2006 LBNL ADDENDUM
TO THE
MEMORANDUM OF UNDERSTANDING

between the

INTERNATIONAL LINEAR COLLIDER
GLOBAL DESIGN EFFORT

and

the Lawrence Berkeley National Laboratory

for the period

October 1, 2005 to September 30, 2006

Summary and Motivation for FY07 Proposed Work

Throughout this addendum—both in the section describing tasks funded in FY06 and expectations for this work to continue in FY07, and in the appended section on new work for FY07—we have fit our proposed work into the prescribed addendum format, categorized according to the present WBS structure for the ILC. While this format is useful for the review of proposed R&D, it tends to present a fractured picture of what we intend to accomplish. We take the opportunity here to simplify the picture by briefly pointing out our rationale for selecting the proposed tasks.

First, we propose to continue our FY06 work on the optics of the damping rings, including design of the injection and extraction lines, on characterization of the ring dynamic aperture, and on our contributions to the kicker design and understanding of beam dynamics for the KEK-ATF.

Almost all of the new work we propose for FY07 is directly related to collective effects in the damping rings. This is an area of strong expertise at LBNL, where we have a record of performance, from SSC calculations to ALS design and experiments, to PEP-II design and commissioning. We led the damping ring effort for the NLC, and included in that effort was calculation of collective effects, linked with mechanical design of the ring, and performance of the feedback systems. We propose here to apply this experience and expertise to the ILC damping rings. This is the surest way of obtaining a credible design and attendant cost estimate rapidly. Thus our proposed tasks include:

- calculation of collective effects
- studies of the dynamic aperture of the rings
- experimental studies of the fast-ion instability at the ALS
- specification and design of the damping ring transverse multi-bunch feedback system
- damping ring vacuum system design (iterating with calculations of impedance-induced collective effects and electron cloud effects)
- mechanical design of ring components, including alignment capabilities and vibration analysis, which relate to collective effects and feedback system specifications

As all of these tasks relate to each other through collective effects, close coordination in these activities will be critically important in developing an optimized and cost-effective damping ring design. We feel that these items fit together well as a coherent package, and likewise fit well with our experience and proven expertise. We would, of course, be happy to collaborate with other Labs and to help coordinate their efforts as appropriate.

There are three additional tasks proposed for FY07 that are not damping-ring-related. We propose these tasks because of our strong expertise and interest. These are: (1) R&D for LLRF controls and signal distribution, (2) evaluation of possible designs for superconducting magnets for the IR, and (3) design work for the positron source undulator. In each of these areas our expertise is unique and advanced, so that we can lead any effort and jump-start the design and costing. Moreover, ILC work in these areas will benefit from recent work: on LLRF for the SNS; concurrent work in the LARP program on SC magnets; and LBNL work on undulators for the LCLS and ALS, as well as prototyping of several short period planar Nb_3Sn undulators.

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1. *Introduction*

This Addendum constitutes the Statement of Work to be performed by Lawrence Berkeley National Laboratory (LBNL) in support of the International Linear Collider (ILC) for the period of October 1, 2005 to September 30, 2006. During this time period it is anticipated that the baseline design for the ILC will be derived under the auspices of the GDE and a reference design report and cost estimate will be started. It is conceivable that during the time period of this Addendum more emphasis and thus more resources may be allocated to the R&D efforts described in this Addendum. Alternatively it is possible that more emphasis will be placed on the reference design report and cost estimate. Such decisions are expected to be made jointly by the GDE and LBNL within the context of the international collaborative R&D program.

The activities detailed in this document fall within the scope of the Memorandum of Understanding (MoU) between the GDE and LBNL dated 15 February, 2006. 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.

Work at LBNL for the period covered by this Addendum will primarily involve: damping ring R&D coordination for the GDE, optics design for the damping rings, beamline optics design of damping ring injection/extraction lines; analysis of beam dynamics effects in the damping rings; design of fast extraction kicker for KEK-ATF damping ring test facility; beam dynamics studies at KEK-ATF. A detailed description of the work to be performed has been developed by LBNL and the GDE as one of the first FY06 tasks. This description includes a summary of the manpower and costs assigned to each task. Funds at the level of $500k for ILC R&D will be established at LBNL in FY06 by transfer from the DOE as recommended by the GDE-Americas Region Director.

2. *Statements of Work*

This Section contains the Statements of Work to be done at LBNL 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.

Semi-annual technical progress reports for each work package will be submitted at the mid-point 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*

2. Accelerator design, including reference design report
    - 2.1 Management
    - 2.5 Damping rings

5. Infrastructure and Test Facilities
    - 5.5 Damping rings

Our request for FY07 adds the following categories:

2. Accelerator design, including reference design report
    - 2.2 Global systems
    - 2.7 Beam delivery system

3. Research and Development
    - 3.2 Global systems
    - 3.4 Positron sources

3.5 Damping rings and bunch compressor
3.6 Main linacs, including RF systems

2.2 ***Definition of Work***

Specific work packages for the period of time covered by this Addendum are defined in this section. These work package definitions describe in detail the work to be done, giving milestones and deliverables. The work packages are listed by order of their category, as defined by the list given above.

