ADDENDUM

to a

MEMORANDUM OF UNDERSTANDING

between the

INTERNATIONAL LINEAR COLLIDER
GLOBAL DESIGN EFFORT

and

The Fermi National Accelerator Laboratory

for the period

October 1, 2005 to September 30, 2006

1. Introduction

This Addendum constitutes the Statement of Work to be performed by the Fermi National Accelerator Laboratory (FNAL) 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 FNAL within the context of the international collaborative R&D program.

The activities detailed in this document falls within the scope of the Memorandum of Understanding (MoU) between the GDE and FNAL dated Nov, XX 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.

Work at FNAL for the period covered by this Addendum will primarily involve the R&D directed at the ILC Main Linac. The main thrust of the Fermilab ILC R&D is to establish US technical capabilities in the Superconducting Radio Frequency Cavity and Cryomodule technology. The main technical goals of the ILC R&D at Fermilab described in detail in this MOU are

1. Main Linac Design
   a. Main Linac Accelerator Physics and Design
   b. Cavity technology development in the US to routinely achieve ≥ 35 MV/m and Q ~0.5-1e10
   c. ILC Cryomodule design and fabrication
   d. Develop capabilities to fully test the basic building blocks of the Main Linac
2. Accelerator design: Damping Ring, Beam delivery system
3. Development of an ILC site near Fermilab
4. Instrumentation, Controls and Feedback

This detailed description includes a summary of the manpower and costs assigned to each task. Funds at the level of $11M for ILC R&D will be established at FNAL in FY06 by transfer from the DOE as recommended by the GDE-Americas Regional Director.

2. Statements of Work

This Section contains the Statements of Work to be done at FNAL 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 ILC-Americas WBS

The ILC-Americas WBS categories are listed below. The work packages defined in the next section are numbered according to this WBS.

WBS	Description
1	Program direction and administration
2	Accelerator design, including RDR
2.1	Management
2.2	Global systems
2.3	Electron sources
2.4	Positron sources

- 2.5 Damping rings
- 2.6 Ring to Main Linac
- 2.7 Main Linacs: Optics, beam dynamics, instrumentation
- 2.8 Main Linacs: RF systems
- 2.9 Main Linacs: Cavities and Cryomodules
- 2.10 Beam delivery system
- 2.11 Conventional facilities

3 Research and development
- 3.1 Management
- 3.2 Global systems
- 3.3 Electron sources
- 3.4 Positron sources
- 3.5 Damping rings
- 3.6 Ring to Main Linac
- 3.7 Main Linacs: Optics, beam dynamics, instrumentation
- 3.8 Main Linacs: RF systems
- 3.9 Main Linacs: Cavities and Cryomodules
- 3.10 Beam delivery system

4 Engineering and cost estimation in support of RDR
- 4.1 Management, technical and engineering services
- 4.2 Global systems
- 4.3 Electron sources
- 4.4 Positron sources
- 4.5 Damping rings
- 4.6 Ring to Main Linac
- 4.7 Main Linacs: Optics, beam dynamics, instrumentation
- 4.8 Main Linacs: RF systems
- 4.9 Main Linacs: Cavities and Cryomodules
- 4.10 Beam delivery system
- 4.11 Conventional facilities

5 Infrastructure and test facilities
- 5.1 Management
- 5.2 Global systems
- 5.3 Electron sources
- 5.4 Positron sources
- 5.5 Damping rings
- 5.6 Ring to Main Linac
- 5.7 Main Linacs: Optics, beam dynamics, instrumentation
- 5.8 Main Linacs: RF systems
- 5.9 Main Linacs: Cavities and Cryomodules
- 5.10 Beam delivery system
- 5.11 Conventional facilities

6 Reserve

2.2 Scope of Work

WBS 1.2 Project Management-Fermilab

Motivation: The motivation of central ILC Program management at Fermilab is to make the most efficient use of Fermilab ILC resources throughout the laboratory. The organization is a matrix management scheme with the Technical and Accelerator Divisions managing most of the accelerator R&D activities. The Computing Division will be responsible for various ILC-related computing, control, and simulation activities.

Description: The Fermilab ILC program office was reorganized in FY06**.** The ILC R&D effort is now managed from the Fermilab Directorate. This reorganization was in response to a Fermilab Long Range Planning Committee (FLRPC) recommendation that a new management structure be formed at Fermilab to manage the ILC Program and that an ILC Program Director be appointed. The Fermilab Director has stated that the ILC is the highest priority long term goal of Fermilab and has restructured the Fermilab ILC organization following the FLRPC recommendation. The ILC program at Fermilab will pool resources from divisions and sections of Fermilab. The ILC Program Director's office will be the point of contact for the GDE and all institutions collaborating with Fermilab on the ILC.

Collaboration with other Institutions: The ILC Program Director's office is responsible for developing collaborations with other institutions described in this MOU. These collaborations will be managed under bi-lateral MOU's between Fermilab and the collaborating institutes. At present Fermilab is developing bi-lateral MOU's with DESY, KEK, SLAC, Jlab, Cornell, INFN, LANL and Indian universities and laboratories. The Fermilab ILC Program Director will keep the GDE-Americas Regional Director informed of all such MOU's.

Milestones and deliverables: The ILC Program Director's office is responsible for all the milestones and deliverables described in this document.

Key Personnel: Robert Kephart is the ILC Program Director. Shekhar Mishra (Technical Division) and Sergei Nagaitsev (Accelerator Division) serve as Deputy ILC Program Directors. Richard Stanek is the ILC Resource Manager and will assist the ILC Program Director in the management of Fermilab ILC resources, reports to the GDE and DOE, and management of the schedule and milestones. Shekhar Mishra and Robert Kephart are members of the GDE and serve as contact persons for Fermilab.

