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, 2006 to September 30, 2007

1. Introduction

Fermilab will play a special role in the ILC. In the ILC era it will be the only remaining U.S. laboratory dedicated to High Energy Physics. It is also the designated host site for the ILC if it is hosted in the United States. Recently published EPP2010 report: Strongly endorsed the ILC and it recommended a "strong and vital Fermilab" program in HEP and also said "Fermilab must play a major role in advancing the priorities identified in this report". Fermilab Director Pier Oddone has stated that ILC is our # 1 long term priorities.

A main focus of the Fermilab ILC R&D is to lead and establish US technical capabilities in the Superconducting Radio Frequency (SCRF) Cavity and Cryomodule technology. The ILC-TRC second report outlined the critical R&D needed for the ILC. The main focus of ILC R&D efforts at Fermilab is to develop technology to reliably achieve 35 MV/m with a Q of ~0.5e10. In addition, we are working to develop the ILC cryomodule design, and fully test the basic building blocks of the ILC Main Linac with beam.

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 have begun the development of infrastructure at Fermilab and ANL for High Pressure Water Rinse (HPR), Buffer Chemical Processing (BCP), Electro Polishing (EP) and Vertical Testing System (VTS) as these will be needed to perfect the cavity processing technology. We are establishing the capability to assemble cavities into a clean cavity string and install cavities in cryomodules. Our ultimate goal is to develop a cryomodule design and assembly process suitable for ILC. Our extensive experience with large scale magnet cryomodule technology will play an important role in developing superior designs and lower costs.

The ILC-TRC report gave the highest ranking, R1, to the cavity gradient and performance, "The feasibility demonstration for the ILC requires that a cryomodule be assembled and tested at the design gradient of 35 MV/m in the presence of beam and for long periods. This test should prove that the quench rates and breakdowns, including couplers, are commensurate with the operating expectations. It should be shown that dark currents at the design gradient are manageable, which means several cavities should be assembled together in a cryomodule."

ILC-TRC ranked the testing of the several ILC Main Linac building blocks with beam as R2. The recommendation stated, "To finalize the design choices and evaluate the reliability issues it is important to fully test the basic building block of the linac. This means several cryomodules installed in their future machine environment, with all auxiliaries running, like pumps, controls etc. This test should as much as possible simulate the realistic machine operating conditions, with the proposed klystron, power distribution system and with beam. The cavities must be equipped with their final HOM couplers. The cavity relative alignment must be shown to be within requirements. The cryomodules must be run at or above their nominal field for long enough periods to realistically evaluate their quench and breakdown rates."

The cost of the main linac is about one-half the total ILC cost, of which a major fraction is the cryomodule cost. In order to best estimate the cost of the cryomodule we think it is essential to build one, then two RF units (consisting of 3 modules, a klystron, and a modulator) using industry supplied components processed and assembled using laboratory infrastructure. The first few cryomodules cannot be made solely in industry because they do not have the experience. However, the model we are pursuing is the construction of the cryomodule by "teaming" with industry. Our cryomodule plan begins with assembly of one type III+ TTF cryomodule assembled from a kit of parts supplied by DESY, the next cryomodule will also be type III+ but will use cavities processed and tested in the U.S. Subsequent cryomodules will be type IV, the first modules designed for use with ILC. The goal is then to fabricate and test a series of 35 MV/m cryomodules with industry to demonstrate that the technology is under control and to provide a basis for a credible cost estimate.

Fermilab ILC R&D Goals is to complete one ILC RF unit operating with beam by the end of FY09 and a second unit by 2010. This will answer the crucial R&D, design, cost etc. issues for ILC.

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, 2006 to September 30, 2007. 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.

The vast majority of the proposed FY07 R&D effort at FNAL is focused on crucial R1, R2 R&D issues (namely cavities & cryomodules). This will be a continuation of Fermilab's FY06 R&D. In FY06, FNAL engaged is in the ILC in a major way. The total Fermilab FY06 effort amount to ILC (funded via the GDE) is ~$12.0 M. SCRF infrastructure ~ $9.1 M, ILC detector ~$1.9 M, 3.9 GHz effort ~$3.9 M, with a total of $ 26.9 M. The support to build SCRF infrastructure, for 3.9 GHz, and for ILC detector R&D was from laboratory core funds. In FY06, the US-ILC-GDE funded about 30 FTE (~$4.5 M SWF) at FNAL which is only a small fraction of the effort in progress at Fermilab. The overall effort has grown to over 120 FTE in FY06.

In order to make a better estimate and plan for FY07, Fermilab ILC management met with all the ILC task leaders at Fermilab to carry "bottoms up" planning. The request from task leaders resulted in FY07 requests for > 230 FTE to carryout the program outlined by the ILC Management at Fermilab. This was reduced to 186 FTE by limiting personnel to existing staff or approved openings, focus on highest priority work. 186 FTE represents 8% of the FNAL staff. In our planning we also cut back the "bottoms up" M&S request. For example we will not purchase of an EB welder and defer it to FY08. We will not start of a big refrigerator for ILCTA_NM and work with adding satellite refrigerators to the system. We are working towards a fully resource loaded schedule for the FNAL ILC work.

Work at FNAL for the period covered by this Addendum will primarily involve the R&D directed at the ILC Main Linac to address R1 and R2 issues as defined by TRC and high priority R&D issues as defined by ILC-GDE R&D board. The main thrust of the Fermilab ILC R&D is to establish US technical capabilities in the Superconducting Radio Frequency Cavity and Cryomodule technology. Fermilab will continue to work on the development of RDR. We expect this work will continue through the significant part of FY07 and will redirect towards the development of the ILC Technical Design Report. We expect the TDR will continue to be of more global in the details of the hardware but could have more site specific layout of the accelerator components. The main technical goals of the ILC R&D at Fermilab described in detail in this MOU are

1. Main Linac:
    a. Main Linac Accelerator Physics and Design. We are working with SLAC, DESY, CERN and KEK in the Linac performance simulation including linac emittance preservation, full simulation with static and dynamic errors, Study emittance preservation and tuning issues for RTML to BDS (start to end simulation) etc.

b. Superconducting Cavity Material, Fabrication, Preparation, Processing (HPR, BCP, EP and Bake) and Testing (Vertical and Horizontal) development. The goal is to routinely achieve $\geq$ 35 MV/m and Q ~0.5-1e10 for the ILC design cavity.

c. Develop infrastructure to test individual cavity in vertical test stand, dressed cavity in Horizontal test stand and Cryomodule with 8 cavities.

d. Type-III+ Cryomodule assembly to understand and improve the design of ILC Cryomodule. Fermilab plans to assemble two Type-III+ cryomodule in FY07. 1st cryomodule will be assembled with a kit provided by DESY/INFN and 2nd with the components purchased from US (may be international) industries. We may invite US industry to participate in the assembly to help us with value engineer the Type-IV ILC cryomodule. These cryomodule will be used in ILCTA as described in f.

e. ILC Cryomodule (Type-IV) design and initial procurement of long lead item parts.

f. Develop infrastructure to fully test the basic building blocks of the Main Linac with ILC quality beam at ILCTA. (Superconducting components lead by Fermilab and RF Power lead by SLAC). This will answer the crucial R2 issue.

