort will continue in FY08, with the development of specific recommendations and standards for ILC control system. Specific goals would include completing the cost-benefit analysis which evaluates the identified high availability techniques, and developing an appropriate ILC framework and methodology based on the results of the evaluation.

3.2.4 High Availability Control System & Standard Instrument Modules

3.2.4.2 High Availability Standard Modules for Instrumentation Systems

Abstract:

This work package is to investigate the suitability of the ATCA ("Advanced Telecom Computing Architecture") electronics platform as a High Availability compliant standardized electronics platform for the ILC accelerator control system. Both hardware and software suitability and performance must be investigated.

Project Description:

The ILC Controls Global Systems Group has begun investigations into the new commercial standard modular processor architecture (ATCA) designed for High Availability systems in the range of that required for the ILC. Some of the features that make it attractive as an alternative to more commonly used hardware platforms (VME, VXI, etc) include: redundant power sources and backplane, remote power up/power down of modules, hot swap, module self-identification, a "Shelf Manager" for intelligently managing resources, and high speed point-to-point serial links within the crate for redundancy and higher performance than traditional parallel bus backplanes.

ATCA has many attractive features for the ILC control system, but to date the platform has not been deployed in accelerator controls and instrumentation environments. This work package will continue the initial investigations into prototyping both hardware and software environments, and assess the performance and capabilities of the ATCA platform in accelerator controls and instrumentation applications. Particular areas that require evaluation are: performance of high sensitivity analog & LLRF circuits in an ATCA environment; electronics design/implementation challenges; cabling and connector options for bringing precision analog and RF signals into the ATCA framework. The feasibility of using ATCA with existing accelerator controls frameworks will be evaluated by porting EPICS (as a representative system) to the ATCA environment.

This work is strongly coupled with the work described under 3.2.4.1, "High Availability Control Systems".

Motivation:

The technical and geographic scale of the ILC places unprecedented demands on the control system hardware and software for availability and remote diagnosis and troubleshooting. It is highly desirable to adopt standard modular electronics platforms for the ILC controls and instrumentation to reduce overall cost of development, deployment, and support. Additionally, backplane bandwidths in the existing VME/VXI frameworks are likely to be performance limiting in the ILC. The ATCA framework has the potential to address these shortcomings and to provide high availability and remote diagnostic features that could significantly improve ILC accelerator recovery times when failures occur. This task is targeted at evaluating the ATCA platform for accelerator controls and instrumentation applications in the ILC.

Collaborations with other institutions:

The evaluation of ATCA has already spawned collaborations within the Americans Region. SLAC, ANL, and FNAL have all procured similar ATCA development environments. DESY has also procured ATCA hardware and has a proposal to port LLRF electronics (Simcon 3.1) to the ATCA platform. SLAC has also initiated collaboration with the HEP group at University of Illinois, Urbana Champaign. Efforts and interests amongst the member Laboratories are considered complementary.

Lead roles amongst the partner Labs are currently being developed, based in part on the availability of specific individuals at each site.

Key Personnel:

SLAC: Ray Larsen, Robert Downing (Downing Inc), UIUC staff
FNAL: Vince Pavlicek, Manfred Wendt + staff
ANL: Claude Saunders + staff

Milestones and Deliverables for FY07:

- Procure test equipment for high frequency digital/analog R&D.
- Prototype a precision instrumentation digitizer for use with beam position monitors. Evaluate analog & digital performance and suitability for precision accelerator instrumentation applications.

- Prototype representative electronics functions to the AMC mezzanine card, and integrating with the IPMC diagnostic module to assess ease of integration into custom designs and to evaluate the IPMC diagnostic module. Develop software drivers to utilize and evaluate IPMC capabilities.
- Evaluate cable and connector options for full-size ATCA and AMC mezzanine cards and their suitability for accelerator instrumentation applications with the ATCA framework.
- Procure a real-time operating system for ATCA CPU modules.
- Port EPICS to the ATCA platform to allow evaluation of the High Availability and "Shelf Management" features in an accelerator control system framework.

3.2.4.2 Cost Summary (FY07):

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL	0.75	110	37	40	11	198
FNAL						
SLAC						
UIUC via SLAC						

Expectations for FY08 and beyond:

It is anticipated this effort will continue in FY08, with the development of specific recommendations and standards for ILC electronic systems. Specific goals would include: evaluating and demonstrating redundancy, fail-over, and self-healing capabilities in the real-time operating system and EPICS controls framework running on ATCA front-end controller(s); evaluating the cost-benefit of using ATCA instead of alternatives such as VME or VXI as the standard platform for the ILC control system.

3.2.6 Control Systems

3.2.6.1 High Stability RF Phase Distribution System Development

Abstract:

This work will develop and implement prototype hardware for distributing a highly stable, high precision 1.3GHz RF phase reference throughout the ILC accelerator complex. The task is separated into two components: phase-stabilized fiber optic links for distribution of phase references over many kilometers from the central timing system to the accelerators; local distribution of the phase reference and timing fiducials to multiple RF stations over a distance of 100's of meters. To meet ILC availability requirements, the phase distribution link systems shall be redundant and have fault detection and automatic fail-over.

Project Description:

To meet the luminosity goals of the ILC, unprecedented phase stability is required for the RF systems throughout the ILC accelerator complex. Most stringent are the stability requirements of the Ring to Main Linac and Beam Delivery Systems, which require less than 0.1 degree stability at 1.3GHz. This phase stability must be budgeted across multiple subsystems, including the RF power system, LLRF system, RF master oscillator, and phase distribution system. The large geographical scale of the ILC (10's km) places stability requirements on the phase reference distribution system that have not been demonstrated.

Active phase-stabilized distribution systems have been prototyped before with some success, for example at SLAC and at DESY, but the performance requirements of the ILC phase reference distribution system have not been accomplished, even in a laboratory environment. This work package will build on the previous work at SLAC and DESY, and will culminate in a prototype "trench test" demonstration of both long-distance and local phase reference distribution system at the Fermilab ILC Test Accelerator (ILCTA).

There are several candidate approaches for active phase stabilization of the long distribution links, including: frequency-offset optical interferometry, phase shifting via thermal or mechanical fiber stretching, and an optical trombone. These must be evaluated, and a candidate selected for prototyping. Additionally, there are design choices that must be evaluated or tested, including whether or not to chop the RF source at a high rate in order to reduce cross-talk between forward and reflected waves in the long-distance fiber link.

The need for high availability and seamless failover of the RF phase reference presents some important challenges, not just in detecting a failure or "flaky" channel, but also in providing seamless failover to a second (redundant) link such that beam is not lost because of phase jumps between the two links.

Candidate technologies for the short-distance local distribution system include both copper (wired) and fiber optical transmission, phase-stabilized cable with or without active phase stabilization or phase averaging. Again, redundancy must be provided, with seamless failover.

Prototype systems will be evaluated in a laboratory environment and in real accelerator environments on the ILCTA at Fermilab.

Motivation:

Meeting the LLRF stability specs for the ILC will be extremely challenging. This work package will build on previous development work at other laboratories, evaluate candidate technologies, and prototype a preferred solution that includes redundancy & seamless automatic fail-over.