Manpower and Cost Summary:

FTE-years	Labor (K$)	M&S (K$)	Indirect costs (K$)	Total cost (K$)
5.0	575	300	223	1098

The M&S estimate includes the general operation of the ILC Program office at Fermilab and travel. ILC travel is also included in several other work packages.
Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond at this level.

WBS 2.1.2: Development of Reference Design Report

Motivation: The Reference Design Report (RDR) will be a key document for defining the scope of the ILC project, the R&D program, and the project cost. Fermilab's objective in these activities is to both secure approval and funding of the ILC as an international project and to develop an Illinois site near Fermilab as the preferred site.

Description: Fermilab scientific and engineering staff will work with the ILC GDE for the next 12 months in development of the Reference Design Report. The Snowmass workshop (Aug 05) began the definition of the ILC baseline configuration document with the baseline and alternate configuration recommendations. The Working Groups, Global Groups and GDE are working on finalizing the Baseline Configuration Document (BCD) by the end of 2005. The ILC baseline configuration will be put under configuration control and will be used to develop the ILC RDR by the end of 2006.

Fermilab actively participated in the Snowmass Workshop and is participating in the development of the BCD with several members of its staff on the editorial team. Fermilab has proposed to participate in the overall document preparation with primary focus on the Main Linac, Site and Conventional facility, and cost and schedule development. We also plan to play a secondary role in Damping Ring and Beam Delivery System development. We will also actively participate in the instrumentation, controls and feedback for the ILC.

Fermilab is committed to developing a world class superconducting RF capability. This capability will be used for the ILC Main Linac design and development. Fermilab also coordinates the International Linear Collider Test Areas at Fermilab (ILCTA@Fermilab). These areas will provide world class SRF testing capability. The Civil group at Fermilab is playing a central role in developing methods for understanding the site and its interplay with the tunnel and machine design. Plans are being developed to build strong e^+e^- accelerator physics, instrumentation and controls groups at Fermilab for the ILC.

Milestones and Deliverables: Fermilab will help write the Main Linac, the Americas region site, and the Cost and Schedule chapters of the RDR. Fermilab will actively participate in the development of the full document, with specific emphasis in the areas described in this MOU. As requested by the GDE, Fermilab will provide engineering resources in support of the ILC cost estimate. The RDR will be completed by end of FY06.

Collaboration with Other Institutions: The ILC GDE is coordinating the development of the BCD and RDR. Fermilab, under the direction of the GDE, will collaborate with partner institutions to finish this document in a timely manner.

Key Personnel: Shekhar Mishra, Robert Kephart, Peter Garbincius, Vic Kuchler, Sergei Nagaitsev, Tom Peterson, Harry Carter, Chris Jensen, John Tompkins, Paul Czarapata.

Manpower and Cost Summary: The M&S cost summary for this work package includes travel related to GDE meetings and towards the development of RDR.

FTE-years	Labor (K$)	M&S (K$)	Indirect	Total cost (K$)

			costs (K$)	
2.0	230	100	86	416

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will slowly transform into the Technical Design Report work. Fermilab's activity in the area is expected to at least double.

WBS 2.11.2: Conventional Facilities Design

Motivation: Develop an Americas region sample ILC site near Fermilab in a comparative and cost effective way. Develop criterion for comparison of sites in all three geographic regions (Americas, Europe, and Asia)

Description: The Fermilab Civil Group, in collaboration with SLAC, Japanese and European engineers, is developing methods of analyzing site issues and comparing ILC sites. The current effort is not intended to select a final ILC site, but rather to understand from the beginning how the features of sites will effect the design, performance and cost of the ILC. These studies will lead to the specifications for an Americas region site near Fermilab.

Northern Illinois presents numerous possibilities for the site of the International Linear Collider. Several possible sites are being explored. Each proposed site has implications that are favorable or less favorable to successful conventional construction fulfilling the project requirements. Several sites are conducive to near surface construction methods such as open cut or braced excavation construction while other locations are suitable for deep rock tunneling construction methods. Cost, proximity to Fermilab, access to power, population density, and environmental impacts are just a few of the many items that need to be considered when choosing a site. Various sites have features that affect initial construction cost, operational costs and ease of technical operations.

Partnering with engineers at SLAC, the ILC Conventional Construction team has begun to develop methods of comparing various sites while continuing to refine and document the technical criteria. The current effort is not intended to select a potential site, nor are the sites being examined fixed in their location. In most cases, the siting can be adjusted by miles without substantially changing the pertinent site features. This process is intended to provide insight on the effects that various site choices might have. Our current effort is limited to two rock tunnel design solutions and three near surface design solutions. Work continues with geologists at NIU characterizing the geological characteristics of the rock in northern Illinois.

Milestones and deliverables: For the sample America's region site to be used in the RDR, all the drawings, text, and cost and schedule estimates will be developed by Sept 06.

Collaboration with Other Institutions: This work at Fermilab is being carried out in close collaboration with SLAC for the Americas region ILC site development. The site matrix studies are carried out in collaboration with KEK, DESY and CERN.

Key Personnel: Vic Kuchler and Tom Lackowski

Manpower and Cost Summary:

Labor (K$)	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
Included in M&S	450	73	523

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will transform into the US Expression of Interest to host the ILC at Fermilab. The funding required to support Fermilab's activity in this area is expected to be about $4M in FY07.