2. Instrumentation R&D for ILC and fabrication for ILCTA

3. Controls R&D for ILC and ILCTA

4. Development of the ILC Reference Design Report

5. Development of the ILC Technical Design Report

6. Accelerator design: Damping Ring, Beam delivery system

7. Development of an ILC site near Fermilab

This detailed description includes a summary of the manpower and costs assigned to each task. Funds at the level of $XXM for ILC R&D will be established at FNAL in FY07 by transfer from the DOE as recommended by the GDE-Americas Regional Director.

The GDE ILC R&D focus is to develop ILC design and technology as a global project. GDE by design is not expected to focus on the regional interest to host ILC and hence the development of regional technical strength and site specific design to host the ILC. Fermilab in collaboration with US institutions plans to carry the following tasks with a focus on making US and Fermilab to become a viable host for the ILC.

U. S. bid to host ILC at Fermilab

a. Fermilab site specific design of the ILC

b. Industrialization of ILC components in US

c. Development of the ILC test facility (5 GeV Linac)

d. Strength US technical capability in all major technical areas of ILC

We expect that there will be a considerable overlap between the GDE directed ILC R&D and US bid to host ILC at Fermilab.

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 Scope of Work

The Fermilab ILC R&D Program is subdivided in the following general categories and sub-categories. A detailed WBS structure has been developed to track the ILC program, resources (both SWF and M&S) and milestones. The initial WBS has been redefined by the program managers and will continue to evolve as the program develops further in FY07. All the WBS codes defined in this section are not covered in the Definition of Work section of this MOU. They are defined here for future projects.

1. Project Management

2. Development of RDR and TDR

   2.1 Accelerator Physics and Engineering Design

2.2 Magnet for RDR

2.3 Cryogenic System Design

2.4 Industrial Cost Study for RDR and TDR

3. Conventional Facility and Site Development

3.1 US Site Development

3.2 ILC Public Relation

4. Damping Ring

4.1 Damping Ring Accelerator Physics

5. Main Linac

5.1 Main Linac Accelerator Physics

5.2 Alignment and Vibration Studies

5.3 ILC Cavity R&D

5.3.1 Cavity Fabrication (Fine Grain, Single and Large Crystal Niobium ILC Cavity)

5.3.2 Cavity EM Simulation

5.3.3 SRF Cavity Cost Reduction

5.3.4 SCRF Material Research

5.4 Cavity Processing (BCP and EP)

5.4.1 Buffer Chemical Processing (BCP)
a) BCP and Vertical Testing at Cornell
b) Development and commissioning of BCP at Argonne National Laboratory (ANL)/FNAL

5.4.2 Electro-Polishing (EP)
a) EP and Vertical Testing at Thomas Jefferson National Accelerator Facility (Jlab)

9.3 Conventional Facility

9.4 Public Outreach

9.5 Industrial development of ILC components

2.2 Definition of Work

2.2.1 Project Management (WBS 1.2)

Motivation: The ILC program management is directing the technical program for ILC. 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. The Particle Physics Division is mainly responsible for ILC Physics and Detector.

Description: The Fermilab ILC program office was reorganized in FY06**.** The ILC R&D effort is now managed from the Fermilab Directorate. The ILC program at Fermilab is pooling resources from divisions and sections of Fermilab to help carryout ILC R&D and support the US Bid to Host ILC at Fermilab. The ILC Program Director's office will be the point of contact for the GDE, collaborations (TTC, SMTF, SFT, ATF-II etc.) and institutions collaborating with Fermilab on the ILC.

Collaboration with other Collaborations, Institutions and Countries: 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. These collaborating institutes are members of the US based Super-conducting Module Test Facility (SMTF) collaboration. At present Fermilab is has or 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. Fermilab is also member of the TESLA Technology Collaboration (TTC) and works closely with Super-Conducting Test Facility (STF) at KEK. Fermilab is also taking a lead in developing international collaboration with countries like India and China.

Fermilab ILC management office is in process of setting up to track the program, schedule, expenditure and progress in the R&D program. We will use this for reporting to American Region Team. We have task leaders of every WBS code in place that is helping in planning.

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 and Sergei Nagaitsev 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. Harry Carter and Jerry Leibfritz are the ILC Project engineers in Technical and Accelerator divisions respectively. Robert Kephart, Shekhar Mishra, Peter Garbincius and Vic Kuchler are members of the GDE. The administrative staff, computer administrator and webmaster will help run the program office.

Manpower and Cost Summary:

FTE-years	Labor (K$)	M&S (K$)	Indirect costs (K$)	Total cost (K$)
6.0	753	601	325	1679

The M&S estimate includes the general operation of the ILC Program office at Fermilab and travel. Some of the travel of groups like LLRF, Instrumentation and controls are explicitly included in this, where are travels related to RDR and Conventional Facility is in those WBS codes. Some of the ILC travel is also included in several other work packages.

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond at this level.

2.2.2 Development of Reference and Technical Design Report (WBS 2.1.2)

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. This work will transform into development of a ILC Technical Design Report (TDR).

Accelerator Physics and Engineering Design

Description: Fermilab scientific and engineering staff will work with the ILC GDE for the next 12 months in development of the Reference Design Report and subsequently on TDR.

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 finalized the Baseline Configuration Document (BCD) in Dec. 2005 at the Frascati Meeting. The ILC baseline configuration is now under Configuration Control Board (CCB) and we are using it to develop the ILC Reference Design Report (RDR) by the end of 2006. The RDR activity is supported by Area System, Technical and Global Groups, R&D, Cost and Schedule and Change Control Boards. Fermilab has key roles in many of these groups and boards.

The Reference Design Report will be the key document defining the scope of the ILC project, the R&D program, and the project cost and schedule. 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. This work will expand into development of an ILC Technical Design Report (TDR). The TDR is envisioned to be an international document with sections on site specific accelerator layout and conventional facility. Similar to RDR Fermilab will actively participate toward development of TDR.

Fermilab scientific and engineering staff will work with the ILC GDE for the next 12 months in development of the Reference Design Report and subsequently on TDR. Fermilab's primary participation is in the Main Linac, Site and Conventional facility, Magnet and cost and schedule development. We also plan to play a secondary role in Damping Ring, Beam Delivery System, Controls, Instrumentation and feedback development. The concept of the ILC TDR will develop though FY07, Fermilab plans to fully participate in the TDR as the US Host site with ILC collaborating institution from US and international.

Magnet for RDR (WBS 4.3.1)

The scope of this work is to produce a Conceptual design and cost estimation of magnet systems in support of the RDR

The FY07 Goals are

a) Continue to provide conceptual design and cost estimation for magnets in support of the RDR

The 'first pass' conceptual design and overall cost estimate will be reviewed in the first quarter of FY07. Following this review, it is anticipated that further refinement of designs and cost estimates will continue. Revisions of the Area Systems lattice design as well as further details of magnet requirements will be required and new or revised conceptual designs and associated cost estimates will be developed. Optimization of the number of different magnet types, power supplies and cable lengths.

b) Work on detailed designs for magnets to better understand parameter space and physical dimensions

In certain areas, alternative magnet designs, whose study was precluded by the initial time frame and resources, will be explored. These areas may include magnets in the final focus region of the BDS, tradeoff between conventional and superconducting magnets in the e+ source, as well as studies of wiggler and undulator magnets. Studies of magnetic center stability in Main Linac superconducting quadrupoles, low and high gradient designs, including influence of correction coils on center stability; position of magnets in the main cryomodule or in separate cryostat.