Collaborations with other institutions:

Four major US laboratories will collaborate on this work package: FNAL, ANL, SLAC, and LBNL. Lead roles are being developed, based in part on the availability of specific individuals at each site.

Key Personnel:

ANL: Frank Lenkszus + staff
SLAC: Joe Frisch + staff
Fermilab: Vince Pavlicek, Brian Chase + staff
LBNL: John Byrd, L. Doolittle

Milestones and Deliverables for FY07:

- Phase stabilized link (long distance distribution)
  - Perform preliminary evaluation of candidate technologies.
  - Establish test stand for component evaluation
  - Select and evaluate components.
  - Begin developing a phase reference receiver to evaluate fault detection and seamless fail-over techniques.
- Local phase reference distribution (~250m distances)
  - Perform preliminary evaluation of candidate technologies.
  - Establish test stand for component evaluation
  - Select and evaluate components.

3.2.6.1 Cost Summary:

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL	0.6	88	30	70	20	208
FNAL						
SLAC						
LBNL						

Expectations for FY08 and beyond:

This development will continue during FY08, leading to the installation and evaluation of prototype long-distance and local distribution systems in the Fermilab ILCTA. Specific goals would include:

- Phase stabilized link
    - o Prototype the fiber stretcher, using favored technique from preliminary evaluation.
    - o Prototype a phase reference receiver. Evaluate fault detection and seamless fail-over techniques.
    - o Prototype and evaluate the performance of a complete phase-stabilized link.
    - o Install prototype and evaluate in accelerator environment at ILCTA at Fermilab.
- Local phase reference distribution
    - o Prototype and evaluate the performance of a local phase distribution system.
    - o Install prototype and evaluate in accelerator environment at ILCTA at Fermilab.

3.2.6 <u>Control Systems</u>

3.2.6.2 Control System Framework

<u>Abstract</u>:

The ILC will place many demands on the control system, and none of the presently-available candidate control system frameworks meet the requirements "out of the box." Since the cost of developing a new control system from scratch would likely be prohibitively high, the Controls Global Group must assess the viability of extending an existing framework to meet the ILC requirements.

This work is to perform a "gap analysis" between the capabilities of known, stable control system frameworks and the specific requirements of the ILC. The gap will be characterized in terms of the work required to modify or extend each framework to meet ILC requirements.

<u>Project Description</u>:

This work package will assess the various candidate control system frameworks, and perform a gap analysis relative to ILC control system requirements. The goal of a "gap analysis" for controls systems is not necessarily to find the system that offers the minimum "gap", but rather to inform the larger decision making process which must optimize a larger set of variables. It also provides the basis for developing a work breakdown structure for a detailed costing effort.

The set of ILC control system requirements shall be identified and documented. A candidate set of potential control system frameworks shall then be identified that do not initially violate any of the requirements. Some potential candidates are EPICS, DOOCS, ALMA ACS, Tango, and quite possibly others. Each will be evaluated in turn with respect to the ILC requirements, and potential modifications or extensions proposed in order to meet any shortfall. The proposed modifications or extensions may well also include combining portions of existing frameworks.

This work package will leverage work performed under two other work packages for High Availability Control Systems and High Availability Standard Modules for Instrumentation Systems.

Motivation:

In order to make an informed choice of framework for the ILC control system, it is necessary to make a fair analysis of the candidate frameworks, and assess their true cost, including costs associating with enhancing the framework. A basic analysis of the options in the context of ILC requirements will prevent any surprises in the later detailed technical design and costing.

Collaborations with other institutions:

An effective gap analysis will require experience with different control system frameworks. Collectively, the collaborating laboratories have sufficient expertise to make informed assessments of the various candidate systems. Existing collaborative efforts on other controls areas will be brought together to collectively address this work package.

Lead roles amongst the partner Labs are currently being developed, based in part on the availability of specific individuals at each site.

Key Personnel:

ANL: Claude Saunders + staff
FNAL: Margaret Votava, Jim Patrick + staff
SLAC: Ron Chestnut + staff
DESY: Kay Rehlich
KEK: Kazuro Furukawa

Milestones and Deliverables for FY07:

- Document ILC control system requirements.
- Identify candidate control system frameworks.
- For each framework, perform and document the gap analysis and any required modifications and/or extensions.

3.2.6.2 Cost Summary (FY07):

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL	0.5	73	25	30	9	137
FNAL						
SLAC						

Expectations for FY08 and beyond:

It is anticipated that this work will allow a decision to be made about the control system framework to be adopted for the ILC. Work in FY08 and beyond will focus on developing enhancements and expansions to the chosen framework to meet the requirements for the ILC control system.

3.2.7 Development of Time-Resolved Photon Diagnostics for the ILC Multi-GeV Beams

Description:

The next-generation linear accelerators present a number of challenges in the diagnostics of the ultrabright particle beams that are needed to achieve the objectives. In particular, the international linear collider (ILC) designs require effectively very small transverse beam sizes, high peak currents, and a high level of stability at the interaction point [1]. Certain aspects of the ILC beam parameters in the first linac, damping rings, and main linac lend themselves to techniques that already are demonstrated or could be demonstrated at the APS. In the course of developing beam-profiling diagnostics for the APS for beam energies of 50 MeV to 7 GeV in the injector system of APS and the 7-GeV storage ring itself, we have demonstrated the advantages of time-resolved imaging techniques. These techniques are based on the conversion of electron beam distributions to visible, VUV, or x-ray photon distributions and the use of appropriate optics and fast-gated or streak cameras. At the 5- to 7-GeV regime we have performed some of the first optical transition radiation (OTR) and optical diffraction radiation (ODR) experiments in a complementary manner. These are in addition to our optical synchrotron radiation (OSR), x-ray synchrotron radiation (XSR), and undulator radiation (UR) experiments in the rings.

Due to the power density in such beams it is necessary to pursue nonintercepting (NI) diagnostics for beam transverse characterizations. Ideally, the beam transverse size, position, divergence, and angular direction would be measured, but practically speaking, even the monitoring of beam transverse character in the beam generation area, the damping rings, their extraction beamlines, or the high-energy linear accelerator would be useful. One possible technique is based on the generation of optical diffraction radiation (ODR) as a charged-particle beam passes near an edge of a conductor or through an aperture or slit in a conducting plate. Although beam size measurements appeared to be difficult without using double-slit ODR interference phenomena [2], beam divergence, trajectory angle, and position data should be more directly available from a single aperture's ODR. Recently, however, a near-field ODR imaging experiment for a 7-GeV beam passing near the edge of a single metal surface has been done at APS. This demonstrated unambiguously for the first time a relative beam size and position monitor capability that should be relevant to ILC beam issues as well [3].

References:

1. Marc Ross, "Linear Collider Diagnostics," Proceedings of BIW2000, AIP Conference Proceedings 546, p.147 (2000).
2. R.B. Fiorito and D.W. Rule, "Diffraction Radiation Diagnostics for Moderate to High Energy Charged Particle Beams," Nucl. Instrum. Methods B 173, 67 (2001).
3. A.H. Lumpkin et al., "Nonintercepting Electron Beam Diagnostics Based on Optical Diffraction Radiation for X-ray FELs," submitted to the Proceedings of FEL05, Palo Alto, CA, August 21-26, 2005.