WBS 1.6: ILC Public Relation Publications

Motivation: Prepare printed materials to provide information about the ILC or the ILC at Fermilab, to the general public, to elected officials, or to industrial representatives and others. The Fermilab Office of Public Affairs receives frequent requests for such publications.

Description: Publish printed materials, backed up by Web sites, for various audiences, to provide information on various aspects of the ILC at Fermilab.

Collaboration: Fermilab Office of Public Affairs will collaborate with the GDE, the SLAC Office of Public Affairs, the Office of High Energy Physics in the DOE Office of Science, industrial representatives, the Fermilab ILC community, the Community Task Force and other members of neighboring communities to ensure that the materials are available and that they are meeting the needs of the various audiences.

Key Personnel: Judy Jackson and Members of the Fermilab Office of Public Affairs staff

Milestones and Deliverables: A series of print publications (brochures, community newsletters, posters, exhibits) linked to associated Web sites. We expect to finish this by June 06.

Manpower and cost: The cost is for the web site development, design and development of printed materials.

Labor (K$)	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
Included in M&S	50	8	58

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will slowly increase as public participation will continue to be important and will become an integral part of the US Expression to Host the ILC.

WBS 2.5.2: Damping Ring Accelerator Physics

Motivation: Damping Ring Design, Accelerator Physics studies and Kicker design.

Description: During FY06, we will focus on self-consistent modeling of space-charge effects. We will use the 3D, parallel code Synergia, which will allow us to track millions of particles. This will enable us to study potential emittance growth and halo creation for different operational parameters of the baseline design. For example, we will study how close to different resonances we can run. Three-dimensional, self consistent space-charge codes are necessary to study halo generation and emittance dilution. This capability is complementary to the weak-strong codes currently used for ILC DR modeling. We will then include CSR effects in the model and repeat a subset of these studies.
We will include realistic wiggler maps in our model and, in coordination with other such efforts, we will study the effect of non-linearities of the wiggler on the beam dynamics as a function of the wiggler geometry (mainly the width). In addition, we will participate in the effort to develop self consistent electron cloud modeling, including cloud generation and cloud effects on beam dynamics. Since this is a large project, we will work with our collaborators from LBNL, UCLA, and USC, focusing on utilizing PIC codes, such as QuickPIC, for beam dynamics. All the above mentioned simulations will be performed on the Fermilab Computational Physics for Accelerators parallel cluster, and will total an effort of 1 FTE.

Collaboration with other institutions: Fermilab is collaborating with LBNL, UCLA, and USC on these Damping Ring design calculations.

Key Personnel: Panagiotis Spentzouris, Sergei Nagaitsev, King Ng, Francois Ostiguy, John Johnston

Manpower and Cost Summary: The M&S cost covers computer and software licenses.

FTE-years	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
1.0	115	50	43	208

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will increase to a few (3-5) FTE as more accelerator physicists and engineers get involved with the design, engineering and cost reduction.

Main Linac

The main focus of the Fermilab ILC R&D is to lead the effort to establish US technical capabilities in ILC-related Superconducting Radio Frequency Cavity and Cryomodule technology.

The R&D efforts at Fermilab will develop SRF cavity technology to achieve 35 MV/m with a Q of ~0.5e10, ILC Cryomodule design, and capability to test the basic building blocks of the ILC Main Linac with beam. We are collaborating with all major SRF centers in the US: Cornell, Jlab, LANL, ANL, as well as DESY, INFN and KEK abroad to achieve our objectives.

The strategic approach we are taking is to involve US industry in the cavity fabrication and to use the existing infrastructure at the collaborating institutes in processing and vertical testing of the cavities to reliably establish ILC level gradients and Qs. We propose to begin the development of infrastructure at Fermilab and ANL for High Pressure Water Rinse (HPR), Buffer Chemical Processing (BCP) and Electro Polishing (EP) as these will be needed to perfect the cavity processing technology. We are establishing the capability to assemble these cavities into a clean cavity string and tooling to install the cavity strings in cryomodules. Our ultimate goal is to develop a practical end-to-end ILC cryomodule design and assembly process suitable for ILC production. We will also address the important topic of cost reduction of the Main Linac components.

WBS 2.7.3: Main Linac Accelerator Physics

Motivation: Fermilab Main Linac Accelerator Physics work is focused on the lattice design, the specification of alignment tolerances of the components, instrumentation development, and the study of the preservation of low emittance beam in the ILC.

Description: There are many main linac design and engineering issues that require accelerator physicists and engineering staff to work closely together. The Fermilab staff is ideally suited for such work. There are main linac lattice issues regarding the placement of the quadrupole and BPM in the cryomodule, Wakefield, higher order modes, and their effects on the beam quality that all need to be studied. The transport of a low emittance beam from the exit of the damping ring to the IP will be one of the challenges for achieving the design luminosity of the linear collider. Fermilab, in collaboration with SLAC, Cornell, and DESY, is developing tools to study the preservation of emittance in the main linac.

Milestones and deliverables: In collaboration with other US and international laboratories, under the co-ordination of the GDE, Fermilab will finalize the ILC Main Linac Lattice by March 06. We will finish the detailed Low Emittance Transport calculations for this lattice, including the specifications for the alignment, resolution by June 06. We are also using several accelerator modeling codes for Main Linac Studies. These studies will evolve during rest of FY06.

Collaboration with other institutions: Within the Americas region, Fermilab is collaborating with SLAC and Cornell on these Main Linac design calculations.