Category 2.1: Accelerator Design – Management

2.1.1 Coordination of GDE-wide Damping Ring R&D Studies

Description:

- Coordination of studies of damping ring configuration options, leading to a recommendation for the configuration to be used for the RDR.
- Co-leadership for Damping Rings Area Systems, including coordination of design studies and damping rings costing.
- Production of documentation and information as needed to support production of the RDR.

Motivation:

Studies for the damping rings are widely distributed between the three regions, with most institutions contributing a relatively small effort to the whole. Making the most effective use of the available resources requires careful coordination. LBNL has been playing a leading role in coordinating damping rings R&D studies, and has established close collaborations with all the major contributors to this work. The demanding schedule for production of the RDR and cost estimate, and the success of ongoing damping ring R&D studies, requires continued careful coordination.

Collaboration with other institutions:

LBNL is collaborating on damping ring studies with ANL, CERN, Cornell, Daresbury, Cockcroft Institute, FNAL, IHEP, KEK, LNF and SLAC.

Milestones and deliverables:

November 2005:	Damping ring configuration recommendation (coordinated, with other members of damping ring area board)
January 2006:	Detailed report on damping ring configuration studies (coordinated and co-edited)
	Coordinated R&D list for global damping rings studies.
July 2006:	Coordinate, with other members of the damping ring area board, the preliminary cost estimate for damping rings.
November 2006:	As a member of the damping ring area board, oversee final cost estimate and draft of damping rings sections of RDR.

Key personnel:

Andrzej Wolski: 25%

Total: 0.3 FTE

Cost summary:

$68 k will be paid for this activity from carryover funds from FY05.

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
51.5	*see below	28.6	80

* **Note: Travel for A. Wolski is paid from the base program.**

2.1.2 Coordination of ILC Accelerator Effort at LBNL

Description

Coordination and management of all ILC accelerator work at LBNL, including coordination with ILC Americas and the GDE.

Key Personnel

Wolski: 10%
Zisman/New Hire: 5%
Celata : 10%

Total: 0.25 FTE

Andy Wolski and Mike Zisman will co-lead the effort until the end of March, when Andy leaves for his new position in the U.K. Thereafter Mike Zisman will lead. We have posted a position for a person to take Andy's place as head of the ILC effort at LBNL, and our plan is that this new hire will succeed Mike when he or she arrives.

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
25.8*	10.2	15.0	51

***Note: Celata labor paid for by base program**

<u>Expectations for FY07 and beyond:</u>

It is expected that this activity will be needed at the level of 0.35 FTE in FY07.

<u>Key Personnel:</u>

New Hire: 20%
Celata: 15%

Total: 0.35 FTE

The "new hire" will lead the effort in FY07.

<u>Cost summary:</u>

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
68.7	18.2	39.3	126

Category 2.5: Accelerator Design – Damping Rings

2.5.1 Damping Ring Injection/Extraction Line Lattice Design and Characterization

Description:

- Optics design of injection and extraction lines for damping rings.
- Tracking studies to characterize dynamics in injection/extraction lines (particle loss and sensitivity to errors).

Motivation:

Designs for the injection and extraction lines are necessary for engineering (particularly for designing the layout), costing, and for beam transport simulations. The injection and extraction lines include the compensating bends for the septum dispersion, and must carry the beam through the septum and kickers, matching into the damping ring optics. In the case of the positron rings, the injection/extraction lines include the separators and combiners that divide bunches between the upper and lower rings. Tracking studies will be needed, particularly for the positron injection line, to ensure low particle loss and define apertures. Tracking studies will be needed for the extraction line to characterize sensitivity to magnet strength and alignment errors.

LBNL has the skills and experience needed to produce designs for the injection and extraction lines, and to perform the necessary characterization studies. We previously developed designs for the injection and extraction lines for the NLC damping rings.

Collaboration with other institutions:

LBNL will work closely with ANL, who are working on the damping ring lattice design and the positron source, and with SLAC who are working on the positron and electron sources.

Milestones and deliverables:

April 2006: Preliminary lattice decks for damping rings injection/extraction lines.
June 2006: Completed optics designs for damping rings injection/extraction lines.
August 2006: Completed tracking studies to characterize particle loss and sensitivity to magnet strength and alignment errors.

Key personnel:

Ina Reichel: 20%

Total: 0.2 FTE

Work package leader: Andy Wolski, succeeded by Mike Zisman (see Category 2.1.1: Coordination of GDE-wide Damping Ring R&D Studies)

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
0 *	2.2	0.2	2

* Labor for this activity is paid by the base program.

Expectations for FY07 and beyond:

Further optimization of the injection and extraction lines will be ongoing, to meet geometry requirements, changes in anticipated kicker performance, inclusion of diagnostics, increasing performance margin, etc. and to reduce costs. LBNL can supply effort at the level of 0.5 FTE for these tasks.