Motivation:

The work will support the baseline designs that result in the generation of bright, multi-GeV electron or positron beams. Our time-resolved imaging techniques are based on the conversion of lepton beam distributions to visible, VUV, or x-ray photon distributions and the use of appropriate optics and cameras. Depending on the location in the facility different conversion mechanisms and time scales are relevant. We expect to use OSR or XSR in the damping rings and OTR and ODR in the first linac, the extraction beamlines from the damping rings, and main linac.

In the transport lines the nonintercepting aspect of ODR will be exploited at high charge densities by referencing to OTR images from lower intensity beams to provide both relative beam size information and complementary beam position information.

The proposed work addresses the tasks listed in IS PM (profile monitors) in the linacs. It is complementary to the laser wire task and less expensive per station. It also addresses a gap in the LP_ instrumentation tasks which support emittance preservation by monitoring the beam size noninterceptively.

Collaboration with Other Institutions:

Some feasibility experiments have been done on the FFTB or will be done on other high-energy end station (SABER) at SLAC. Collaboration with D. Rule of NSWC on XTR or ODR analytical modeling is proposed, as funds permit.

Milestones and Deliverables:

Proposed Work Milestones:

We have recently developed an analytical model for near-field ODR imaging that supports the concepts of monitoring beam size and position even in the 10-micron-rms-size regime for several nC of charge at multi-GeV beam energies. If more charge is integrated in the image, the technique may be developed further to perhaps smaller beams. One imaging station should reside in the transport line downstream of the damping ring to monitor the extracted beam with 1-ns time resolution.

Our initial tasks would be:

1. Evaluate an ODR experiment at 7 GeV on APS in terms of ILC parameters.
2. Evaluate an OTR/XTR experiment performed at 28 GeV on SPPS.
3. Evaluate an optical interferometer concept to be tested on the 25-μm beam size in the APS diagnostics sector.

Key Personnel:

Alex Lumpkin (8%)

Cost Summary (06):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
0			0

ANL internal funding of $20K will be provided for this project.

Proposed Work and Milestones for FY07 and Beyond:

During FY07 and beyond we would continue to develop the time-resolved techniques adapted to ILC issues that take advantage of our ODR and ring diagnostics experience.

We will perform the following tasks:

FY07:

1. Design, procure, and install the OTR/ODR test station (or modify an existing flag station)
2. Perform initial ODR feasibility experiments at 7 GeV with slit geometry.
3. Develop with a consultant the capability to model the ODR patterns observed at 7 GeV and determine sensitivities. Scale to 5 GeV and 250 GeV as feasible.
4. Perform an ODR experiment at SLAC at high energy (SABER as available)

Key personnel:

Alex Lumpkin (10%), Bingxin Yang (5%), Don Rule (10%) (NSWC)

Cost Summary (FY07):

	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
FY2007	22.4	55	15.3	92.7

FY08:

1. Perform more extensive ODR experiments with polarizers and bandpass filters to improve sensitivity to beam parameters. Evaluate impact parameter, slit dimension, and beam offset effects. Utilize intensified camera as needed.
2. Continue to develop with a consultant the capability to model the ODR patterns observed at 7 GeV and 28 GeV to determine sensitivities.
3. Test an optical interferometer on APS test station.

Key personnel:

Alex Lumpkin (10%), Bingxin Yang (5%), Don Rule (10%) (NSWC)

Cost Summary (FY08):

	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
FY2008	22.4	55	15.3	92.7

FY09:

1. Based on the results in the first two years, an ODR experiment would be designed for tests at SLAC at 14 GeV in LCLS or 30 GeV in the end station with a higher duty factor beam as deemed appropriate. Alternatively, the APS booster might be run with a lower emittance lattice or a different energy and the beam-dump line might be modified for smaller beam sizes for further tests of ODR.
2. Continue studying ODR scaling issues analytically.
3. Continue time-resolved tests with OSR and XSR at S35 or other source using fast cameras.

Key personnel:

Alex Lumpkin (10%), Bingxin Yang (5%), Don Rule (10%) (NSWC)

Cost Summary (FY09):

	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
FY2009	22.4	55	15.3	92.7

3.2.8 Survey and Alignment

3.2.8.1 Implementation of a New X-ray Alignment Technology for the ILC

Description:

Both the ILC main linacs and the 200-m-long-undulator section for the positron production require high precision alignment of the beam-guiding multipoles placed along the cryogenic accelerating structures or between undulator sections. Even more stringent are the requirements for the alignment of the final focus beam delivery system (BDS). A viable alignment technology defining a straight line with required accuracy will have important implications for the overall layout and construction of the ILC. In particular it will provide a reliable and repeatable starting point for the beam based alignment process and possibly a long term real time monitoring system for the ILC.

We propose a novel alignment technique utilizing the x-ray beam of an undulator in conjunction with pinholes, zone plates and position-sensitive detectors for positioning ILC beamline components. Two retractable pinholes at each end of the beamline define a stable and reproducible x-ray beam axis (XBA). Pinhole and zone plate targets are precisely positioned on the XBA using a pinhole camera technique. Position-sensitive detectors responding to both x-ray and electron beams enable direct transfer of the position setting from the XBA to the electron beam. This system has the potential to deliver superior alignment accuracy on the order of micrometers for target pinholes/zone-plates in the transverse directions.

Details of this new technique are discussed in Reference 1. The 200-m-long undulator of the ILC positron source is similar in length and aperture size to the LCLS undulator discussed in the paper. We propose to expand the system described in the paper to adapt to the 10-km length scale of the linacs, or the km-long final focus beam delivery system. The ILC main linac is based on superconducting technology so the integration issues, such as on-axis versus off-axis techniques, proper mounting and actuation of alignment targets in low temperature environment, need further consideration. In addition the designs of several zone plates are required to maintain the focusing condition at different locations in the linacs.

This work package has currently not been assigned a particular line item in the existing R&D master list (RD_Master.xls). The proposed technique delivers superior alignment accuracy compared to conventional laser alignment. Therefore it will complement the conventional laser alignment, LP_instrumentation_auto_laser_alignment, listed on line 162. In addition, this proposal impacts several key areas of the ILC, especially in the final focus beam delivery system, where the alignment issue and real-time position feedback control are most critical, as shown in line items 271, 288, 335, 350 and 372 – 373 of the R&D master list. All of these tasks have been assigned a high priority, and therefore the R&D of the x-ray alignment technology should be considered at the same priority level.

[1] B. Yang and H. Friedsam, High-resolution accelerator alignment using x-ray optics, Phys. Rev. ST Accel. Beams 9, 030701 (2006). http://prst-ab.aps.org/

<u>Motivation</u>:

As the electrons gain energy in the main linac, the beam size continues to decrease. At the end of the linac, the vertical electron beam size is well below 1 micrometer. To preserve the beam emittance, the beam delivery system leading up to the final focus needs to be accurately aligned. Although no specifications have been made yet, we could estimate that, based on FFTB experience at SLAC, the alignment tolerance could be on the order of 5 to 10 micrometers.

Whether the main linacs will be straight or following the time-varying equipotential surface on earth is of primary importance for the ILC design. Limitations on alignment and position monitoring technology will be a major factor in this decision, along with the technical challenges associated with beam based alignment on a curve.