Key Personnel: Nikolay Solyak, Sergei Nagaitsev, Kirti Ranjan, Paul Lebrun, Mike Church, Francois Ostiguy

Manpower and Cost Summary: The M&S cost covers computer and software licenses.

FTE-years	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
3.0	345	75	117	537

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will increase to 5-10 FTE as more accelerator physicists and engineers get involved with the design, engineering and cost reduction.

WBS 3.9.2: Cavity Fabrication:

Motivation: The US has very limited industrial capability for the fabrication of ILC-like SRF cavities. This R&D effort is meant to assist in the development of a US capabilities. Our program includes fabrication with both the normal (fine grained) Niobium and Single Crystal/Large Grain Niobium. Fermilab, in collaboration with Jlab and Cornell, will work with US vendors to develop their capabilities for the fabrication of 1.3 GHz standard ILC cavities.

Description: In FY05, we initiated fabrication of 1.3 GHz cavities. We are using the TESLA Technology Collaboration (TTC) cavity design. The TTC drawings have been converted for manufacture by US vendors. The design has been modified to take into account improvements discussed at Snowmass.

Fermilab ordered 4 cavities from Advanced Energy Systems (AES), Long Island, NY. This order is phase-funded using FY05 and FY06 M&S funds. The TTC drawings have been transferred to AES. In FY05 Fermilab purchased sufficient niobium material for the construction of a total of twelve 9-cell cavities. The sheets for forming half cells for the fabrication of first 4 cavities at AES have been eddy-current scanned.

In collaboration with Fermilab, Jlab is developing tooling and infrastructure to fabricate standard ILC 9-Cell cavities. Fermilab will collaborate and take part in this fabrication program to the greatest extent possible. The goals of this MOU with Jlab are, 1) Fabricate tooling, and use it to develop 2 single and/or large grain 9-cell standard ILC cavities. 2) Provide Jlab with the means to carry out technology transfer of expertise to industry under the stewardship and guidance of this collaboration, 2) Develop the required tooling for production of ILC 9-cell cavities.

We are working with another US vendor, Roark of Indianapolis, Indiana, in developing these 1.3 GHz cavities. The company has several electron beam welding machines and is interested in developing niobium welding expertise.

Milestones and deliverables:

1) 8 Standard 1.3 GHz 9 Cell cavities by the end of FY06. 4 Cavities have been ordered from AES. They are expected by Jan 07. We will order 4-6 additional cavities using an open bid process in FY06 from industry.

2) One set of tooling for the 1.3 GHz cavities at Jlab by Feb 06. This work is being done as a part of Fermilab-Jlab MOU Addendum-II.

3) The production of two single/large grain 9 Cell Standard 1.3 GHz ILC Cavities (June 06). (Fermilab-Jlab MOU Addendum-II)

4) Procurement of Nb, including large grain and single crystal for the fabrication of cavities.

Collaboration with other institutions: Fermilab is collaborating with DESY and Jlab on cavity fabrication.

Key Personnel: Mike Foley, Scott Reeves, Albert Beutler, Helen Edwards, W. Muranya, B Smith.

Manpower and Cost Summary:

Expense Description	**FTE-years**	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
AES cavities (4)			250	40	290
Additional industrial cavities (4-6)			470	75	545
Jlab (2 Large Grain)			200	32	232
Purchase niobium for 12-15 cavities			480	77	557
Fermilab	2.0	230		70	300
Totals:	**2.0**	**230**	**1370**	**289**	**1924**

Expectations for FY07 and beyond: This works is expected to continue in FY07 and beyond. We expect this activity will increase by a few (3-4) FTE as more engineers get involved with the design, engineering and cost reduction. We expect to fabricate twice the number of cavities in FY07 and hence the M&S should double.

WBS 3.9.3: Cavity Processing

Motivation: Upgrade and develop infrastructure in the US for BCP and EP of cavities to reliably achieve 25 MV/m and 35 MV/m respectively.

Description: At present, the US does not have an operational BCP and EP facility to process the 1.3 GHz 9-Cell ILC Cavities. Fermilab, in collaboration with Cornell, Jlab and ANL will upgrade existing processing facilities and develop new facilities. This work is being done under Fermilab-Cornell MOU Addendum-I and Fermilab-Jlab MOU Addendum-III and Fermilab-ANL MOU Addendum-I.

We are in the process of establishing MOUs with Cornell and Jlab for processing and vertical testing of the cavities that were ordered in FY05 from ACCEL and AES. AES and Fermilab collaborators will work with Cornell in learning the BCP and vertical testing process. The contract is also being set up to transfer the technology to AES. As full participants, Fermilab personnel will undergo intensive training in all procedures. The goal is to develop the BCP procedure to reliably achieve cavity accelerating gradients of 25 MV/m.

Jlab will develop tooling for the EP and vertical testing of the 9-cell ILC cavities. We will also use the Jlab EP facility to develop the EP parameters to reliably achieve cavity accelerating gradients of 35 MV/m. Fermilab collaborators will work with Jlab to learn the EP and vertical testing process.

In parallel with the BCP and EP efforts at Cornell and Jlab, Fermilab will develop BCP and EP processing facilities at ANL. The plan is to build a new Elector polishing facility with the latest and best technology located near Fermilab at ANL. It would leverage the infrastructure from the joint ANL/FNAL BCP facility described below.

A new BCP system (for 3.9 and 1.3 GHz cavities) was built at Fermilab and is being installed in a new facility to ANL. Initial operations will be for processing 3.9 GHz cavities while we build the necessary tooling and fixtures needed for BCP of 1.3 GHz cavities. This is a joint facility, half of which supports ILC and/or Proton Driver cavity processing, while the remaining half supports the ANL RIA program. Cavity BCP processing and ultra pure water rinsing are planned to take place at the joint FNAL/ANL facility. The facility is expected to be fully operational in January 2006 after the safety and operational readiness review at ANL is successfully completed.