Industrial Cost Study for RDR and TDR (WBS 4.10.1)

Motivation: The ILC RF Unit cost estimation using the input from US industries.

Description: In FY05, Fermilab initiated the formation of the Linear Collider Forum of Americas (LCFOA), a non-profit organization of industries from Americas. The LCFOA has held technical meetings at Fermilab and SLAC. There are several US companies who are interested in ILC. The RDR will have a cost estimate and we proposed to use the US industries in developing a US ILC cost estimate. Fermilab has made a proposal to US industries to carryout such cost estimation for 1, 25, 250 RF units. We will provide all the technical information including drawings and design specifications to allow for accurate cost estimate. We are also in process of developing a proposal for the Conventional Facilities cost study. This cost study could continue in FY07 to allow for more accurate estimate of cost with industrial construction input.

Fermilab in collaboration with SLAC and Jlab is also undertaking a US laboratories based ILC cost study. This is a parallel effort to the industrial cost study and will include the cost estimate of the required infrastructure. It is anticipated that ILC must build these infrastructures for the industries to use during the ILC component fabrication and testing. In FY07 we will refine these studies with simulated model for fabrication process and include what-if scenarios.

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 is expected to be completed by end of FY06. Although not fully defined the ILC TDR work is expected to start in CY07 with similar motivation with milestone to be defined by Fermilab and GDE.

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

Key Personnel: Shekhar Mishra, Robert Kephart, Peter Garbincius, Vic Kuchler, Sergei Nagaitsev, Tom Peterson, Harry Carter, Jerry Leibfritz, 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.

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond as development of ILC TDR. We expect that the Reference Design Report activities will slowly transform into the Technical Design Report work. Fermilab's activity in the area is expected to at least double.

2.2.3 Conventional Facilities and Americas region Site Development

2.2.3.1 US Site Development (WBS 2.11.2)

Motivation: Develop an Americas region sample ILC site near Fermilab in a comparative and cost effective way. Work with other regions in developing and comparing the 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:

Perform option studies in conjunction with Value Management: The designs for the shafts, tunnel, and halls for the RDR cost estimate provide a set of engineered solution for the criteria provided for the installation, operation and maintenance of the beamline components. Many elements of the Conventional Facilities, space configuration, electrical distribution, ventilation and cooling systems can normally be accomplished several ways. By employing established methods of Value Management to identify and compare alternate design solutions the goal is to establish design that provides the best overall value for the project.

Continue to develop drawings of machine and facility layouts: It is important to maintain a set of drawings that is consistent with the current criteria of the beamline equipment requirements for the System Areas. As various areas of the machine are defined in more detail, specific design solutions will be developed.

Refine & optimize cost estimate in conjunction with A&E firms: Major cost drivers and especially those that are associated with large cost risks will be refined by developing bottoms up estimates or expanding the data points used for the analogous estimate to provide a higher level of confidence for the overall estimate. This process normally requires a more detailed level of design for the element under consideration.

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$)**	**Total cost (K$)**
75	385	85	545

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond. We expect this activity will transform into the US Expression of Interest to host the ILC at Fermilab.

2.2.3.2 ILC Public Relation Publications (WBS 1.4)

The overall Scope of this activity is ILC communication. If the particle physics community succeeds in building the International Linear Collider, no matter where it is built, it will require succeeding at the greatest communication challenge our field has ever faced. As the primary particle physics laboratory in the United States, Fermilab will play a key role in that task. In the field of particle physics, most communication initiatives are based at the national laboratories, which have the budgets, the mission, the staff and the expertise for that purpose—in close collaboration with universities and funding agencies. In support of the ILC, the Fermilab Office of Public Affairs will undertake a number of major communication activities in FY2007.

This activity will strengthen ILC communication at local, state, and national level by producing print and electronic materials. Building on the success of “The Quantum Universe” and “Discovering the Quantum Universe,” the Fermilab Office of Public Affairs will produce both print and electronic materials of high quality to support the International Linear collider. They will be targeted at particular audiences and will respond to demonstrated needs.

ILC Communication will be carried out at many levels.

a. Envoy program: In partnership with the SLAC Office of Public Affairs and the LCSCA, the Fermilab Office of Public Affairs will take the lead in the organization and implementation of an **envoy program** that matches particle physicists, one to one, with policy makers and opinion leaders. The envoys will receive training, direction and Web-based support in order to carry out their mission of creating long-term relationships with key officials to support the ILC and US particle physics.

b. Media campaign (national and international): Through the use of available resources, including symmetry magazine, the Fermilab Web site, coordinated press releases, tours and briefings, the Fermilab Office of Public Affairs will work with the science press to communicate the nature and excitement of the ILC to a national and international audience.

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 will continue to develope ILC related

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$)**	**Total cost (K$)**
126	50	46	222

Expectations for FY08 and beyond: This work is expected to continue in FY08 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.

2.2.4 Damping Ring Accelerator Physics (WBS 2.5.2 and 7.3.2.1)

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

Description: Fermilab, in collaboration with ANL, Cornell, LBNL, and SLAC, will participate in the expanding the accelerator design and cost estimation studies for the baseline ILC damping ring. These studies will include a study of the acceptance, studies aimed at improvement of the lattice, specifications of the required higher order magnetic field quality, studies of alignment and correction schemes and instability calculations.

We will focus on self-consistent modelling 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. 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 Damping Ring modelling. We will then include CSR effects in the model and repeat a subset of these studies. We will also include realistic wiggler maps in our model and, in coordination with other such efforts. We will study the effect of non-linearity 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 modelling, including cloud generation and cloud effects on beam dynamics.

During FY07 we will perform acceptance studies of the baseline design employing multi-physics simulations. First, we will utilize the 3D self-consistent space-charge model developed in FY06 together with higher-order single-particle optics, to study dynamic aperture of the baseline design, including field errors and misalignment effects. The model will include CSR effects and realistic wiggler maps. We will then add impedance effects in the model (single-bunch) and repeat the studies. For the simulations we will use the 3D, parallel code Synergia, which will allow us to track millions of particles. In addition, we will develop an electron-cloud model of the machine using the 3D code QuickPIC (UCLA/USC; leveraging resources from our SciDAC supported collaboration). We will investigate the possibility to include the electron-cloud effects in the same model used for the studies described above. All the simulations will be performed on the Fermilab Computational Physics for Accelerators parallel cluster, on the 20 dual CPU nodes purchased in FY06 for ILC specific simulations, and 20 additional dual CPUs will be purchased in FY07 to accommodate the large scale simulations required for dynamic aperture studies. These additional nodes will fully utilize the remaining slots in the existing Myrinet parallel switch. In addition, we will support any site-specific design effort with studies of necessary baseline design variations, injection line design, etc.

We will utilize and further develop existing codes for these calculations. We would upgrade the Fermilab computing infrastructure to carryout these studies in a timely manner.

This group will also perform similar calculations for the Fermilab site specific ILC Damping Ring.

Collaboration with other institutions: Fermilab is collaborating with ANL, UIUC, Cornell, LBNL, and SLAC on these Damping Ring design calculations.

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

Manpower and Cost Summary: The M&S cost covers computer and software licenses. The FTE is equally divided in this WBS and WBS on Damping Ring Accelerator Physics under US Bid to Host (WBS 7.3.2.1). A total of 2.5 FTE is allocated to work on this WBS.