Key Personnel:

Ina Reichel: 30%
New Hire: 20%

Total: 0.5 FTE

Work package leader: "new hire", who will be the leader of the ILC effort at LBNL in FY07

Cost Summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
98.1	3.4	54.6	156

2.5.2 Damping Ring Beam Dynamics: Dynamic Aperture

Description:

- Characterization of dynamic aperture in damping ring lattices This will include studies of the efficacy of injection into the ring, because of the strong overlap of this acceptance with dynamic aperture questions.

Motivation:

Good injection efficiency is critical for operation of the damping rings, and the dynamic aperture is a key component of this. LBNL will collaborate with those working on the lattice design to characterize the dynamic aperture under a range of conditions using a variety of tools (for example, frequency map analysis) and identify approaches to optimization of the dynamics.

LBNL has played a leading role in recent efforts to develop a lattice for the damping rings, and to understand the beam dynamics issues. We performed detailed dynamic aperture studies for the configuration recommendation, including tracking with errors and physical apertures, and use of frequency map analysis.

Collaboration with other institutions:

Work will be performed in close collaboration with laboratories developing the damping ring lattice design, including ANL, SLAC, and IHEP. LBNL will also collaborate closely with laboratories working on the electron and positron sources (ANL and SLAC), for tracking studies using realistic particle distributions.

Milestones and deliverables:

April 2006:	Preliminary characterization of damping rings dynamic aperture.
September 2006:	Complete studies of optimized dynamic aperture and injection efficiency with a range of magnet errors and realistic injection distribution.

Key personnel:

Mike Zisman	5%
Christoph Steier	5%
Weishi Wan	5%
Ina Reichel	20%
Greg Penn/New Hire	15%

Total: 0.5 FTE

Work package leader: Mike Zisman

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
51.5*	3.42	28.8	84

* Reichel paid for by base program

Expectations for FY07 and beyond:

Optimization of the damping ring lattices (baseline and alternative) is expected to be a continuing process, as results of beam dynamics analysis and engineering design indicate areas requiring improvement.

Key Personnel:

New Hire: 50%
Ina Reichel: 20%
Christoph Steier: 5%
Weishi Wan: 5%

Total: 0.8 FTE

Work package leader: New Hire (see Category 2.1.1: Coordination of GDE-wide Damping Ring R&D Studies)

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
157.0	3.4	87.2	248

2.5.3 Damping Ring Beam Dynamics: Collective Effects

Description:

- Characterization of selected collective effects in the damping rings, including space charge, IBS, microwave instability, electron cloud effects, and the resistive-wall instability.

Motivation:

Collective effects in the damping rings need to be thoroughly understood to validate the design, and to allow further optimization or development of alternatives to the baseline (e.g., for reducing technical risk or reducing costs).

LBNL has played a leading role in recent efforts to develop a lattice for the damping rings, and to understand the beam dynamics issues. For the ILC damping ring configuration studies, we performed detailed studies of space charge, IBS and other collective effects. Electron cloud effects are calculated to be severe in the damping rings, and we have unique capabilities, as described below, in electron cloud simulation. We led studies of collective effects in the NLC damping rings.

Collaboration with other institutions:

Studies within this work package will be coordinated with all other institutions working on the damping rings. LBNL is presently collaborating on damping ring studies with ANL, CERN, Cornell, Daresbury, Cockcroft Institute, FNAL, IHEP, KEK, LNF and SLAC. Financial support for these studies at LBNL will not be provided by other institutions, nor will LBNL use any of its funds for supporting damping ring studies at other institutions.

Milestones and deliverables:

July 2006: Preliminary estimates of the impact of selected collective effects.
Sept. 2006: Report on selected collective effects analyzing likely impact on damping ring performance, quantifying growth rates and thresholds etc.

Key personnel:

Marco Venturini: 80%
Mike Zisman: 5%

Total: 0.85 FTE

Work package leader: Mike Zisman

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
146.0	3.8	81.2	232

Expectations for FY07 and beyond:

In FY07 we will continue work (which will begin in the latter part of FY06), which will quantify the effect of the electron cloud in the positron damping rings. At LBNL we have the means to add significantly to the quantitative assessment of electron cloud physics, using the WARP/POSINST code. This code suite has capabilities that are needed for this problem and found in no other codes. With WARP/POSINST the **3D self-consistent** dynamics of the electron cloud and positron beam can be followed in detail for a much longer time than with other codes. This will allow for more complete physics, including calculating the effect of the electron cloud on the beam self-consistently, as well as benchmarking of codes that use more approximate models. WARP/POSINST is presently being used to study the electron cloud effect on the beam in the LHC.

We propose to apply the code to study the effect of the electron cloud in the wigglers, since the effect is most serious in this area. WARP/POSINST would be used to calculate electron cloud effects for a series of problems of ascending scale. This would include calculations of the fast head-tail instability, comparisons of 2D and 3D calculations, simulations to determine the electron-clearing of different-sized gaps in the bunch train, and a self-consistent calculation of the effects of the electron cloud on a bunch train during a time approximately equal to the damping time.

In FY07 we will also begin to apply WARP to a 3D, self-consistent calculation of the fast ion instability in the electron damping ring. This supports the damping ring design and also the experimental studies of the fast ion instability to be conducted at the LBNL Advanced Light Source (see below).