Fermilab has initiated a collaboration discussion with the ILC collaboration (KEK, DESY, Jlab, ANL, and LANL) for jointly developing an ILC EP system to be located at the Fermilab/ANL facility. We plan to specify, design and start construction of an EP system in FY06 with a goal of operation in early FY07. Discussions of an ILC EP design study were begun at the SMTF collaboration meeting at Fermilab and are expected to continue at the TTC meeting in Frascasti in Dec of 2005. The design specification for the system is expected to be completed at this meeting. A design study will be carried out by this collaboration with the goal of finishing the design by mid FY06.

Milestones and Deliverables:

1) Develop BCP Processing parameters to reliably achieve cavity accelerating gradients of 25 MV/m (best effort). Four cavities will be processed and vertically tested at Cornell by June 2006.
2) Develop EP Processing parameters to reliably achieve cavity accelerating gradients of 35 MV/m (best effort). Between 4 and 10 cavities could be EP processed and vertically tested at Jlab by the end of FY06.
3) Design of a state-of-the-art EP system by May 2006.
4) Procurement and installation of the EP system at the joint FNAL/ANL Facility, with the goal of operation in FY07 (depending on funding).

Collaboration with other institutions: The processing infrastructure, parameters and design are being developed in collaboration with DESY, KEK, Jlab, ANL and LANL. There are several bilateral Mouse for the BCP and EP processing and testing work.

Key Personnel: Alan Rowe (BCP), Cristian Boffo (EP), Charlie Cooper (EP), Tsuyoshi Tajima (Fermilab Guest Scientist from LANL), Antoine Claire (Fermilab Guest Scientist from Saclay), Wade Muranyi, Michael Heinz, Michael Rauchmiller

Manpower and Cost Summary:

Expense Description	**FTE-years**	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
BCP @ Cornell (MOU)			165	26	191
EP @ Jlab (MOU)	1.0	115	400	99	614
BCP Facility @ANL	1.0	115	165	61	341
EP System Design Study	1.9	219	250	106	575
EP System Procurement and installation at ANL Facility	0.1	12	400	68	479
Grand Totals	**4.0**	**461**	**1380**	**360**	**2201**

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect the BCP activity to transform from construction and commissioning to operation. We expect the EP activities to continue in construction, commissioning and R&D phase in later part of FY07. The SWF part should remain similar but we anticipate the M&S to decrease.

WBS 5.9.1 and 5.9.2: Cavity Test Stands: Horizontal and Vertical Test Stands

Motivation: A Horizontal Test Stand is needed to perform High Power tests of the dressed ILC cavities. A Vertical Test Stand is needed to perform CW RF tests of bare ILC cavities after processing and before He vessels are added.

Description: A horizontal test cryostat has been designed for the ILCTA-MDB (FNAL Meson Detector Building). The cryostat will be connected to the existing cryogenic system at MDB via a standard A0-type "feedbox". The system will be capable of testing single "dressed" (in helium vessel, with tuner, couplers, etc.) cavities, either 1.3 GHz or 3.9 GHz, at 2 K. The system initially will include a 300 KW klystron, 600 KW modulator, and LLRF to provide pulsed RF power to the cavity. Costs associated with this RF system are covered in the RF Power sections of this MOU. The Horizontal cryostat design is similar to the Chechia system at DESY but differs in being stainless steel with access at both ends. It also differs in other details.

The horizontal cryostat consists of a vacuum vessel which houses an 80K thermal shield, a 5K thermal shield, and a mechanical support system holding the helium vessel. The cryostat has a port for the vacuum line that pumps on the RF cavity. Another port allows installation of the input coupler. A vacuum relief valve sits on top of the cryostat. Six 4-inch diameter ports are available for electrical feedthrus. The cryostat rests on two cradles which sit on the floor or on a support structure for further elevation. The cryogenic distribution and control system are being fabricated for the Horizontal Test Stand at MDB.

The design of a second horizontal test cryostat for ILCTA-IB1 will start after the commissioning of the 1st. This cryostat will incorporate design improvements based upon the experience with ILCTA-MDB cryostat. It will be designed to accept and test two 1.3 GHz cavities simultaneously.

CW RF testing of bare cavities after fabrication and processing is required to check cavity performance before the cavity is incorporated into a He Vessel and cryomodule. Fermilab will initially use the vertical test capabilities of Jlab and Cornell. However, to insure rapid turnaround between processing a cavity and determining its performance Fermilab will build an on-site vertical test stand. Fermilab designed and built two such dewar systems for the TESLA collaboration a number of years ago. Small modifications were made to the Fermilab built vertical test stands at DESY. We plan to get the design change information from DESY and build a vertical test dewar system to be installed at IB1. The IB1 cryogenics system will require some modification. We will need RF power and controls installed at IB1. IB1 is ideal for this facility since it already contains a refrigerator and pumping system that can deliver 60 W at 1.8 K. The cryogenic distribution and control system will be fabricated for the Vertical Test Stand after the conclusion of the LHC magnet testing program at IB1. In addition to the cryostat, and components required for its connection to the IB1 cryogenic system, the pit in which the cryostat will be suspended, and an enclosure/cover that functions as a radiation shield will also be constructed and installed in IB1. Details of the design requirements for this new test facility are still being defined; however, the plan is to use existing drawings for the TTF cryostat and for the magnet pit as a starting point for these two designs, and to incorporate any additional specific requirements for the SRF Test Facility.