We propose to develop an x-ray optics-based alignment and monitoring technique that will provide 10- to 25-μm transverse position accuracy over the length of the final focus beam delivery system, or over the entire length of the ILC main linacs.

Collaboration with Other Institutions:
Close collaboration with SLAC alignment personnel will be needed to interface with the conventional alignment which provides the foundation for the x-ray alignment system.

We will also work with the ILC main linac machine physicists at SLAC to integrate the x-ray alignment procedure with the beam-based alignment technique.

For the hardware development, we envision outside vendor support through SBIR contracts.

Milestones and Deliverables:

We will perform simulations of the alignment optics from the undulator source, through pinhole or x-ray zone plates, to the detector end of the beamline, with ILC parameters. The simulations will be used to optimize the optics design for best attainable resolution and accuracy. We will also design and test a kinematic mounted actuator prototype to obtain needed reproducibility and accuracy of several micrometers for positioning the source and target pinholes. The actuator can also serve as a reference design for positioning alignment targets (pinholes and zone plates).

Proposed Work Milestones:

In FY2006, we will provide a written report and assess the applicability of the x-ray alignment technique for the ILC. We will also complete the test of a first version of a kinematic mount for positioning the source and target pinholes.

Key Personnel:

Horst Friedsam, 18% FTE; Bingxin Yang, 18% FTE.

Cost Summary (06):

FY06 work will be supported by ANL internal funding.

Expectation for FY07 and Beyond:

Assuming the success of the pre-design simulation work in FY06, we propose to develop the engineering specifications though simulations in FY07 and beyond. Due to the unusual properties of the x-ray zone plate design and development, we anticipate significant vendor involvement in the hardware development, such as through SBIR contracts. No hardware development at this stage is planned at ANL. The cost of the development program and the detailed work breakdown structure is shown below.

	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
FY2007	52.9	20	20.6	93.5
FY2008	52.9	20	20.6	93.5

3.2.8.x Implementation of a new X-ray alignment technology for the ILC

3.2.8.x.1 Conceptual layout considerations for implementing this technology

3.2.8.x.2 Integration issues (compatibility with the cryogenic environment, on-axis vs. off-axis considerations)

3.2.8.x.3 X-ray source R & D
- 3.2.8.x.3.1 Undulator calculation and specification
- 3.2.8.x.3.2 Source pinhole and detector pinhole R&D and specification
- 3.2.8.x.3.3 Investigation of requirements for alternative x-ray sources

3.2.8.x.4 Target development
- 3.2.8.x.4.1 X-ray pinhole calculation for the final focus delivery system
- 3.2.8.x.4.2 Alignment pinhole specification
- 3.2.8.x.4.3 X-ray zone plate calculation for the final focus delivery system
- 3.2.8.x.4.4 Alignment zone plate specification
- 3.2.8.x.4.5 Conceptual design of zone plate mountings in a cryogenic environment

3.2.8.x.5 Detector R & D (to be specified later)

3.2.9 Collaboration Tools and Remote Operations

Abstract:

Effective international collaboration on a large project such as the ILC is a technically demanding problem. There are tools available, but no single tool has been adequate to address the issue of remote operations of an accelerator complex. The goals of this work package are to research and implement collaborative tools that enhance international collaboration and

participation in ILC activities, particularly ILC Test Accelerator activities. This work will build on the LHC@FNAL effort at Fermilab and corresponding efforts in Europe to collaborate on LHC machine studies. These collaborative activities have been addressed in the Global Accelerator Network (GAN) community, and in this work package will be addressed in the context of remote operation of ILC test facilities to enhance international collaboration. This section is included for reference only. ANL is not requesting resources specifically for this activity.

Project Description:

Current efforts to establish remote operations capabilities for the LHC accelerator and experiments have provided experience with available collaboration tools. Similarly, the Fusion Energy Sciences community is preparing for construction and operation of the International Thermonuclear Experimental Reactor (ITER) and is including remote operations in their plans. We have been working with members of this community in studying collaboration tools and network and security issues.

This work package will research concepts that have been developed in the context of GAN, and build on current efforts to design a remote operations center at Fermilab (LHC@FNAL) for the LHC accelerator and CMS experiment. For example, the LHC@FNAL Task Force initiated a three-month evaluation of a commercial web-collaboration tool called WebEx to evaluate its effectiveness for meetings, collaborative work in small groups, and as a means to link control rooms with remote operations centers. At the end of the evaluation period the ILC Controls Group successfully incorporated WebEx in meetings that included participants from the U.S., Europe, and Asia. This work package will evaluate the use of tools for international collaboration and participation in ILC test facilities, and will explore the use of other tools that enhance collaborative efforts.

Requirements for effective international collaboration will be developed, especially with regard to a future ILC operations model that involves multiple control rooms distributed around the globe. We will evaluate tools for role-based access, application and desktop sharing, data acquisition and distribution to international collaborators, and collaborative visualization environments.

Motivation:

The motivation for this work package is to improve international collaboration and share information in real time.

Collaboration with Other Institutions:

Effective deployment of collaboration tools and remote operations requires experience with available tools to assess capabilities and identify areas that require future development. Every collaborating ILC institution will eventually work with the tools that have been chosen, and it is essential that the assessment and decision-making process is coordinated with the Global

Design Effort across the three regions and across multiple laboratories. For this work package we will work with established ILC controls groups in each region. We plan to work with the GAN community and with the Fusion Energy Sciences (FES) community. We have submitted a joint HEP/FES SciDAC (Scientific Discovery through Advanced Computing) proposal to the Department of Energy.

Key Personnel:

SLAC: Ray Larsen (point of contact)
FNAL: Erik Gottschalk
ANL: John Carwardine (point of contact)
DESY: Ferdinand Willeke
KEK:

Milestones and Deliverables:

FY07

- Develop requirements for remote operations of ILC test facilities.
- Identify, evaluate, and recommend suitable tools for remote operations.
- Work with international collaborators to develop a model for remote operations.

3.2.9 Cost Summary:

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL						
FNAL						
SLAC						

Expectations for FY08 and beyond:

This work will continue during FY08. Deliverables will include establishing remote operations capabilities for the ILC test facilities at Fermilab.

3.4 Positron Sources

3.4.4 Gamma-ray Undulator

Description:

APS has been working towards developing a superconducting undulator (SCU) for use on the APS storage ring. Several test pieces with 14.5 and 15-mm periods, 4 to 22 periods in length, have been wound using NbTi superconducting wire. The measured quench current of the wound test pieces matched what was expected from quench measurements of short wire samples. The short section SCU was stable against quenching even near its critical current density of 1.4 kA/mm^2 where the temperature margin was less than 0.5 K, and even when a heater was turned on to simulate thermal load from the electron beam. Similar tests with Nb_3Sn superconducting wires reached a current density of up to 1.9 kA/mm^2. This scheme for building a 14.5 or 15-cm-period undulator for APS that would deliver photons ranging from 20 to 25 keV in the first harmonic looks feasible.