FTE-years	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
1.25	157	50	56	263

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.

2.2.5 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.

2.2.5.1 Main Linac Accelerator Physics (WBS 2.7.3 and 7.3.2)

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: Fermilab is actively involved in the ML accelerator physics studies and will continue with its efforts in FY07. Our goals for the FY07 are as follows:

Static tuning – We will continue with our present studies on the static misalignment issues in the ILC main linac. We will keep working on the design of the realistic main linac lattice, carry out the emittance dilution studies, continue with the understanding of steering algorithms in the presence of static misalignments, and participate in setting the tolerances on the various beam-line components. So far, we have been working on simulation codes LIAR and MERLIN to perform most of these simulations. However, we are also working on the development of a robust simulation code, CHEF, for the emittance preservation studies and will continue with it. We will also keep working on the wakefield calculations for different RF cavities.

Dynamic tuning – Once the alignment tolerances on the linac components is set (on the basis of static tuning studies), it is important to understand how well those tolerances can be maintained over time in the presence of components vibration and ground motion. We will carry out beam-based feedback (intra-train, train-by-train, interaction point etc.) studies, which would be essential to maintain the (a) gold orbit established by initial tuning and (b) desired luminosity in the presence of the vibrating components. Based on the various ground motion models, long term stability issues (time scale of hours to months) will also be studied.

Integrated (Start-to-end) simulation – We will carry out full Low-Emittance Transport (LET) studies from the damping ring exit to the interaction point with a particular emphasis on the tuning algorithms, alignment issues, tolerances on beam line elements, and operational concerns. This study is particularly important to understand the final luminosity performance.

MPS design – It is required to understand full specifications on the components, procedures, and algorithm logic required for MPS to assure that each bunch can be transported safely to beam dump without causing hazards (like hitting the non-dump components).

Dark current studies – Even small fraction of the dark current, produced by cavities and accelerated in a few cryomodules might causes problems like extra heating of the SC cavities, radiation and formation of the beam halo. Goal of studies is simulate beam trajectories and estimate the fraction of captured dack current and it's effect to the linac performances.

Beam instrumentation issues – We will continue with our efforts to further understanding and addressing the beam instrumentation concerns, for example, the number of diagnostic sections in linac, required BPM resolution to achieve the desired emittance budget etc.

Milestones and deliverables: In collaboration with other US and international laboratories, under the co-ordination of the GDE, Fermilab will continue to develop the ILC Main Linac Lattice. We will continue the detailed Low Emittance Transport calculations for this lattice, including the specifications for the alignment, resolution etc. We are also using several accelerator modeling codes for Main Linac Studies. We will do the comparison studies.

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. The FTE is equally divided in this WBS and WBS on Main Linac Accelerator Physics under US Bid to Host (WBS 7.3.2.2). A total of 8.2 FTE is allocated to work on this WBS.

FTE-years	**Labor (K$)**	**M&S (K$)**	**Indirect cost (K$)**	**Total cost (K$)**
4.10	515	95	171	781

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond.

2.2.5.2 Alignment and Vibration (WBS 2.7.4)

Motivation: Develop alignment procedure and study vibration of RF cavities at all frequencies.

Description: In FY06, Fermilab installed several vibration and ground motion sensors in the MINOS hall and Conco Western Mine in Aurora. The data is being recorded for systematic studies. We have also started a set of vibration studies on the Capture Cavity in the Meson Lab.

In FY07 we propose to continue monitoring of slow ground motion in MINOS hall and Conco Western mine North Aurora. We will develop model to understand sources of slow ground motion and use these in Main Linac Simulation. We need to develop tools to monitor fast motion of RF cavities. These studies will be used to determine the sources and causes of vibration and its possible solution. The alignment of the ILC cavities and Cryomodule is important for the preservation of Emittance. We will develop fiducialization process for RF cavities and quadrupole magnets and network for test areas in Meson lab and New Muon.

2.2.5.3 ILC Cavity R&D:

2.2.5.3.1 ILC Cavity Fabrication (WBS 3.9.2):

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.

In FY06, Four Type III+ (asymmetric end tubes) cavities were purchased from ACCEL and have been delivered. These cavities were built from fine grain niobium. AES is fabricating four Type III+ cavities using fine grain niobium supplied by Fermilab. These cavities are due for completion in the October-December time frame.

JLab is fabricating two Type III+ cavities using fine grain niobium to be supplied by Fermilab from current stock. JLab is also building two Type IV (symmetric end tubes) cavities using large grain niobium they had acquired previously. These two cavities will incorporate a modified HOM coupler design, if tests currently in progress yield positive results. Aside from supplying the cavities, an additional benefit is that the tooling, weld fixtures, and fabrication techniques developed by JLab will be shared with US industry.

A bid package using FY06 funds is in preparation for 8-10 Type IV cavities. Possibly half of these may be fabricated from large grain niobium, with the remainder constructed from fine grain material.

In FY07, Bid packages will be issued for fabrication of approximately twenty four Type IV cavities. The objectives here are to:

(1) Develop additional US vendors for cavity fabrication
(2) Build a large enough pool of cavities to allow establishment of a robust processing technology to reliably achieve accelerating gradients of 35 MV/m.

Approximately half of the above cavities will be formed from fine grain niobium, while the remainder will be large grain/single crystal niobium. The fine grain cavities will be processed using electro-polishing, while the large grain/single crystal cavities will be processed by BCP only.

The highest performing cavities from the entire FY06 and FY07 production effort will be installed in the first Type IV cryomodule to be built at Fermilab in FY08.

Milestones and deliverables:

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:

Expectations for FY08 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 FY08 and hence the M&S should double.

2.2.5.3.2 Cavity EM Simulation (WBS 3.9.2.1)

Motivation: Cavity HOM trapped modes and wakefield study

Description: The cavity design requires calculation of HOM and the wakefield it will generate. Fermilab has several commercial software codes (HFSS, Analyst, Omega3P) that we maintain to carryout these calculations.

The license of these codes will be continued in FY07. We propose to carry out simulation of HOM trapped modes for ILC Baseline and Alternate Design cavities and study the wake field effects in the ILC cavities.

2.2.5.3.3 SRF Cavity Cost Reduction R&D (WBS 3.9.2.2)

Hydro-forming of Weld-free Cavities: To reduce fabrication costs of the ILC elliptical superconducting accelerating structures, the development of weld-free cavities is proposed. Seamless niobium and copper clad niobium tubes will be produced using extrusion or dynamic flow forming techniques. The tubes will then be formed into the multi-cell shape using hydro-forming and swaging. Commercial bellows manufacturers in the US have been contacted, and have already demonstrated that the inexpensive industrial bellows forming techniques can be applied to elliptical niobium cavities. By utilizing these technologies, a single seamless niobium tube could be formed into a complete cavity in one or two steps.

Production of multi-cell 1.3 GHz cavities will be studied with industrial and DESY hydro-forming experts. The DESY experts have recently joined the staff at FNAL. The initial prototyping will be done using copper, followed by high RRR niobium. The weld-free niobium cavities will be chemically processed and tested to high accelerating gradients. By using the proposed techniques, it is estimated that the cost of ILC's elliptical accelerating structures could be reduced as much as 50 %.