The Vertical Test System will also take advance existing infrastructures such as controls system, control room, trained refrigerator operating crew, measurement and data base infrastructure, etc. The existing cryogenics system will require some small modifications to make the connections to new Vertical Dewar location. RF power, LLRF, and additional controls for the modulator and klystron will need to be installed at IB1 for this facility.

Milestones and deliverables:

Schedule Goals for the Horizontal Test Stand: Finish Design by Nov 05. Finish procurement by April 06. The commissioning of the Horizontal Test Stand should end by May 06.

Schedule Goals for the Vertical Test Stand: Finish new drawing Feb 06. A contract has been given to FESS to get a vertical cavity pit built by Feb. 06. The procurement of the test stand part is expected to start by March 06. The modification to the IB1 cryogenics and commissioning of the Vertical Test Stand is expected to finish by Sept 06.

Key Personnel: Andy Hocker, Tom Peterson, Mayling Wong, Clark Reid, Oleg Prokofiev

Manpower and Cost Summary: Horizontal Test Stand

Expenditure Description	**FTE-years**	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
Design	1.0	115		35	150
Cryostat			120	19	139
Mechanical components			30	5	35
Cryogenic distribution system	.25	29	50	17	96
Commissioning and Operation	.5	57		17	74
Grand Total	1.75	201	200	93	494

Key Personnel: Camille Ginsburg, Cosmore Sylvester, Tom Peterson, Mayling Wong, Clark Reid, Oleg Prokofiev

Manpower and Cost Summary: Vertical Test Stand

Expenditure Description	**FTE-years**	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
Design	1.0	115		35	150
Pit Construction			90	14	104
Cryostat			130	21	151

Mechanical components			30	5	35
Cryogenic distribution system	.25	29	50	17	96
Commissioning and Operation	.5	57		17	74
Grand Total	1.75	201	300	109	610

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We propose to fabricate another vertical and horizontal test setup to keep up with the increased number of cavities. We expect similar level of effort in FY07 but with more M&S for larger Horizontal Cryostat.

WBS 5.8.3: RF Power

Motivation: RF Power (Modulator, Klystron, distribution system) systems are needed for the Horizontal, Vertical Test Stands and ILC Cryomodule.

Description: Two new large modulators are currently under construction at Fermilab. This work was started in FY05. These are designed specifically to power any of the following: the 10 MW 1.3 GHz multi-beam klystrons from Thales, CPI, or Toshiba; the 325 MHz JPARC/Toshiba klystron planned for the $\beta < 1$ linac, or the commercial 5 MW, 1.3 GHz klystrons. One Modulator is designed for the 1.5 msec ILC pulse. The other modulator is designed for 4.5 ms pulse width for the proton driver but can be reconfigured to support pulse widths of 1.5 msec for ILC and 3 msec for the Proton Driver. Fermilab has a spare 5 MWatt multibeam klystron that we plan to use at the start but we would like to order a new high power klystron as soon as funding permits.

The large modulators are being built by collaboration between SLAC and Fermilab with components acquired from industry. This new modulator and 5 MWatt Klystron pair will be used to power the 1st ILC Cryomodule when it becomes available in FY07.

In addition to these large modulators, several other smaller RF Systems are under fabrication or being rebuilt. The list of the modulators and klystrons under fabrication for the test stands are given below. They will be used to provide RF power for the Horizontal and Vertical test stands:

Cavity	Klystron nominal power	Klystron status	Modulator	Modulator status
Tesla cavity	Phillips YK 1240 300KW	Exists	600 kWatt "Small 1"	being rebuilt
Tesla cavity	Phillips YK 1240 300KW	exists, under rebuild	600 kWatt "Small 2"	under fab/parts procure

In addition to these modulators and klystrons, other klystron and RF ancillary equipment will also be needed. This ancillary equipment includes:

- Klystron auxiliaries (shielding, solenoid, solenoid power supply, filament supply, vacuum pump power supply, etc.)
- Waveguide, splitters, directional couplers, circulators, loads (This is the equipment that takes the RF power from the klystron to the input couplers of the cavity.)
- RF system controls-interlocks

Milestone and Deliverable: Finish fabrication of the 1st large Modulator by Dec 05, 2nd one by July 06. The RF Power (Modulator and Klystron) for Horizontal Test Stand May 06. At present we are evaluating the RF power for the Vertical Test Stand (VTS). We expect to provide RF power for the VTS by Sept 07.

Key Personnel: Sergei Nagaitsev, Chris Jensen, John Reid (Klystron), Howard Pfeffer (Modulator), Brad Claypool, Kevin Martin, Damon Boyd, Peter Prieto, Glenn Johnson Ralph Pasquinelli,

Manpower and Cost Summary: The M&S cost estimate includes cost of several small rebuilds of the modulators and klystrons.

Expenditure Description	**FTE-years**	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
Finish modulators/ refurbish Klystrons /distribution	1.0	115	250	75	440
RF for HTS	.25	29	100	25	154
RF for VTS	.25	29	100	25	154
Grand Total	2.5	288	450	160	748

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will increase as we will be developing capabilities to power up to four cryomodule by end of FY09. We need to purchase two 10 MWatt klystron and build another Modulator.

WBS 5.8.4: LLRF Controls

Motivation: Develop LLRF systems for the ILCTA test areas and work towards an ILC LLRF system.