Because of the realistic 3D physics models used, these studies with WARP and WARP/POSINST require large amounts of computer time on a massively parallel computer (e.g., one of the NERSC computers). Successful accomplishment of the goals outlined here would require a grant of approximately 500,000 processor-hours. This is an estimate—the CPU time required for the runs depends on numerical parameters (e.g., spatial resolution required, number of macroparticles per physical particle, etc.) which are determined by the dynamics of the problem, and therefore would be ascertained as a part of the work scope. We hope to accomplish enough on this scoping in FY06 that the request for NERSC time for FY07 would be well defined. If less CPU time were available than what is optimal, fewer 3D runs would be done, and instead, 2D studies would be conducted. We would still, however, use WARP/POSINST to benchmark other less realistic codes with many fewer selected runs. Work on electron cloud and other collective effects in FY07 would include design optimization leading to improvement of lattice and vacuum chamber designs to minimize the impact of collective effects.

Key Personnel:

Celata: 85%
Venturini: 70%
Vay: 10%
Byrd: 10%
Visiting faculty (summer): 25%
Summer student

Total: 2.0 FTE and summer student

Work package leader: "new hire", who will be the leader of the ILC effort at LBNL in FY07

Cost Summary (FY07)

1.75 LBNL FTEs and a summer visiting faculty member plus a summer student. $10 k for travel expenses.

Labor (K$)	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
371	9.1	205	585

Please note: Approximately 500,000 processor hours of CPU time on a NERSC supercomputer would also be required.

Category 3.2: Research and Development – Global Systems

3.2.1 Development of Universal Accelerator Parser

Description:

- Development of Universal Accelerator Parser, a software tool to facilitate exchange of lattice and beam information between different accelerator modeling and simulation codes.

Motivation:

A wide variety of computer codes are in use for modeling different parts of the ILC and simulating the beam dynamics. There are benefits to having a diversity of codes in use: studies proceed more efficiently by having codes that are specialized to particular effects; and where several codes can study the same effects, confidence in the results is improved by being able to perform comparisons between the results from different codes. However, exchange of information between the codes is currently difficult, because there is no widely accepted standard format for the description of lattices (including parameters of the main components, apertures, wakefield information, magnetic field and alignment errors etc.)

A standard has been proposed (AML, [1]) for an extensible format that will allow a complete description of a beamline, including full information on the design and "error" conditions. It remains to develop a software tool to enable any particular simulation code to read input data in the AML format. This may be achieved by use of a class library, that can either be integrated into a simulation code so as to read the input AML file directly; or else can be used to construct a converter from AML into an existing input format.

LBNL is collaborating with Cornell on development of AML and associated software tools (generically known as the "Universal Accelerator Parser.") In particular, we are employing a Student Assistant who has the necessary computer science skills to develop the code with the specified functionality and flexibility.

[1] D. Sagan, "AML: Accelerator Markup Language Proposal" (July 2005).

Collaboration with other institutions:

LBNL is collaborating on this project with Cornell.

Milestones and deliverables:

March 2006: Functioning prototype of class library for converting common input formats (e.g. xsif) to and from AML.

September 2006: Version of Universal Accelerator Parser available for distribution; allowing conversion between different input formats, or integration into existing simulation codes to allow reading of AML files directly.

Key personnel:

Dan Bates: 50%

Total: 0.5 FTE

Work package leader: Andy Wolski, succeeded by Mike Zisman

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
12.9	0	7.1	20

Expectations for FY07 and Beyond:

This work is expected to continue at the same level through FY07.

Key personnel:

Dan Bates: 50%

Total: 0.5 FTE

Work package leader: "new hire", who will be the leader of the ILC effort at LBNL in FY07

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
13.4	0	7.4	21

Category 5.5: Infrastructure and Test Facilities – Damping Rings

5.5.1 Development of Injection/Extraction Kickers at KEK-ATF

Description:

- Physics design of stripline kickers for single-bunch extraction at KEK-ATF.

Motivation:

The KEK-ATF is presently the only damping ring test facility. Single-bunch extraction from the storage ring is a key capability for the planned development of the KEK-ATF as a test facility for final focus issues. Single-bunch extraction will also support development of the critical injection/extraction system for the damping rings.

Collaboration with other institutions:

Studies within this work package will be coordinated with other institutions working on the injection/extraction kickers, particularly KEK and SLAC (with which there are existing collaborations).

Milestones and deliverables:

March 2006: Physics design for single-bunch fast extraction kicker.

September 2006: Complete EM modeling of the kicker, including high-order modes and longitudinal impedance calculations.

Key personnel:

Stefano DeSantis: 15%

Work package leader: John Byrd

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
25.8	4.56	14.6	45

Expectations for FY07 and beyond:

LBNL should be involved in the construction and testing of the fast extraction kicker for the KEK-ATF. Studies at the LBNL-ALS are also possible.