High Purity TIG Welding of Niobium Cavities: Currently all welding of niobium components for SRF cavities is done using electron beam welding. Because of the high cost of electron beam welding, other joining methods are being pursued. The conventional method of tungsten inert gas (TIG) welding may be adaptable for this purpose. Non-critical niobium TIG welds have already been successfully incorporated into high gradient SRF cavity assemblies at Michigan State University. The construction of an ultra-high purity inert gas welding chamber to facilitate completion of these non-critical welds and to test the applicability of this technique for all welds is underway. This testing will be done by TIG welding niobium coupons of known, high RRR in varying levels of argon purity and then measuring the RRR of the resulting welds and surrounding material. Next single-cell cavities will be fabricated and tested to high accelerating gradient. This will confirm that no defects such as tungsten inclusions are left on the surface and that the high RRR is maintained.

FY2007 Resources for WBS 3.9.2.2

Description	FTE years	Labor K$	M&S K$	Indirect Cost	Total Cost
Hydro-forming	0.6	$ 60	$ 30	$ 30	$ 120
High Purity TIG Welding	0.4	$ 40	$ 20	$ 20	$ 80
Grand total	1	100	50	50	200

2.2.5.3.4 SCRF Material Research (WBS3.9.14)

The primary goals of the SRF materials effort at Fermilab is to develop an intellectual understanding that relates SCRF cavity performance to materials characteristics measurable in the lab with the goals of a) achieving reliable & predicable cavity performance,

b) achieving significant cost reduction for the ILC. The effort also aims at providing leadership within a US collaboration on SCRF materials R&D in support of the goals of the ILC GDE.

During FY06 we concentrated on developing material testing and characterization facilities at Fermilab and to strengthen university collaborations on SRF materials R&D. One of the recent achievements of this group was to fully characterize a niobium batch of 250 sheets, including Eddy current scans, RRR, chemical analysis, microscopy and mechanical & thermal analysis at Michigan State University. This analysis revealed insufficient re-crystallization, which caused problems in forming and depressed material properties (e.g. reduced thermal conductivity). The sheets are back at the manufacturer where they will be heat-treated, a step that was found to cure the problems.

The SRF university program, with Northwestern University (on niobium nano-chemical analysis with 3D atomic probe tomography), the Applied Superconductivity Center at the University of Wisconsin (on vortex penetration into SRF niobium) and Michigan State University (on thermal and mechanical characterization of niobium), has already produced significant results. Among them are first glimpses of the nano-chemistry of niobium at an unprecedented atomic scale, the experimental evidence of non-uniform property distributions in the superconductor and the hot spot model.

This entire effort, including characterizing material (eddy current scans of Nb) for cavity fabrication was supported in FY06 by FNAL core funds. We cannot do this in FY07. We furthermore have to expect that the activities will grow according to the increased production of cavities. The budget proposed for 07 therefore assumes that all FY06 activities continue and/or grow according to the increase in SRF cavity fabrication. In addition we will ramp up a program on cavity cost reduction with MSU, e.g. exploring the possibility to use TIG welding and hydro-forming.

Most of the budget request from the GDE will be to support the additional material characterization needed for a successful cavity fabrication for the SRF modules at Fermilab. This includes funds to run the SRF materials lab as well as to expand the SRF materials lab infrastructure. At least one new employee will join Fermilab to support this activity. While the GDE funds will allow consolidation or even growth in the already developed areas of activity, Fermilab will launch some new programs, mostly supported with laboratory funds. Among them is a single cell cavity program to develop and test alternate materials (e.g. large grain niobium) and fabrication technologies (e.g. hydro-forming). Only a modest amount, less than was spent in FY06, will be requested from the DOE to support the university programs. The reason is that there are efforts to support the fast growing university collaboration with supplemental funding from the DOE.

2.2.5.4 Cavity Processing (BCP and EP)

<u>2.2.5.4.1 Buffer Chemical Processing (WBS 3.9.3, 3.9.3.1 and 5.9.x)</u>

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

Description: Under 06 funding, Cornell SRF group at LEPP has upgraded its facilities for BCP (buffer chemical polishing) and HPR (high pressure rinsing) and vertical cavity testing for 9-cell ILC cavities. Cornell has received two 9-cell cavities from Fermilab. One of these has gone through all the procedures and the first RF test has been completed. The cavity was etched 60 microns. Together with the etching at ACCEL company during fabrication, the total etching was > 100 microns, as needed for good performance.

This is the first ILC cavity treated and tested in the US. During the RF test at 2 K, the low field Q was $> 10^{10}$. The maximum field achieved was Eacc = 17 MV/m, and Q was still near 10^{10}. At this field the cavity quenched. There was no field emisison, which speaks well for the HPR system and water quality. We plan to etch the cavity another 50 microns and re-test to confirm that the cavity has a defect problem. We also plan to test the second ACCEL cavity. Fermilab plans to sends more cavities to Cornell

As can be seen from the first result, BCP treatment and testing is important at this early stage to weed out any sub-standard cavities. This step is especially important for AES cavities, since AES is a new cavity supplier. BCP treatment has been used at Cornell successfully for many years, and the parameters are well known. Cornell routinely get Eacc between 20 - 30 MV/m with BCP on single cell cavities, without field emission.

In FY07 Cornell University will continue with a buffered chemical polish (BCP) processing and testing program on 1.3 GHz ILC style RF cavities that Fermilab purchased in FY06. The primary goal for the processing program at Cornell is to develop BCP processing parameters to achieve 25 MV/m accelerating gradient. Once the RF cavities achieve the required gradient, Fermilab will use them to populate the first ILC cryomodule assembled in the US. The secondary goal of this processing program at Cornell is to provide training for Fermilab employees in BCP processing, high pressure rinsing, and vertical testing operations.

At Fermilab, BCP processing on ILC cavities will begin following the commissioning of the joint ANL/FNAL Superconducting Cavity Surface Processing Facility (SCSPF) and the retrofit of BCP System for 1.3 GHz cavities. A substantial engineering effort is required to modify the existing BCP System to function with ILC cavities. Also, cavity transport, handling, and cleaning issues will be addressed. A good portion of this work will progress in FY06, however, the required manpower is not yet available due to Accelerator Division shutdown related activities.

ILC cavities will be processed in the SCSPF using the BCP System after the BCP System is approved by the ANL Physics Division. The effort toward achieving this approval is ongoing and will increase when required manpower is identified. The earliest estimated month in which ILC cavities will be processed using the BCP system is May 2007. Once the processing effort is underway, the estimated FTE-years and M&S required are 3.7 and $50k respectively for FY07.

Milestones and Deliverables:

1) Develop BCP Processing parameters to reliably achieve cavity accelerating gradients of 25 MV/m (best effort).

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

Key Personnel:

Manpower and Cost Summary:

Expectations for FY08 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.

2.2.5.4.2 Electro Polishing (WBS 3.9.3.2, 3.9.3.3 & 5.9.x)

The BCD surface treatment for ILC cavities is electro-polishing (EP). There are three EP set-ups available in the world. Two have been used successfully for ILC cavities to reach 35 MV/m, one at DESY and one at KEK. Fermilab, in collaboration with Cornell, Jlab, LANL and ANL will upgrade existing processing facilities and develop new facilities. The Jlab system is presently being modified to accommodate ILC 9-cell cavities. We are also developing an R&D EP facility at ANL/FNAL Facility. We propose to upgrade the vertical EP facility at Cornell to accommodate 1.3 GHz 9-Cell Cavities. This work is being done under Fermilab-Jlab MOU Addendum-III and Fermilab-ANL MOU Addendum-I and a new MOU under development for EP between Fermilab and Cornell.