Description: The Fermilab LLRF Group is designing a LLRF system for commissioning the Meson Test area using the Capture Cavity 2(CC2) at the ILCTA-MDB. This system will also be used for the Fermilab ILCTA-MDB Horizontal Test Stand. The design is based on the proven FPGA-based, single-cavity Simcon 2.1 LLRF system from DESY. This system has been successfully used in the past for the CHECHIA horizontal test facility. The fundamental components of this system were delivered by DESY to Fermilab in March 2005, and with help of DESY staff the Simcon 2.1 system has been used twice to operate the A0 Capture Cavity 1. Given this experience, this design approach should represent a relatively low risk in terms of a LLRF system deliverable for a single-cavity CC2 test.

However, much work remains to be done in terms of providing all the components that are needed for a stand-alone LLRF system, and to integrate these components with the DESY DOOCS control system to provide a complete LLRF solution for a single cavity test at Meson. Fermilab is developing the LLRF system in collaboration with DESY. A stand alone LLRF system consists of a Sparc CPU-56 running DOOCS and Matlab, a 8-Ch Timer Module (FNAL design), a 8-Ch, 10 MHz fast digitizer (DESY design), a 8-Ch Function Generator board (DESY design), a Simcon 2.1 FPGA board (DESY design + commercial FPGA board). Fermilab has designed and is building a Master oscillator for the LLRF. At present most of the LLRF work is in integration of these systems and developing LLRF expertise.

DESY is now working on the multiple-cavity Simcon 3.1 LLRF system, which is a higher performance system capable of controlling multiple cavities fed from a single Klystron. The first production Simcon 3.1 modules are expected to be available from DESY by Jan 06. Much of the work that we are doing with Simcon 2.1 will be transferable to Simcon 3.1. Fermilab will not require a multiple-cavity LLRF system for at least another year, when the first cryomodule becomes available for testing at the HPTF facility. We are also developing the LLRF system for Horizontal and Vertical Test Stands and developing system for future projects including 1.3 GHz Cryomodule. We are evaluating other technologies suitable for the LLRF system as well.

Milestone and Deliverable: Design and Fabrication of the LLRF system for the Horizontal Test Stand: May 06.

Collaboration with Other Institutions: This work is being done in collaboration with DESY, University of Pennsylvania.

Key Personnel: Ruben Carcagno, Margaret Votava, Brian Chase, Sharon Lackey, Dennis Nicklaus, Daniel Klepec

Manpower and Cost Summary:

Expenditure Description	**FTE-years**	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
LLRF controls	2.0	230	150	94	474

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will increase to 4 FTE as more accelerator physicists and engineers get involved with the ILC LLRF design, engineering and cost reduction. We plan to use components developed by industry. This will have an additional initial cost.

WBS 5.9.3: Cryogenics for Test Stands

Motivation: Develop cryogenic capability to cool a Horizontal Test Stand and a Vertical Test Stand, as well as the capability to cool one Cryomodule to 2 deg K**.**

Description: The Cryogenic Test Facility (CTF) refrigerator system at the Meson building at Fermilab is being upgraded to supply the initial helium for the test facility at the Meson Detector Building (ILCTA-MDB). It is expected that this system will be capable of ~60 Watt at 2K after its upgrade.

The Fermilab Cryogenic Department started working in FY05 to develop the CTF facility for the initial operation of MBD test facility. These upgrades will enable us to test components at 4K helium temperatures. At present the cryogenic, RF power, controls etc are being commissioned.

In FY06 further upgrades are underway to achieve the goal to cool the Horizontal Test Stand in the Meson Hall. This upgrade will provide 60 Watt at 2K of cryogenic capability. The upgrade will require the installation of a vacuum pumping system, the construction of a large feed box and module feed and end cans, construction of the cryogenic transfer line and installation of associated cryogenic controls.

Milestone: Achieve 60 Watt capacity at 2K by May 06. Initially this capacity will be used for the Horizontal Test Stand. There is no plan to cool an ILC Cryomodule at this location. The IB1 cryogenic system will be modified by Sept 06 for the Vertical Test Stand.

Key Personnel: Jay Theilacker, Arkadiy Klebaner, Paul Lambertz, Roger Milholland, Alexander Martinez, Robert Hibbard, Greg Johnson, John Junean, Frank Rucinski

Manpower and Cost Summary:

Expenditure Description	**FTE-years**	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
Cryogenics for HTS	2.0	230	400	134	764

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will require increases in both SWF and M&S as we will need cryogenics at the New Muon Lab to cool an ILC Cryomodule. There will be additional costs associated with the operation of the cryogenic system.

WBS 3.9.4: ILC Cryomodule Design

Motivation: The present ILC Cryomodule design Type-III+ is from the TESLA Technology Collaboration. During the Snowmass ILC workshop it was concluded that a new ILC Cryomodule design should be developed. Fermilab in collaboration with DESY, INFN and KEK will carry out a design study for a new ILC Cryomodule (Type IV). This will be a several year process so the plan is to build a Type-III+ module while the Type IV design proceed to learn the various steps and exercise the new Fermilab Infrastructure.

Description: In FY05 we initiated the process of converting all the DESY and INFN TYPE III cryomodule drawings into the US system. We plan to participate in the planned fabrication and assembly of two TYPE III+ cryomodules in Europe to gain experience with the process. The ILC Cryomodule Group has been discussing the issues with the current cryomodule design (TTF Type III+) and the effort that will be required for the next generation cryomodule (Type IV) design. It is estimated that the Type-IV Cryomodule will require about twenty man-year of effort from design through testing.