Key personnel:

Stefano DeSantis: 15%

Work package leader: John Byrd

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
29.4	8.0	16.8	55

5.5.2 Studies of Beam Dynamics at KEK-ATF

Description:

- Contribution to beam-dynamics studies at KEK-ATF, including CSR studies, low-emittance tuning and nonlinear dynamics.

Motivation:

The KEK-ATF provides a unique facility for tests of beam dynamics issues expected to be crucial for damping ring operation, including low-emittance tuning and effects of coherent synchrotron radiation.

LBNL has collaborated for the past several years with KEK and SLAC on beam dynamics studies at the KEK-ATF, including annual visits for experimental studies.

Collaboration with other institutions:

Studies within this work package will be coordinated with other institutions working on the damping rings, particularly KEK and SLAC (with which there are existing collaborations). Funding will not be shared with or supported by other institutions.

Milestones and deliverables:

March 2006: Participate in an experimental study of the microbunching instability driven by coherent synchrotron radiation. Provide far infrared bolometers for detecting CSR.

March 2006: Analysis of performance of upgraded BPMs at the ATF, and benefits for beam-based alignment and low-emittance tuning.

Note: The ATF does not operate in the summer, so this activity will begin again, after the March deliverable and the departure of Andy Wolskii, in the next fiscal year.

Key personnel:

Stefano DeSantis: 5%
Andy Wolski: 10%

Total: 0.15 FTE

Work package leader: Andy Wolski

Cost summary:

Travel for A. Wolskii is paid for by the base program.

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
25.8	3.42	14.5	44

Expectations for FY07 and beyond:

LBNL should continue to be involved in beam dynamics studies at the KEK-ATF. Major issues will be maintenance of high beam quality at high bunch charge and multi-bunch operation, which will be particularly important for ATF II.

Key Personnel:

Stefano DeSantis: 10%
New Hire: 10%

Total: 0.2 FTE

Work package leader: "new hire", who will be the leader of the ILC effort at LBNL in FY07

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
39.3	11.4	22.5	73

5.5.3: Damping Rings Studies at LBNL-ALS

Description:

- Experimental studies of fast ion instability at the LBNL Advanced Light Source

Motivation:

The fast ion instability is a potentially limiting effect on the performance of the ILC electron damping ring. Recent studies indicate the need for extremely demanding vacuum levels, which could be difficult to achieve and will certainly add to the cost of the damping rings. The present theories and models have not been rigorously tested in the regime of the damping rings, leading to significant uncertainty in the predictions. The LBNL-ALS has the ability to operate in the low-emittance regime where fast-ion effects are expected to occur, together with the diagnostics and instrumentation needed to make detailed studies of these effects. LBNL also has significant expertise with fast bunch-by-bunch feedback systems, which will likely be needed to maintain beam quality in the presence of fast ion instability in the damping rings. Calculations that include gaps in the bunch train to decrease the ion density indicate fast-ion growth rates of tens of turns, a regime in which feedback is necessary and viable.

Collaboration with other institutions:

LBNL will collaborate with researchers at SLAC, KEK and PAL who are using analytical and simulation tools to study the fast ion instability.

Milestones and deliverables:

January 2006: Verification of low emittance regime, and operation of the instrumentation needed to observe fast ion effects in the LBNL-ALS.
April 2006: Preliminary measurements of fast ion effects.
September 2006: Characterization of fast ion effects under a variety of conditions.

Key personnel:

John Byrd: 5%
Marco Venturini: 20%

Total: 0.25 FTE

Work package leader: John Byrd

Cost summary:

$60 k will be paid for this activity from carryover funds from FY05.

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
43.0	3.4	24.0	70

Expectations for FY07 and beyond:

The LBNL-ALS offers opportunities for ongoing studies of beam dynamics effects important for the damping rings, as well as tests of instrumentation (for example, fast kickers that could be used for injection/extraction in the damping rings).

Key Personnel:

John Byrd: 10%
Stefano DeSantis 10%
Marco Venturini: 20%
Postdoctoral fellow: 35%

Total: 0.75 FTE*

Work package leader: John Byrd

* This work is leveraged by parallel work and interest from the ALS, resulting in significant collaboration with ALS accelerator scientists.

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
115.4	11.4	64.7	192

THE FOLLOWING IS NEW WORK WHICH WILL BE PROPOSED FOR FY07 (AND BEYOND)

Category 2.5: Accelerator Design – Damping Rings

2.5.4 Damping Ring Vacuum Systems Design

Description:

We propose to develop design concepts for the damping ring vacuum systems in order to provide required vacuum performance and minimize impedance from geometric wakefields. Synchrotron radiation fans and heat loads, particularly from the wigglers, will be analyzed, and vacuum chamber apertures and any antechambers required will be designed such that all direct synchrotron radiation impinges only on cooled photon stops. The work will involve close communication with impedance and collective effects, lattice design, and magnet design efforts.