The goals of these facilities are to define a procedure to routinely achieve 35 MV/m.

EP at Jlab: In FY06 Jlab developed tooling for the EP and vertical testing of the 9-cell ILC cavities. They are ready to process cavities purchased in FY05. We also plan to 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 FY07 we will continue to work with Jlab on EP. We propose to EP and vertical test 8-12 cavities using Jlab facility.

Vertical EP at Cornell (WBS 3.9.3.3):

In all three EP systems (DESY, KEK and Jlab) that ILC is using, the cavity is mounted in a (beam axis) horizontal orientation, the entire cavity is rotated for stirring, the electrode contact has to be maintained over a rotating cavity, and the acid volume continuously exchanged through an outside heat exchanger to control the acid temperature.

Cornell is developing a variant of the system based on electropolishing the cavity in a vertical orientation. The electrical contacts are fixed. Stirring is accomplished by a rotating paddle inside the cavity, and cooling is accomplished by water flow over the outer wall of the cavity. The vertical orientation set-up has elements of simplicity over the horizontal one and should result in cost savings, especially when multiple set ups are needed to electropolish a large number (> 5) of cavities per day.

Cornell has successfully used the vertical EP set up to etch single cell 1.3 GHz cavities. Gradients between 35 - 47 MV/m have been reached in several single cells. One 5-cell cavity has been electropolished and 100 um of material has been successfully removed uniformly. The RF test will be carried out soon.

We propose to develop the fixtures necessary to extend the EP to ILC 9-cell caviites, and carry out the procedure for 1 -2 cavities. Several iterations will be necessary to check on reproducibility of the process, the danger of hydrogen absorption, and the reproducibility of performance.

At present we are using a very large dewar (originally used for 200 MHz cavities) to carry out 9-cell tests. We plan to purchase a streamlined dewar which will result in a significant savings of liquid helium over one year. We would also like to purchase more CW RF power to reach high fields and allow for CW RF processing in case of field emission limitations.

<u>EP Facility Development at ANL/FNAL (WBS 3.9.3.3, 3.9.3.4 and 5.9.x):</u>

The goal for FY07 is to increase the contribution to the international collaborative effort in better understanding the EP process, develop local EP capability for ILC 9-cell cavities in collaboration with ANL and at the same time start the effort of designing a pre-industrial EP facility.

R&D is essential to investigate the fundamental aspects of the process and to support the facility design. As well known within the SRF community, electro-polished cavities do not consistently reach 35 MV/m. In order to systematically reach the goal gradient, the process shall be studied at all possible level to ultimately define the ideal operating parameters and the effect on performance due to out of optimal range operation. Thanks to the simple geometry, small tests on flat samples shall help in increasing the fundamental knowledge of EP. This activity shall concentrate on: sulfur formation, HF online measurement, optimal working parameters, alternative acid mix, study of the formation of the viscous layer and acid physical properties. Test performed on half-cells shall help in visualizing the hydrogen evolution and the electric field distribution within the acid leading to the design of a better cathode configuration and more efficient gas screening. Within the proposed 1-cell program at Fermilab we will develop procedures and technology to be transferred to the 9-cell setup present at J-Lab and at ANL. The one-cell program will drive the development of cheaper and reliable cavity processing procedures extending the understanding on polycrystalline, large gain and single grain cavities. The combination of electro-polishing with tumbling will play a strong role in this program. Fermilab is now setting up a 1-cell 3.9 GHz EP setup and a simple tumbler to start practicing with these technologies and we are prepared to scale-up this R&D program to 1.3 GHz in FY07. With the input of all the mentioned R&D programs, the 9-cell cavity tests performed at J-Lab will pursue the goal of systematically process cavities performing at 35 MV/m. We expect that the several bench-top R&D programs and the processing performed at J-Lab on 9-cells cavities will iteratively interact allowing reaching the performance goal and strengthening the international collaboration.

Within a wider program involving J-Lab and Saclay, a collaborative effort with University through the work of two students at Fermilab will focus on process simulation. Step by step simulation is an efficient way to support the experimental activities and an optimal context for university collaboration.

The facility work will focus on two activities. The ANL R&D facility construction, started in FY06, will be supported by providing the design and the installation of the control system, by implementing new solutions resulting form the R&D activity, by completing and upgrading the cavity support components designed and installed in FY06. In collaboration with industry we will start the specification and the design of an industrial EP tool that can meet the ILC production expectations.

1. Develop EP Processing parameters to reliably achieve cavity accelerating gradients of 35 MV/m (best effort).
2. Design of a state-of-the-art Pre-Production EP system.
3. Procurement and installation of an R&D EP system at the joint FNAL/ANL Facility, with the goal of operation by end of FY07.

<u>Expectationa Beyond FY07:</u> We expect the EP activities to continue in construction, commissioning and R&D phase in FY08. The SWF part should remain similar but we anticipate the M&S to increase for a Pre Production Facility.

2.2.5.5 <u>Cryomodule Assembly Facility (WBS 5.9.5)</u>

In FY06, Cryomodule Assembly Facility is being setup based on DESY TTF Hall 3 Cryomodule Assembly Area. Cavity String Assembly Clean Room was purchased, designed and constructed by an outside vendor. The clean room was successfully certified in April 2006. All the string assembly related fixtures drawings were transferred from DESY, the drawings were Americanized with optimizations and 75% of the fixtures were procured. We expect to install the fixtures in the clean room by June 2006.

The main use of the CAF in FY07 will be the assembly of the 1st ILC Cryomodule in US. DESY & INFN will provide a kit of a type III+ Cryomodule to Fermilab. The kit from DESY will have 8 individual dressed, horizontally tested cavities with an average 25MV/meter gradient. They will also provide all the peripheral components (gate valves, BPM, bellows, tuners, magnetic shielding etc.) and hardware (studs, nuts, washers etc.) necessary for cavity string assembly. We are not planning to have a quadrupole for the 1st Cryomodule.

The kit from INFN will have all the cold mass related components (300 mm diameter gas return pipe, cold mass support, all the cryogenic pipes, MLI etc.), vacuum vessel including cold mass support attachments and all the necessary assembly hardware.

We expect to use 2 main assembly building for CAF, CAF-MP9 will house the cavity string assembly clean room and cold mass assembly area (non clean room) adjacent to the clean room. We are planning to use Technical Division ICB building for partial cold mass assembly and vacuum vessel assembly of the cryomodules. CAF-ICB will be setup in FY07 once the LHC quadrupole assembly work is completed.

In summary, CAF-MP9 and CAF-ICB infrastructure will be capable to assemble 2 ILC cryomodules per month. DESY-INFN cryomodule kit will be used to shake down the infrastructure and planned work flow at CAF. We will also practice assembly procedures that we are currently learning at DESY by witnessing Cryomodule #6 at Hall 3 in May-June 2006.