In FY06 we propose to undertake the detailed specification and initial design studies towards the Type-IV Cryomodule. Main design changes that are being considered are quadrupole-steering-BPM package and its location, packing factor, change in tuner design, alignment and positional stability. The design study will also study the reliability, industrialization and cost reduction issues.

Milestones and Deliverables: Convert all the DESY/INFN Drawings by April 06. Conclude on the ILC Cryomodule design specification issues July 06, in collaboration with DESY, INFN and KEK. Start of the Cryomodule Type IV design Aug 06. This is expected to take 24 months at 10 FTE level and will run into FY07**.** We will address the design changes due to quadrupole centering and packing factor improvements by Sept 06.

Collaboration with other institutions: This work in being carried out in collaboration with INFN (Milan and Pisa), DESY, KEK and SLAC.

Key Personnel: Tom Peterson, Don Mitchell, Tom Nicol, Mike McGee, Salman Tariq, Contract Drafts Persons

Cost Summary for Type IV Cryomodule Design Effort:

FTE-years	Labor (K$)	M&S (K$)	Indirect cost (K$)	Total cost (K$)
3.0	345	100	121	566

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will increase considerably in FY07 (by 5-10 FTEs) as more accelerator physicists and engineers get involved with the design, engineering and cost reduction. We are planning to start construction of an ILC Cryomodule by the end of FY07.

WBS 3.10.6: Beam Delivery System-Collimators

Motivation: This study is to design a collimation system for the ILC near the IP to reduce background and beam dump.

Description: The Energy Deposition Group of Fermilab is collaborating with groups from SLAC, BNL and RHUL in the study of three related issues for the ILC:

- Energy deposition and collimation for design of the beam delivery system and the interaction regions,
- Backgrounds in the detectors and their mitigation,
- Treatment of the spent beams downstream of the interaction points.

During FY05 a MARS15 calculation model was generated including geometry, materials and magnetic fields over 2 kilometers of beam line, including the 1.5-km beam delivery system, the interaction point (IP) and experiments, and the 0.5-km region downstream of the IP for stopping the spent beams. This model is used to study beam impact on accelerator equipment and operation (quenching, cryogenic load, and radiation damage/activation), to the experiments, and to the environment. A preliminary specification for the collimation system was prepared. Initial estimates of experimental backgrounds were studied.

Studies are planned to include

- A refinement of the geometric, magnetic, and physics models.
- The first attempt to minimize backgrounds and radiation loads to the experiments and radiation loads to machine components.
- The first application of real engineering constraints to the design study and optimizations.

Milestones and deliverables: The scope of this work needs to evolve during the RDR process. We plan to finish the refinement of the geometric, magnetic, and physics models (March 06). The first attempt to minimize backgrounds and radiation loads to the experiments and radiation loads to machine components (July 06). The first application of real engineering constraints to the design study and optimizations (Sept 06).

Collaboration with other institutions: This work is being done in collaboration with SLAC, BNL and RHUL.

Key Personnel: Nikolai Mokhov, Aexandar Drozdin, Mikhail Kostin

Manpower and Cost Summary: The M&S cost provides for computer and software licenses.

FTE-years	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
1.0	115	50	43	208

Expectations for FY07 and beyond: This work is expected to continue in FY07 and beyond. We expect this activity will increase to 2 FTE as more accelerator physicists and engineers get involved with the design and engineering of the beam delivery system.

3. Proposed plans for FY07 and beyond

In this section we briefly describe the R&D program we propose to carry out in FY07. Most of these activities are continuation of the Fermilab ILC R&D activities started in FY06. In many areas we will be moving from the R&D phase towards an engineering and industrial involvement phase.

Accelerator Physics: ILC Main Linac Design, Damping Ring Design, Machine Detector Interface and Energy Deposition Studies.

The Main Linac Cavity and Cryomodule program will include fabrication of 20 cavities for processing (EP and BCP) development. We are proposing to finish construction of an Electro-polishing facility at ANL/FNAL Facility. We propose to continue to developing BCP and EP processing parameters using all the three US facilities (LEPP, Jlab, and ANL/FNAL). We propose to build first U.S. Cryomodule and finish the ILC Cryomodule (Type-IV) design. RF power (modulator, 10 MWatt Klystron, distribution and LLRF) will be developed to power two cryomodules. ILC R&D program at Fermilab will require a 300 W 2 deg K Helium Plant. We propose to place the order for this plant with split funding in FY07 and 08. The ILC electron source will be upgraded to have ILC beam quality.

The new work packages we propose to start are magnet for the Main Linac and the beam delivery system, Instrumentation, Controls and Feedback systems.

Budget for FY07: The Fermilab ILC R&D is proposing to grow to 85 FTE in FY07 with a budget of $15M. The proposed M&S budget for ILC R&D activities is $18M. It is proposed that the ILC R&D staff will increase by 10-20 per year beyond FY07. Fermilab will also work towards development of the US site for the Expression of Interest to Host the ILC in US. An additional budget allocation of $3.5M is proposed to support this activity.

It will be important to begin some level of industrial contact base for the ILC (beyond fabrication contracts) in FY07. This involvement would include industrial studies, and participation with laboratories in module processing, testing, and assembly are also desirable. This should lead up to Industrial participation in planning and prototyping of tooling, etc for pre-production industrial activities. Additional minimal funds of $5M are requested to indicate the importance of initiating the required ILC industrialization.

4. *Execution*

4.1 *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.

4.2 *Approval*

The following concur in the contents of this Addendum:

_________________________	_________________________
Gerry Dugan, GDE-Americas Regional Director	Robert Kephart, Fermilab, ILC Program Director
_________________________	_________________________
Date	Date