Motivation:

Vacuum systems are a critical component for stable storage rings. The vacuum system must provide not only a high vacuum environment for beam lifetime and minimizing ion-related effects, but also a minimal geometric impedance of the structure. Care must be taken to absorb direct synchrotron radiation only on specially designed and cooled surfaces (e.g., photon stops). Integration of diagnostics and instrumentation needs to be carefully considered. The cross section of the vacuum chambers is influenced by lattice acceptance, injection oscillations, and propagation of traveling waves and their potential interaction with BPM systems. An additional challenge is to minimize photo-emitted electron density in the beampipe (for the positron beam), by suitable materials choices or coatings.

Collaboration with other institutions:

We propose to collaborate with existing efforts at Daresbury Laboratory (ASTeC), and with SLAC and IHEP in the vacuum chamber design in coordinating development of low-impedance vacuum chambers, with ANL in lattice design to ensure proper location of photon stops to intercept synchrotron radiation.

Key Personnel:

Steve Marks: 50%
Dave Plate: 25%

Total: 0.75 FTE

Work package leader: Ross Schlueter

Cost Summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
147.2	4.6	81.9	234

2.5.5 Damping Rings Mechanical Systems Design & Integration

Description:

We propose to develop integrated systems design concepts for the damping rings magnetic lattices in order to provide required stability and performance. Magnets, together with vacuum systems, diagnostics, and other systems will be integrated onto supports and movers and girders.

Motivation:

The damping ring mechanical systems must be maintained in a stable configuration, while also maintaining ability to move some magnet components where required for beam dynamics optimization. An integrated approach including magnets, vacuum, diagnostics, and other components, is required for a system meeting performance requirements and cost-effective engineering design.

Collaboration with other institutions:

We will collaborate in vacuum systems design with ASTeC, with ANL in lattice design, and other investigators as identified in magnet and diagnostics systems components.

Key Personnel:

Dave Plate: 25%
Steve Marks: 15%
Ross Schlueter: 10%

Total: 0.5 FTE

Work package leader: Ross Schlueter

Cost Summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
98.1	3.4	54.6	156

2.5.6 Multibunch Impedance

Description:

Estimate the multi-bunch instability growth rates in the baseline and alternative damping rings, based on a realistic model of the long-range wakefields. Characterize the effects (induced jitter, emittance growth etc.) of injected bunches on damped bunches, mediated by long-range wake fields, feedback systems etc. In the positron damping ring, the stored beam current will fall by 10% at the start of the extraction cycle, before new bunches generated by the electron beam can arrive at the positron damping ring. The current will stay at a reduced level, until the end of the extraction cycle, when it will return to its full value. The changes in current will generate transient beam loading effects in the transverse impedance. These transient effects have a potential for impacting the projected transverse beam size of the multibunch beam.

Motivation:

With the large numbers of bunches in the damping rings and the transient nature of the injection and extraction process, the effects of long-range wakefields will be one of the determining factors in reaching the desired performance. Our group at LBNL has extensive experience in calculation, simulation, and measurement of these effects at the ALS, PEP-II, Next Linear Collider damping rings, and several other storage ring light sources.

Collaboration with other institutions:

We will collaborate with SLAC and IHEP in using wakefield and impedance models to calculate multi-bunch instability growth rates.

Key Personnel:

John Byrd: 20%
Postdoctoral fellow: 35%

Total: 0.55 FTE

Work package leader: John Byrd

Cost Summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
76.2	5.7	42.6	125

2.5.7 Development of the Transverse Broadband Multi-bunch Feedback Systems

Description:

We propose to study the technical issues associated with transverse broadband multi-bunch feedback systems operation, such as allowable system noise and gain, and phase margins. If appropriate, these studies will be accompanied by experimental tests on the Advanced Light Source. This also includes modeling bunch-by-bunch feedback systems to determine limits of beam stability, including all relevant effects (instability growth rates, pick-up and amplifier noise etc.) in baseline and alternative damping rings under a range of conditions (including variations in fill pattern, effects during injection and extraction etc.).

Motivation:

Electron cloud and ion instabilities in the positron and electron damping rings are expected to drive transverse multibunch instabilities with relatively fast growth rates. Broadband transverse feedback (TFB) systems will be necessary to control these instabilities. The predicted growth rates will require about an order of magnitude higher gain than is typically achieved in normal operation of these systems. Our group at LBNL has extensive experience in the principles, simulation design, and commissioning of TFB systems with operating systems installed in the Advanced Light Source, PEP-II, and the Duke Storage Ring FEL.

Collaboration with other institutions:

We propose to collaborate with SLAC and IHEP in using wakefield and impedance models to calculate multi-bunch instability growth rates in order to specify feedback systems performance.

Key Personnel:

Walter Barry: 25%
John Byrd: 10%
Larry Doolittle 10%

Total: 0.45 FTE

Work package leader: Walter Barry

Cost Summary:

We have a small, internally funded activity in FY06. We plan to continue and expedite the work in FY07 and FY08. $8k per year is required for travel.

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
88.3	11.4	49.7	149

2.5.8 Damping Ring Low Emittance Tuning

Description:

We propose to investigate and validate techniques for coupling correction in the damping ring lattices, leading to a robust procedure for obtaining and maintaining low emittance. This task will include specifying steering magnets and skew quadrupoles for coupling.