A proposal was made by collaborators at the National High Magnetic Field Lab (NHMFL) in Florida to use Nb_3Sn conductor instead of NbTi. Nb_3Sn conductor has both higher critical current and higher critical temperature. The expectation is that higher undulator fields can be reached with a more robust temperature margin. To further enhance this margin, an undulator could be designed to have a separately cooled beam tube at 77 K. This would allow much of the beam heat load to be removed at 77 K without it reaching the 4K superconductor. A quench of the superconductor would not affect the temperature of the beam liner nor result in a vacuum pressure burst seen by the stored beam. Such a design would be very attractive for a high-reliability storage ring, so this option is being pursued.

In a collaboration with NHMFL, short sections of Nb_3Sn undulator, with enough pieces of the cryostat to demonstrate the feasibility of the overall concept, are being built. Two different schemes for assembling the windings are being tested, one involving a single monolithic mandrel that is wound as a single piece, and one that is modular with coils that are individually wound and stacked alternately with pole pieces. Tests of these devices are expected to take place in summer 2006.

In a separate collaboration with Lawrence Berkeley Lab, an alternative scheme for insulating the superconducting wire with a thin ceramic coating is being tested. Bulky insulation and the resulting small packing factor for the superconductor reduces the achievable field on axis.

Measurements of the magnetic field quality are an important part of the APS program. APS has already assembled a vertical measurement system and made preliminary measurements of field quality. A horizontal measurement system that can map the field of a completed device is being designed. The measurement drive system and basic probe handling hardware will be in a separate chamber that attaches to the horizontal cryostat. This chamber will be attached to the cryostat by a flange so that different probe control systems for special magnet configurations or for special or unusual measurements can be built and attached without handling the test magnet in the cryomodule.

Motivation:

The positron source relies on having an intense source of gamma rays, to be provided by a long undulator. Based on research at Cornell, Daresbury, and Rutherford Labs, it has been decided to pursue a superconducting design. The present concept is for a helical undulator, in contrast to the planar undulator that is the immediate goal of the APS work. It is also for a shorter period (~1 cm) than the 1.4 to 1.5 cm period of the APS device. Nonetheless, there is much in the APS effort that would be immediately applicable to an ILC undulator. The magnet measurement equipment and techniques being developed at the APS could be of particular value to the ILC design effort. Developing horizontal measurement techniques and building the associated hardware is fairly expensive and time consuming.

The design of the cryostat for horizontal measurements of the 2.4 m long APS undulator will be completed in 2006 and the construction should be complete in 2007. The measurement instrumentation, drive system and associated chamber will also be built and tested in 2007. The application of these designs to a helical undulator would require additional hardware and effort for setup and performance of the measurements. However, the adaptation of the measurement system to the measurement of a helical field geometry and the use of APS expertise in developing the equipment and performing the tests would be very cost effective for the ILC program.

Also in 2006, conceptual design work for a very short test section of a helical superconducting undulator is being carried out at Argonne with ANL LDRD funds. Fabrication of this short section will begin in 2006. The resulting test section will be available for use in the first tests of magnetic probes. A longer helical test section should be built in 2007 for tests of the horizontal measurement system.

Collaboration with other institutions:

The APS is presently collaborating with the National High Magnetic Field Lab in Florida and Lawrence Berkeley Lab, as described above.

Participation in the superconducting undulator part of the ILC project would entail good communication and probably collaboration with the existing efforts at Cornell, Daresbury, and Rutherford Labs.

Milestones and deliverables (FY07):

An assessment of the design changes needed to make field measurements on an ILC helical undulator, and a start of fabrication of the drive and probe systems would be the goals for 2007. Research will be necessary to determine good measurement techniques for a superconducting device with the small gap anticipated for the ILC device. This research, along with initial measurements of the first helical test section, will be carried out in the existing vertical dewar. Design work for the horizontal measurement system will begin, probably carried out by an outside company.

The new measurement hardware for horizontal measurements will be completed in 2008 and preliminary measurements performed. A short helical model would be begun in 2007 for these first tests and is included in the cost estimate. Setup and tests of ILC undulators would start in the last half of 2008 and continue throughout 2009. It would be expected that the laboratories designing and building the ILC helical undulators would send at least one individual to help and participate in the measurements at APS, but APS would be responsible for the setup and performance of the measurements.

Key personnel:

E. Gluskin, S.H. Kim, R.L. Kustom, E. Moog at APS; H. Weijers, J. Miller at NHMFL; R. Schlueter, S. Prestemon, D. Dietderich, and S. Marks at LBNL.

Cost summary for 2007:

The cost of adapting APS measurement hardware to a helical undulator will be better estimated once we know better what the final APS designs are. Initial estimates, however, include (overhead is included):

$114 K for contracted cryostat design services
$114 K for the magnetic measurement techniques study (modifications to existing vertical dewar; probe purchases; setup and motion control; cryogen; etc.)
$114 K for the helical test section (include $50K in machine shop costs for the mandrels, $30K for specialized coil winding hardware, and other funds to cover drafting, wire purchases, etc.)
$250 K for effort (0.25 FTE for S.H. Kim, 1 FTE for new hire)

Labor (K$)	M&S (K$)	Indirect (K$)	Total Cost (K$)
188	300	105	593

Expectations for FY08 and beyond:

The completion of the hardware and assembly and testing of the measurement and instrumentation equipment using the APS helical model would be completed in 2008. Measurements on the first ILC undulator would be performed towards the end of 2008, depending on the delivery schedule for the ILC undulators. Costs of performing these tests include final hardware fabrication costs, instrument and data IO hardware purchase and assembly, and cryogen; these costs are expected to be $171K. Effort costs for the second year are estimated to be $250K. (Costs include overhead.)

The testing program is expected to continue into 2009. There will be continuing costs for cryogens for performing tests, some hardware changes dictated by experience, and miscellaneous costs. These are expected to amount to about $114K and effort is expected to be about $171K, depending on the number of measurements to be performed.

3.5.4 Development of Time-Resolved Photon Diagnostics for the ILC Damping Ring

Description:

The electron/positron damping rings of the ILC present a number of challenges in the diagnostics of the ultrabright particle beams: very small transverse beam sizes, high peak currents, and a high level of stability at extraction. Certain aspects of the ILC damping ring beam parameters lend themselves to techniques that are already demonstrated or could be demonstrated at the APS.

In the APS storage ring (7 GeV), we have demonstrated the advantages of time-resolved imaging techniques to characterize the electron beam properties and study beam dynamic instabilities, using optical synchrotron radiation (OSR), x-ray synchrotron radiation (XSR), and undulator radiation (UR), in combination with appropriate optics and fast-gated or streak cameras. Over a decade of photon diagnostics development work was summarized in Reference 1 and references therein. For transverse beam dynamics on the 100-μm scale or higher, we use OSR imaging with gated and streak cameras. For those beam dynamics with scales under 100 μm, the APS diagnostics undulator offers improved transverse resolution with reasonable photon flux. The APS has three unique instruments for electron beam diagnostics: a diagnostics undulator (198 × 18 mm periods), a cryogenically cooled silicon monochromator, and an x-ray streak camera [2]. To our knowledge, this is the only x-ray streak camera in the US with dual sweep and synchroscan capabilities. These instruments and our experience of using undulator radiation for electron beam diagnostics will enable us to evaluate the usefulness of using an undulator as a transverse beam diagnostics in the ILC damping ring.