The CAF facility will also be used to Cavity Dressing for high power Horizontal Testing. Fermilab for the 2nd ILC Cryomodule has purchased bare cavities from industry, chemically processed at FNAL and other collaborating laboratories/universities and vertical tested. The cavities will be dressed with helium vessel tank welding at CAF-MP9 TIG welding stations, and then they will be high pressure water rinsed at CAF-MP9 HPR infrastructure before they are transferred into the clean room. In the cavity string assembly clean room, cavities will be prepared for horizontal testing.

In FY07, HPR infrastructure needs to be designed and installed at CAF-MP9. A new larger capacity, more stringent (more sensors for QA) ultra pure water system needs to be procured and installed. In FY07, TIG welding stations needs to be procured and installed at CAF-MP9.

2.2.5.6 Cavity Test Stands:

2.2.5.6.1 <u>Horizontal Test Stands at ILCTA_MD and ILCTA_IB1 (WBS 5.9.1)</u>

Motivation: A Horizontal Test Stand is needed to perform High Power tests of the dressed ILC cavities.

Description: In FY06 we build and commissioned a single cavity Horizontal Test Stand (HTS). The HTS is one bottleneck in timely high power testing of the cavities. We are proposing to build another HTS with a capability to handle two 9-cell ILC cavities.

<u>ILCTA_MD:</u>

A horizontal test cryostat has been designed, constructed and commissioned in FY06 at the ILCTA-MD (FNAL Meson Detector Building). The cryostat will be connected to the existing cryogenic system at MDB via a standard A0-type “feedbox”. The system is capable of testing single “dressed” (in helium vessel, with tuner, couplers, etc.) cavities, either 1.3 GHz or 3.9 GHz, at 2 K.

For FY07 the ILCTA_MD horizontal test stand (HTS) will be in continuous operations mode. The HTS will test fully-dressed single cavities to qualify them for assembly into a cryomodule. The testing program will include high-power pulsed processing of the input coupler and cavity, and measurements of the cavity Q_0 versus the accelerating gradient, X-ray emission from the cavity, and the cavity dark current. We planned turnaround time for cavity installation in the cryostat, testing, and cavity removal is on the order of two weeks. Test data and the results of subsequent analysis will be stored for easy retrieval.

<u>ILCTA_IB1:</u>

A horizontal test facility similar to the ILCTA_MDB HTS will be constructed in the IB1 building, capitalizing on the existing 1.9 K refrigeration system and test infrastructure. A shielding-block cave will be constructed with a mezzanine on top for housing electronics racks. The cryostat for this facility will be based on the ILCTA_MDB HTS design, but will be lengthened to accommodate testing two cavities simultaneously. The idea behind this design is to not only increase overall cavity throughput, but also to provide the opportunity for R&D on driving multiple cavities with one RF system. The FY07 goal for this project is to have the facility completed and commissioned by the end of the fiscal year.

<u>Milestones and deliverables:</u>

<u>Key Personnel:</u> <u>Andy Hocker</u>, Tom Peterson, Mayling Wong, Clark Reid, Oleg Prokofiev

<u>Manpower and Cost Summary:</u>

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond. It will transform from construction to operation of these facilities.

2.2.5.6.2 <u>Vertical Test Stands at ILCTA_IB1 (WBS 5.9.2)</u>

Motivation: A Vertical Test Stand is needed to perform CW RF tests of bare ILC cavities after processing. The proposed facility at Fermilab will be used to test cavities and before He vessels are added.

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.

An in-ground vertical test cryostat facility (ILCTA_IB1_VTS), designed to test single bare 9-cell 1.3 GHz Tesla-style superconducting RF cavities at 2.0 K, will be built in the Industrial Building 1 (IB1) at Fermilab. This facility will become an integral part of the ILC “tight loop” cavity processing infrastructure in the United States, providing measurements of cavity Q vs. accelerating gradient and Q vs. temperature. The existing cryogenic infrastructure in IB1 can provide up to 125 W of cooling power at 2.0 K, and will be capable of supporting a low-power CW test program. The ILCTA_IB1_VTS facility will initially be expected to test approximately two cavities per month; however, this facility can significantly exceed this capacity, assuming a range of cavity performance similar to that measured at existing vertical test facilities.

A detailed schedule has been developed which brings this project from its start in FY06 through construction, component fabrication and assembly, and into operation in FY07.

The ILCTA_IB1_VTS is currently at an advanced design stage. The civil construction and in-ground radiation shielding designs are complete, and the construction project bid process underway. The civil construction is slated to be complete by the end of July 2006. The cryostat design will be completed within the next few weeks. The top plate design is in progress and will mature quickly once the cryostat goes out for procurement. The process and instrumentation diagram for the cryogenic system is complete, with instrumentation procurement to begin shortly.

By the end of FY06, ILCTA_IB1_VTS will be past the construction stage and into the component fabrication stage. The civil construction for this facility will be complete, and the cryostat and top plate assemblies nearly complete. The radiation shielding cover design will be complete, and the cryogenic system modifications started. The RF, LLRF, and controls system designs will also be in progress.

The ILCTA_IB1_VTS facility will be completed in FY07. Early in FY07, the cryostat and top plate will be installed into the prepared pit. This will be followed by the installation of the radiation shielding cover, and associated safety interlock system. The RF, LLRF, and controls systems will be complete and the installation started. The cryogenic system will begin commissioning by the end of December 2006. Shortly thereafter, the RF system will begin commissioning. The facility is expected to begin cavity testing in mid-FY07. The switchover to an operational phase is expected to extend through the end of FY07.

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.

2.2.5.7 <u>RF Power for ILCTA_MD, ILCTA_IB1 and ILCTA_NM (WBS 5.8.3)</u>

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 1^{st} 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

In FY07 we plan to complete the ILC Modulator for the ILCTA_NM. This modulator will be used to power the 1^{st} Type-III+ cryomodule in Fall of 07. We propose to build a new 10 MWatt modulator to power the FNPL RF gun. We need to develop an inventory of spare parts for a 10 MWatt modulator. To support the Horizontal Test Facility we will build two 200 KW (???) RF systems.

The ILC 10 MWatt Multi-beam Klystrons are being developed by three industries worldwide. We propose to place an order of one 10 MWatt MBK from a US Vendor. This klystron will be used to power the 1^{st} ILC rf unit.

<u>Milestone and Deliverable:</u> Finish fabrication of the 1^{st} large Modulator by end of FY06, 2^{nd} ILC Modulator one by early 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.

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond. We expect this activity will increase as we will be developing capabilities to power up to 2 RF Units by end of FY09. We need to purchase an additional 10 MWatt klystron and build another Modulator.

2.2.7.9 LLRF Controls R&D for ILC and ILCTA Test Areas (WBS 5.8.4)

Motivation: Develop LLRF systems for the FNAL ILC Test Areas

Description: For FY07 there are two FNAL ILC Test Areas that will require LLRF systems: ILCTA_NML and ILCTA_IB1_HTS. For the ILCTA_NML, the A0 photoinjector LLRF systems need to be upgraded. Three separate LLRF systems are required (one for the RF Gun, one for Capture Cavity 1, and one for Capture Cavity 2). In addition, later in FY07 the first ILC Cryomodule to be delivered to ILCTA_NML will require an 8-channel LLRF system. For the ILCTA_IB1_HTS, a LLRF system for a two-cavity Horizontal Test Facility is needed. The plan to provide LLRF systems for these test areas during FY07 is based on an improved Simcon 3.1 board developed under WBS 3.8.3. In addition, upgrades to the existing ILCTA_MDB test area LLRF system are expected based on the availability of improved LLRF hardware and software.