Motivation:

The emittance requirements for the damping rings are extremely demanding, particularly for the vertical emittance, and exploration of tuning techniques to minimize coupling in the ring and in the extraction lines is needed to ensure successful operation of the damping ring complexes. Improvement of existing algorithms and specification of diagnostic measurements, as well as location and performance of orbit correction magnets and skew quadrupole magnets, will be highly beneficial.

Collaboration with other institutions:

We propose to collaborate with existing efforts at Daresbury Laboratory (ASTeC), and with SLAC and ANL in lattice design, and interact with persons at LBNL working on extraction line design.

Key Personnel:

Gregory Penn: 50%
Ina Reichel: 25%

Total: 0.75 FTE

Work package leader: "new hire", who will be the leader of the ILC effort at LBNL in FY07

Cost Summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
147.2	4.6	81.9	234

2.5.9 Characterize The Effects Of Transients During The Injection/ Extraction Process On The Damped Bunches

Description:

We propose to characterize the effects of injected bunches on damped bunches in the positron damping rings. The transients induced during injection will be studied, and their potential impact on beam stability and feedback system performance analyzed.

Motivation:

Transient effects inherent in the positron production scheme and the injection process induce long-range wake fields that can couple to the stored bunches and introduce timing (synchronous phase) jitter, energy jitter, and emittance growth. Feedback systems act to correct these effects. The effects need to be characterized to fully understand the injection and extraction stability requirements, and define feedback and/or feed-forward system requirements

Collaboration with other institutions:

We propose to collaborate with ANL in lattice design, and with other groups identified in RF cavity design. We will also interact with the LBNL engineering team working on vacuum system design in the context of impedance issues.

Key Personnel:

Gregory Penn: 50%

Work package leader: "new hire", who will be the leader of the ILC effort at LBNL in FY07

Cost Summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
98.1	0	54.4	153

Category 2.7: Accelerator Design– BDS

2.7.1 Development of Superconducting Magnets for the IR

Description:

Design of superconducting magnets for the baseline IR layouts using 2 mrad and 20 mrad crossing angles. Support for ongoing IR optics studies (such as the head-on collision scheme, intermediate crossing angles etc.) relative to magnet feasibility, performance parameters, fabrication and cost issues.

Motivation:

The baseline configuration of the ILC includes two interaction regions with finite crossing angles of 2 mrad and 20 mrad, respectively. Both options involve significant technical challenges and require advanced superconducting magnets. The final focus magnets for the 2 mrad design must have a large aperture to accommodate both incoming and extracted beams. The main design issues in this case are related to high field and forces in the windings. The 20 mrad option uses separate incoming and extraction beamlines. The main magnet design issues in this case are related to close proximity of the two beamlines, with non-parallel axes. Alternative schemes, such as head-on collisions or the use of intermediate crossing angles, are also under study. In all cases, the designs are complicated by heat loads due to beam losses and synchrotron radiation, and by the requirement to minimize any interference with the detector operation. The feasibility and features of the IR magnets will have a critical impact on the IR layout and optimization, and on the detector design and performance. As a world leader in the development of advanced accelerator magnets, LBNL has significant expertise applicable to this problem.

Collaboration with other institutions:

These studies will be coordinated with other institutions involved in the design of the ILC Beam Delivery Systems. In particular, SLAC and CEA for the IR optics design; FNAL, BNL and CEA for the IR magnets design. BNL, FNAL, LBNL and SLAC are presently collaborating on the LARP R&D program to develop the technology base for a luminosity upgrade at the LHC. There are significant overlaps between the LARP magnet development effort and the ILC requirements. ILC will also benefit from strong collaborative environment established among the U.S. magnet labs through the LARP program.

Key Personnel:

GianLuca Sabbi: 5%
Shlomo Caspi: 5%
Paolo Ferracin: 20%
Postdoctoral fellow: 50%

Total: 0.8 FTE

Work package leader: GianLuca Sabbi

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
112	11.4	62.6	186

Category 3.4: Positron Sources

3.4.1. Design of an Undulator for the Positron Source

Description:

The currently recommended positron source for ILC requires a helical undulator with a length between 100 m and 200 m, a period of 1 cm, and a peak field of 1.1 T. We propose to perform a comparison between the use of NbTi and Nb_3Sn conductor for this device, including performance parameters, magnetic, mechanical and thermal analysis, fabrication issues and cost. A preliminary study will also be performed to describe the fabrication of a small prototype that would demonstrate the critical design features.

Motivation:

The undulator is a challenging and critical component of the ILC positron source. LBNL has significant expertise that can be applied to this component, due to its involvement in an early concept design of a helical undulator for LCLS, the design, fabrication and implementation of Insertion Devices for the Advanced Light Source, and the design and prototyping of several short period planar undulators based on Nb_3Sn.

Collaboration with other institutions:

This study will be coordinated with other institutions involved in the design of the helical undulator for the ILC positron source. The project will benefit from an existing collaboration among U.S. Labs (LBNL, BNL, ANL, NHMFL, SLAC) to develop advanced undulators for next-generation light sources.