The proposed work covers the following tasks listed in the master list of R&D tasks (RD_master.xls): IS_DR_Damping (high priority), IS_DR_Inj (moderate), DR_3.8.3.2 in part (high), DR_3.8.3.3 (high), and DR_3.8.3.4 (high).

1. Develop instrumentation for monitoring emittance damping.
   Develop instrumentation for monitoring the damping of the beam emittance. In the positron ring, the maximum beam sizes start from 20 mm × 20 mm (H × V) at the injection to 50 μm × 5 μm at the extraction. Hence the image tool needs to have a fine spatial resolution and a large field of view, as well as a wide dynamic range (10^6:1).
2. Develop instrumentation for injection imaging (first turn diagnostics)
   Develop instrumentation for imaging the injected beam in the first several turns to aid tuning of injection process.
3. Develop precision bunch-by-bunch beam size monitor.
   Develop a precision monitor, e.g. an OSR or XSR monitor that can be used to measure the beam size and tilt on a bunch-by-bunch basis: this will be important for diagnosing collective effects. The OSR-based imaging tools will be adequate for the ini-

tial stage of the damping process when beam size is above 50 μm, as we have demonstrated in the APS streak camera studies. The XSR imaging offers adequate resolution for the final stage of the damping but its time-resolution is likely to be limited by the energy bandwidth of the imaging optics and the response time of the detector. This may be overcome with our unique x-ray streak camera in slow vertical deflection mode.

[1] B. X. Yang and A. H. Lumpkin, Visualizing electron beam dynamics and instabilities with synchrotron radiation at the APS, Proc. PAC05, p.74 (2005).
[2] A. H. Lumpkin and B. X. Yang, Use of Few-angstrom radiation imaging to characterize ultrabright, multi-GeV particle beams, Phys. Rev. Lett. 82, 3605 (1999).

Motivation:

The work will support the baseline designs for the ILC damping ring. Our time-resolved imaging techniques are based on the conversion of electron / positron beam distributions to visible, VUV, or x-ray photon distributions and the use of appropriate optics and cameras. In the damping ring, time-resolved features will be critical since the lepton beam in the ILC damping rings will attain very high charge density before extraction. A number of instabilities may occur during the damping process, especially in the final stage. While design efforts are made to suppress these instabilities, adequate time-resolved diagnostics tools are required to verify that the design goals have been achieved and characterize the instabilities when they do occur.

Collaboration with Other Institutions:

Milestones and Deliverables:

Proposed Work Milestones (FY06):

In FY06, imaging techniques using OSR and XSR will be evaluated with the ILC damping ring beam parameters. A multi-tool package appears to be needed, with OSR and XSR used for different parts of the beam parameter space and time scale.

Key Personnel:

Bingxin Yang, Alex Lumpkin

Cost Summary (06):

Work in FY06 will be supported by ANL's internal funding.

Proposed Work and Milestones for FY07 and Beyond:

During FY07 and beyond we will develop the time-resolved techniques based on the ILC damping ring beam properties. The high spatial resolution required to measure the damping ring beam requires the use of x-ray imaging tools, where the main issue is the perfection of the optical element. A major part of the development is to reach an optics design practical for the current manufacturing capability.

We will perform the following tasks:

FY2007: Identify appropriate techniques and locations of the imaging device for the damping ring

- Identify appropriate tools for different part of the damping process: visible light, fast x-ray imaging, or other techniques
- Identify appropriate photon source: bend magnet, undulator, or wiggler
- Identify location of the imaging device on the damping ring lattice
- Design x-ray optics prototype and start heat load and thermal distortion analysis

Key personnel:

Bingxin Yang (10%), Alex Lumpkin (10%), an ME to be identified (20%)

Cost Summary (FY07):

	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
FY2007	58.8	20	22.6	101.4

FY2008: Develop specifications of the imaging optics for the damping ring task.

- Conceptual design of the imaging optics for fast imaging
- Complete heat load and thermal distortion analysis
- Design and procure prototype x-ray optics
- Design test stand for prototype x-ray optics

Key personnel:

Bingxin Yang (10%), Alex Lumpkin (10%), and an ME to be identified (20%)

Cost Summary (FY08):

Significant portion of M&S will be used for purchasing prototype x-ray optics. We anticipate no single M&S item of $75 K or more will be required to undertake this effort.

	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
FY2008	58.8	150	40.8	249.6

FY2009: Test prototype optics with OSR and XSR at the APS.

- Design and procure test stand for prototype x-ray optics
- Install test stand in the APS diagnostics beamline as the APS shutdown schedule allows

- Start testing x-ray optics at the APS diagnostics beamline as the APS shutdown schedule allows

Key personnel:

Bingxin Yang (10%), Alex Lumpkin (10%), and an ME to be identified (20%)

Cost Summary (FY09):

Significant portion of M&S will be used for purchasing prototype x-ray optics. We anticipate no single M&S item of $75 K or more will be required to undertake this effort.

	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
FY2009	58.8	150	40.8	249.6

3.5.7 Damping Ring Beam Dynamics

Description:

Specific topics that we want to pursue are:

- Vertical emittance tuning; run APS at lower emittance
- Diagnostics specifications; girder and magnet alignment, magnet stability
- Specify fast orbit correction, optics correction, vertical emittance correction
- Specification for kicker reproducibility (later stage)
- Space-charge effect characterization
- Impedance and instabilities: study single-bunch limits with particle tracking with wakefields modeled from 3D codes
- Specify field uniformity of kicker striplines
- Field quality for damping wigglers
- Specify bunch-by-bunch feedback systems
- Designs for orbit and beam feedback systems
- BPM sensitivity and noise baseline specification
- Specify vacuum system design
- Bunch-by-bunch photon diagnostics
- Injection beam diagnostics specification; rf BPMs, photon diagnostics
- Project coordination

Motivation:

Much of the preliminary calculations would have been done for the RDR in 2006. Some aspects of the calculations will continue through 2007 and later.

Milestones and Deliverables for FY07:

Low-emittance tuning:

Develop strategies for low-emittance tuning: Using a model of the lattice with skew quadrupole correctors included, develop algorithms for correcting vertical dispersion and x-y coupling. We would start with the standard SVD-based and harmonic-based corrections used in present ring accelerators. Misalignment and orbit errors (sources of vertical emittance) will be specified.

Specify requirements for survey and instrumentation for low emittance tuning: Alignment errors of magnets cause linear perturbations of the optics. These perturbations can be in general much reduced by appropriate magnet correctors. The alignment should be specified to a low enough tolerance so that only "small" corrections are required. Magnet rotations and vertical misalignment in particular produce vertical emittance growth, which may not be completely corrected. Thus it is possible that the tightest tolerance are on the latter type of misalignment. Simulations with lattice codes are required for the determination of the tolerances. Simulations will include the vertical emittance correction with readback errors on beam position monitors. From the simulations, a tolerance on the readbacks will be determined.

Demonstrate < 2 pm vertical emittance: Work packages DR_2.1.3.1 DR_2.1.3.2 refer to simulated vertical emittance. These methods can be applied to an existing ring with similar alignment tolerances. Demonstrating < 2 pm vertical emittance on an existing ring, which at the same time, matches the expectation from simulating the same ring would confirm the ability to correct the vertical emittance of the damping ring.