Key Personnel:

Shlomo Caspi: 20%
Dan Dietderich: 5%
Steve Marks: 5%
Soren Prestemon: 20%

Total: 0.5 FTE

Work package leader: GianLuca Sabbi

Cost summary:

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
85.9	11.4	48.4	146

Category 3.5: Research and Development- Damping rings and bunch compressor

3.5.1: Higher-Order Beam Diagnostics and Tune Monitor

Description:

We propose to develop coherent signal receivers to be used to determine the suitability of the beam for extraction: there should be no detectable coherent motion leading up to extraction. There are few rings in the world that routinely achieve beam stability to a level where no coherent motion can be seen. There may be a need in the damping rings for more than one type of coherent signal monitor. The oscillations of charge distribution associated with the microwave instability require a very high frequency receiver (in the case of the damping rings, in the range of 5 to 10 GHz).

We also propose to develop a betatron tune monitor with sufficient resolution that allows observation of ion-induced motion but with sufficiently small excitation levels that the coherent motion is negligible.

Motivation:

As part of our efforts to improve beam stability in the Advanced Light Source, one of the most stable storage rings in the world; we have developed multibunch feedback systems and performed extensive studies of instabilities, including ion-driven effects. As part of this development, we have studied coherent signal receivers for observing coherent dipole longitudinal and transverse motion. This system is part of the existing tune measurement system, which allows excitation and measurement of the tunes of individual bunches.

Collaboration with other institutions:

We propose to collaborate with other groups working on beam diagnostics, and with KEK in developing potential experimental tests at the KEK ATF.

Key Personnel:

Walter Barry: 15%
John Byrd: 5%

Total: 0.2 FTE

Work package leader: John Byrd

Cost Summary:

$15k per year is required for materials.

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
39.3	9.1	22.4	71

Category 3.6: Research and Development- Main Linacs, including RF Systems and Category 2.2: Global Systems **(Note: The intention is to design and test the LLRF for the entire accelerator, not just the Main Linacs, but no category corresponds to this.)**

3.6.1 Low-level RF, and RF Signal Distribution (Timing & Synchronization) *for Entire ILC*

Description:

In this category, we propose work in two areas: low level RF controls and RF signal distribution. This work applies to the entire ILC, not just the main linacs.

In the area of LLRF, we propose to develop and test the hardware and software environments that will help characterize the system, demonstrate them in the available test stands, including FNAL and/or DESY, and contribute the results to the feasibility and technical design baseline of the ILC controllers. This will be integrated with the timing and distribution system, since the two are intimately interconnected.

For our work on RF signal distribution, we propose to scale the fiber-based system currently under development to length scales of 10 km and design an experimental test to quantify the stability.

Motivation:

The subject of RF beam control will be critical for a machine with the complexity of the ILC. We propose to contribute to development in both low-level RF (LLRF) controls, and highly stable RF signal distribution.

In order to minimize construction costs, the ILC will rely heavily on powering multiple cavities with a single klystron. This will impose a strain on the rf controls system, which will nonetheless be required to maintain tight amplitude and phase control of each cavity. Another challenge for the system designer is the scale of the installation: with many thousands of cavities, both the reliability and the unit cost of the rf controller become important on a scale not seen in previous accelerators. After the successful experience of the SNS linac rf controller, where we led the design effort through installation and commissioning, our group is ideally equipped for this work.

For a machine the size of the ILC, distribution of a master RF signal with the requisite stability is not trivial. We have developed an RF signal distribution technique based on interferometrically-stabilized optical fiber, and recently demonstrated femtosecond stability over a hundred meter length of fiber. This technology holds tremendous promise for highly stable RF signal distribution for the ILC.

Collaboration with other institutions:

In the LLRF effort, we have already established collaborations with DESY (which is also part of the TESLA collaboration, of which LBNL is a part), as well as SLAC, FNAL and SNS. We have already shared discussions on the conceptual design of a prototype board, we are planning for common testing, and both SNS and DESY have offered to pay for the hardware construction. We consider this collaborative effort essential to the success of the project, and plan to continue it for the years to come.

For the stable timing distribution system, we have collaborations with the future FEL facilities FERMI and LCLS to develop such systems over several hundred meters.

Key Personnel:

John Byrd:	20%
Larry Doolittle:	35%
Russell Wilcox:	15%
Postdoctoral fellow:	30%

Total: 1.0 FTE

Work package leader: Alex Ratti

Cost Summary:

We have a small, internally funded activity in FY06. We plan to continue and expedite the work in FY07 and FY08. Materials and travel $20k per year.

Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
169.0	22.2	94.9	286

Total Request for FY07 in All Categories: $3.254 M

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:

_________________________ Andrzej Wolskii , LBNL ILC Program Co-Leader	_________________________ Michael S. Zisman, LBNL ILC Program Co-Leader
_________________________ Date	_________________________ Date
_________________________ Gerry Dugan, GDE-Americas Regional Director	_________________________ Steve Gourlay, Accelerator & Fusion Research Director, Lawrence Berkeley National Laboratory
_________________________ Date	_________________________ Date