Single bunch collective effects:

Develop single-bunch impedance models: Determine from the shapes and resistivity of the vacuum chamber the short range wake fields produced by circulating bunch. A 3D electromagnetic code is used.

Characterize the single-bunch impedance-driven instabilities: Using the wake field models of WP DR_2.2.1.1, determine collective effect on circulating bunches. Collective effects are calculated with a tracking program.

Multi-bunch collective effects:

Develop long-range wakefield models: Determine from the shapes of the rf cavities, the set of higher-order mode parameters. A 3D electromagnetic code is used.

Characterize multi-bunch instabilities: Use higher-order mode data to calculate growth rates of coupled bunch modes. Since HOM are narrow and have frequencies not known to sufficiently high accuracy in advance of construction, a Monte Carlo study of randomized frequencies will be done to estimate the distributions of growth rate, and the probability of in-stability. This study can serve to specify the de-Qing of the HOM and the bunch-by-bunch feedback system.

Characterize the effects of injection transients: Use a particle tracking code to track multiple bunches during the injection period where both damped and undamped bunches are present

Key Personnel:

For 2007, required FTE is 1.6
Aimin Xiao, 60%; Louis Emery, 20%; Yong-Chul Chae, 40%; Vadim Sajaev, 40%

Cost Summary for FY07:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
240	30	90	360

3.5.8 Damping Ring Magnets

Description:

Develop specification for alternate-design wiggler magnets, and corrector magnets.

Motivation:

Much of the preliminary calculations would have been done for the RDR in 2006. Some aspects of the calculations will continue through 2007 and later.

Milestones and Deliverables for FY07:

Alternate damping wigglers: The alternate design for wiggler are the hybrid iron/permanent magnet type.

Develop physics and engineering design for hybrid wigglers: Using the specification of the field quality (to be determined from the WP DR_2.1.2.1 on acceptance) and aperture, the dimensions and strength of the magnet is determined.

Corrector magnets:

Specify steering and skew quadrupole magnets: Steering magnet strength, length, and aperture are determine from studies of orbit correction and tolerances on alignment. Skew quadrupole magnet strength, length, and aperture are determined from studies of vertical emittance correction and tolerances on alignment (WP DR_2.1.3.2).

Key Personnel: For 2007, required FTE is 0.4
Shigemi Sasaki, 20%; Aimin Xiao, 10% Louis Emery, 10%

Cost Summary for 2007:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
60	10	25	95

3.9 MAIN LINACS, INCLUDING RF SYSTEMS

3.9.3.4 Electropolishing System for the ILC at the ANL-FNAL Joint Facility

ANL proposes to complete a capability in FY07 for electropolishing (EP) 9-cell elliptical cavities for the ILC. This capability would directly address ILC needs identified by the GDE as having high or very high priority (54 SC_Preparation_EP, 58 SC_Preparation_Preparation_Industrialization). This capability is also the essential first step in a recent multi-year EP plan drafted by technical experts from Cornell, LANL, FNAL and ANL and is intended to help facilitate the processing of as many as 100 cavities in the U.S. in FY2009.

The new pre-production facility will complement existing EP R&D facilities, and will focus on development of an industrialized production capability for the ILC. It is recognized that this is the first attempt to start a production plan and that any future large-scale EP facility or industrial facility, or industrialization effort will have to evolve in concert with participation from the world community.

The local facility will provide the essential hands-on experience with the EP of ILC cavities for local personnel. Such comprehensive experience, gained only through first-hand design, construction and operations is required for credible leadership of the longer-term industrialization process. FNAL, LANL and ANL personnel are working closely with and at JLab on initial ILC electropolishing efforts focused on solving R&D issues and educating personnel from the ILC-Americas region. The proposed effort will also parallel process R&D which is being performed at DESY and KEK. The local effort should be launched as early as possible to fit with this evolving large-scale plan.

Essential requirements of the pre-production facility are:
1. to incorporate what is known from ongoing operations at Cornell, DESY, JLab and KEK/Nomura
2. modularity and flexibility in order to permit evolution as the EP process is developed (worldwide) to meet ILC requirements, and

3. to have a throughput capability, maintainability and availability suitable for processing at least 50 cavities per year by 2009 and
4. to support and enable the design and establishment of a production EP facility which can be updated to achieve an evolving state-of-the-art

In FY06, engineering design and design review of a complete electropolishing system for polishing ILC 9-cell elliptical cavities at the joint facility will be performed. Fabrication and qualification of the system will be completed by the middle of FY07. Initial polishing of ILC cavities will be performed in the second half of FY07.

This proposal requires that fabricated cavities be provided to ANL for electropolishing and that a cold test facility be available elsewhere to test the cavities after electropolishing. The effort will require that ANL personnel have input on critical cavity handling steps which both proceed and follow electropolishing.

All of the major infrastructure, including a large chemical room and fume scrubber, a deionized water system, electropolishing power supplies and other acid-handling equipment, is present, operational and available for this effort. Likewise, important logistics issues such as safety, acid procurement, handling, storage, and disposal have already been addressed at ANL for the existing G150 processing facility.

<u>Motivation</u>:

A U.S.-based expertise in fabrication, processing, and operation of 9-cell elliptical cavities will be required for the proposed International Linear Collider. This expertise will be required if the U.S. is to successfully host the ILC, or if built elsewhere, for the U.S. is to make meaningful contribution to the main linac system. In addition, the pre-production EP facility would help meet the anticipated mid-term cavity processing needs in the U.S. of 100 cavities by 2010, 60-100 cavities in 2009, 20-25 cavities in 2008, and up to 12 cavities in 2007 and would help establish a credible production plan for presentation to the U.S. Department of Energy by 2010. The work proposed will be carried out in support of the goal of building U.S. expertise and will be performed in collaboration with the ILC-Americas.

Recently the international SCRF community, in drafting the ILC baseline configuration document, has adopted electropolishing as the chemical procedure for cavity surface preparation despite many outstanding technical questions on the optimum EP techniques for 9-cell cavities and a relatively small base of worldwide expertise.

ANL Physics Division has used electropolishing to produce state-of-the-art performance in low- and medium-velocity superconducting (SC) accelerating structures for more than 150 niobium cavities. Recently achieved peak magnetic fields in ANL cavities (having twice the surface area of the ILC cavity) are the same as those in ILC cavities running at accelerating gradients 30 MV/m. With the completion of a new $2 M cavity processing facility at ANL (done in collaboration with FNAL), an opportunity has been created to leverage ANL expertise and facilities for the development of high-gradient SC cavities for ILC. This R&D proposal directly addresses the need for additional work on EP directed toward industrialization of this critical production step for the ILC.

In summary, electropolishing is the best available chemical processing technique for niobium cavities today. Establishing a pre-production capability for electropolishing in the U.S. in a relatively short time scale, which we propose to facilitate, is critical to U. S. participation in the longer-term industrialization process.

<u>Collaboration with other institutions</u>:

The proposal to perform electropolishing at ANL for the ILC would build upon ongoing collaborations with FNAL in which chemical polishing of 3.9-GHz elliptical cavities and electropolishing for proton driver cavities is already planned or underway at ANL. This new proposal for the FY07-FY09 ILC effort would involve collaboration among personnel from ANL, FNAL, and LANL. The proposed work would also require ongoing design consultation and review with other technical experts from both the U.S. (Cornell, JLAB) and abroad (DESY, KEK)

<u>Milestones and deliverables</u>:

1. Consulting with outside members of the ILC technical community and also with potential U. S. vendors, design a horizontal, closed-loop electropolishing (EP) apparatus to be housed initially within the ANL portion of the joint processing facility.
2. In addition to consultation during the design process, have the design reviewed by technical experts from laboratories and institutions within the U.S. and abroad in order to maximize the potential benefits to ILC derived from the new system.
3. Fabricate, test, and commission the electropolishing system.
4. Begin electropolishing operations on ILC 9-cell cavities in the second half of FY07.
5. Develop and document techniques and train personnel in electropolishing in such a way that key hardware and expertise may be easily transferable to other U.S. institutions or industry.

<u>Key personnel</u>:

Michael Kelly (ANL) will work with Tsuyoshi Tajima (LANL) and Cristian Boffo (FNAL) to perform the technical design. Additional technical expertise for tasks such as engineering design, conducting a technical design review, and overseeing procurement and construction electropolishing hardware will be gathered in consultation with experts at JLab, Cornell, KEK and DESY.

<u>Deliverables and Milestones for FY06</u>:

Direct support from ANL in FY06 at the level of $125 K has been provided. These funds are supporting manpower and M&S for ongoing development of hardware within the ANL portion of the joint facility and in direct support of the ILC effort. Specifically, a modular and flexible control system for EP and ventilation is being installed presently. The controls will serve as the initial control system for ILC pre-production EP system.

Additional FY06 funding from FNAL ($250 K) is anticipated for this effort and will support ongoing FY06 activities. Activities to be completed in FY06 include:

- Agreement by the ANL-FNAL-GDE collaboration on an EP specification
- Performing engineering design of the physical EP apparatus to be located initially in the ANL portion of the chemistry facility
- Performing engineering design review with technical experts from the U.S. and abroad
- Initiating the procurement and construction of hardware for the EP apparatus

Cost Summary (06):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
174	115	86	375

Proposed Milestones and Deliverables for FY07:

- Assemble and commission an EP system by the middle of FY07 (0.75 FTE, $65 K M&S)
- Electropolish ILC cavities in the second half of FY07 (0.75 FTE, $110 K for six cavities)
- Design and construction of an HPR system at the joint facility for rinsing after EP (1 FTE, $200 K M&S)

Cost summary (07):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
425	300	225	950

Expectations for FY08 and FY09:

The anticipated cavity processing needs for the ILC-Americas region are roughly 20-25 cavities in FY08 and 60-100 cavities in FY09. To meet these needs at least two independent full-time EP units will be required by FY09. This preliminary proposal aims to meet half of these processing needs. FY09 expectations are based on the assumption that a location is available at the joint facility for full time ILC EP operations. The principal investigator and key personnel are not listed here, however, the FY08-09 expectations represent a plausible course in any case for the ANL-FNAL collaboration.

A phased approach to EP activity in the U.S. has been recommended by experts from ANL, FNAL, Cornell and LANL whereby a pre-production EP system at the joint ANL-FNAL facility should be established as soon as possible. This is the system described above for FY07. A separate production facility should be available and operational in FY09, preferably located at and operated by one of the U.S. vendors that may facilitate a substantial part of the EP needs of the ILC.

Proposed FY08 activities for the ANL-FNAL-GDE collaborations are:
- Electropolish 12 ILC cavities (1.5 FTE, $225 K M&S)
- Installation of a PLC-based control system for EP (1 FTE, $75 K)

Proposed FY09 activities for the ANL-FNAL-GDE collaborations are:
- Electropolish 50 ILC cavities (4 FTE, $950 K M&S)
- Operations of an HPR system at the joint facility for rinsing after EP (1 FTE, $50 K M&S)

Total manpower and M&S for this proposed ANL-FNAL-GDE effort are shown below.

Cost summary (08):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
425	240	210	875

Cost summary (09):

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
820	800	480	2100

Category 5.2 Infrastructure and Test Facilities: Global Systems

5.2.2 Control System Design for ILCTA

5.2.2.1 Control Systems Support for ILCTA

Abstract:

The FNAL ILC group has plans for three cryogenic cavity test stands, vertical, horizontal and ILCTA (cryomodule). Much of the controls effort is expected to include deployment of the 'EPICS' toolbox, currently in use at several DOE facilities, including SLAC for L-band and X-band operation, and ANL at the Advanced Photon Source.

Fermilab has primary responsibility for implementing control systems for the three test stands (described in a different work package). This work package provides additional resources from SLAC and ANL to support the primary efforts.

Project Description:

The controls effort for the test stands is substantial and, while centered at FNAL, will require additional resources.

Through negotiation with S. Nagaitsev and M. Votava, leaders of the test stand and associated controls project, respectively, we will arrange for direct SLAC participation in the hardware, software and operation of these critical systems.

Argonne will provide expertise with high level application development, and with EPICS core software. Specific tasks are still being identified, but are anticipated to include developing EPICS applications, database applications, and high level scripting for running experiments, and collecting & analyzing data.

Motivation:

The Fermilab ILCTA program is critical to the R&D efforts on the ILC. Successful and timely deployment of the accelerator control systems will be essential to meeting the project goals. This work package will allow Fermilab to utilize expertise from SLAC and ANL, especially in EPICS, to supplement the expertise already on site at Fermilab, to meet the aggressive test stand installation schedule. This in turn will help to strengthen collaborative efforts on ILC controls efforts overall.

It is expected that SLAC will contribute strongly, perhaps lead, the RF source ILC linac work. The group here must therefore become closely involved with the SCRF development work at FNAL. There will be no large scale development of SCRF at SLAC.

Collaborations with other institutions:

This work package is inherently collaborative, involving staff from Fermilab (with primary responsibility for the ILCTA control system), SLAC, and ANL. FNAL will take the lead role.

Key Personnel:

ANL: Claude Saunders + staff.
FNAL: Margaret Votava, Sergei Nagaitsev + staff
SLAC: Janice Nelson +staff

Milestones and Deliverables for FY07:

The test stand projects at FNAL are in the advanced planning stage and our milestones and deliverables will be closely connected to that plan.

<u>5.2.2.1 Cost Summary</u>:

Institution	Labor (FTEs)	Labor Direct (K$)	Labor Indirect (K$)	M&S Direct (K$)	M&S Indirect (K$)	Total (K$)
ANL	0.75	110	37	25	7	179
FNAL						
SLAC						

<u>Expectations for FY08 and beyond</u>:

It is anticipated that this collaborative support for ILCTA controls will continue through FY08. Beginning in 2008, we expect the rate of PEPII upgrades to slow, freeing expertise on critical LLRF processes, such as fast digital control, feed-forward and feedback.

3. Execution

3.1 Effective Date

This Addendum to the Linear Collider MOU shall become effective upon the latter date of signature of the Parties. It shall remain in effect until superseded or October 1, 2006 whichever should come first.

3.2 Approval

The following concur in the contents of this Addendum:

____
Gerry Dugan,
Regional Director, GDE-Americas

____
Kwang-Je Kim,
ANL ILC Program Leader

____
Date

____
Date