Milestone and Deliverable: ILCTA_NML: Three LLRF system for the A0 photoinjector delivered Q2FY07, one 8-channel LLRF system for the first ILC cryomodule delivered Q4FY07. ILCTA_IB1_HTS: one 2-channel LLRF system for a Horizontal Test Facility delivered Q4FY07. ILCTA_MDB: Upgrades to existing LLRF system.

Key Personnel: Ruben Carcagno, Brian Chase, Gustavo Cancelo, Margaret Votava

Manpower and Cost Summary

Description	FTE years	Labor K$	M&S K$	Indirect Cost	Total Cost
ILCTA_MDB					
Upgrades	0.5	58	30	22	110
ILCTA_NML					
LLRF Photoinjector	2	230	90	84	404
LLRF ILC Cryomodule	1	115	30	40	185
Tuner Controllers	1	115	50	43	208
RF Phase Ref. Line	0.5	58	30	22	110
ILCTA_IB1					
LLRF HTS	0.5	58	30	22	110
Tuner Controllers	0.5	58	5	18	81
RF Test Equipment			100	16	116
Grand total	6	690	365	268	1323

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond. The next major deliverable will be a LLRF system for the first ILC RF unit (3 cryomodules, 24 cavities). A prototype of a new generation LLRF board developed under WBS 3.8.3 is expected to be available for this RF unit.

2.2.5.9 ILC Instrumentation R&D and Instrumentation for ILC Test Areas (WBS 3.2.10 & 5.9.12)

ILC Collaboration Activities (WBS 3.2.10)

Fermilab's ILC instrumentation collaboration activities are focussed on the beam instrumentation of the Main Injector cryomodules. These are:

- Cold BPM's
- HOM coupler signals

Even though there are different ways to realize the Main Injector beam position and orbit measurement, there is a common agreement that a cold cavity BPM is worth to be studied in detail. These studies have to be based on the experience collected over last years on warm cavity BPMs at ATF and SLAC.

Therefore Fermilab plans to continue the recently started efforts, collaborating with SLAC and KEK on beam based cavity BPM measurements at ESA and ATF. Related to these beam based studies, we also might collaborate with CEA-Saclay in FY07 to investigate their coaxial cavity BPM design.

Studies at the DESY TTF show, that HOM signals can be used to characterize the SC cavities in several ways. A beam based modal analysis can identify mechanical imperfections of individual cavities. Signal processing and analysis of a well known dipole mode can be used for detailed alignment analysis of every cavity in the cryomodule with respect to the beam. Finally the HOM coupler signals also may be used as a high resolution BPM. Last may serve as a backup solution in case that a cold cavity BPM development does not meet the requirements. Hence, it could be replaced by a more simple, well known approach, giving only medium resolution (i.e. button or stripline BPMs), while using the HOM coupler signals a precision BPM instrument.

It is mandatory the Fermilab is involved in all beam instrumentation activities related to the ILC cryomodule. Therefore Fermilab plans to continue the participation on HOM coupler beam measurements in FY07 at the DESY TTF in collaboration with DESY, SLAC and CEA-Saclay.

Fermilab staff personal involved are (0.5 FTE total): J. Crisp, N. Eddy, P. Prieto, M. Wendt and D. Voy

2. Fermilab ILCTA Instrumentation (WBS 5.9.12)

Fermilab's ILCTA instrumentation, we distinguish the general non-beam instrumentation, basic beam instrumentation and advanced beam instrumentation. Plans on the FY07 activities are focused on the basic beam instrumentation, i.e. bunch charge and beam position measurements, while finishing up some non-beam instrumentation (RF interlock) and starting with advanced beam instrumentation (bunch phase monitoring).

Major FY07 activities:

a) Development, prototyping, testing and production of a cold cavity BPM pickup.

This monitor should be installed in the first ILC cryomodule, to be assembled at Fermilab beginning 2007. Prototyping and testing have to include:

- network analyzer measurements on a test-stand (to be build)
- acceptance tests at cryogenic temperatures
- testing the cleaning procedures

b) Development of a general purpose digitizer module in ATCA technology.

This development serves two functions:

- Digital DDC for all button BPM and toroid signals within the test facility.
- Practical implementation and test of a high availablility board, based on the proposed ATCA platform for the ILC.

c) The development of related analog interfaces as ATCA RTM is also planned for FY07.

Other FY07 activities:

- Completion of the RF-interlock for the klystron protection.
- RF downconverter for cavity BPM signals.
- Starting the design of bunch phase monitor electronics.

About half of the Fermilab Instrumentation Department staff (13 colleagues) will be involved in these activities. Some help will be required form other departments, summing to a total of 4.5 FTE's for FY07.

2.2.5.10 Controls for ILC and Controls for the ILCTA (WBS 4.7.2, 3.2.9 and 5.9.11)

FNAL FY07 Controls work is happening on 3 fronts: RDR, Global control system R&D, and support of ILCTA. Work in all areas leverages off the strong collaboration among ANL, FNAL, and SLAC (in the Americas).

Global Control System Design (4.7.2)

Starting from the BCD and RDR, perform a more detailed investigation and definition of the requirements of the Integrated Controls System, and interfaces with the technical systems. Begin work on those areas of the Integrated Control System which must be defined early in the technical design phase so as to provide appropriate information and guidance to the Technical System Groups. Early definition of these globally used resources will help avoid duplication of effort and ensure a smooth integration phase of the entire machine

Milestones:

- Complete first-cut WBS, cost estimate, Reference Design Report, and supporting documentation by November 2006
- Begin developing the Technical Design Report, completing requirements document for global controls system

Global Control System R&D (3.2.9)

The most pressing R&D areas for the controls system involve RF Phase distribution and the challenge of a highly available system.

There are several candidate approaches for active phase stabilization of the long distribution links, including: frequency-offset optical interferometry, phase shifting via thermal or mechanical fiber stretching, and an optical trombone. These must be evaluated, and a candidate selected for prototyping.

R&D will be needed to understanding hardware and software platforms that can meet the high availability requirements including ATCA evaluations and an analysis of how existing control systems would need to be developed to meet these needs.

Milestones:

- High stability RF phase Distribution modulator development for FY08 prototype
- Control System Framework: Identify and evaluate candidate systems (gap analysis)
- R&D on high availability hardware/software
- Collaboration tools and remote operations requirements and toolsets

ILCTA Control System Design, Implementation, and support (5.9.11)

The test stand projects at FNAL are in the advanced planning stage and our milestones and deliverables will be closely connected to that plan. The horizontal test stand will be in operational and need support at MDB, IB1 will install and commission the vertical cavity testing facility, and NML will be gearing up for cryomodule testing in FY08. This will include the move of the photoinjector from A0 in addition to the setup of conventional facilities.

Milestones:

- Support of operations at MDB, complete vertical cavity testing test stand, concentrate on NML design and implementation

2.2.5.11 Cryogenics for ILCTA_MD, ILCTA_NM and ILCTA_IB1 Test Areas (WBS 5.9.3 and 5.9.7)

Motivation: Develop cryogenic capability to cool a Horizontal Test Stand and a Vertical Test Stand, as well as the capability to cool one ILC RF unit at 2 deg K.

Description: The WBS element 5.9.3, *ILCTA MDB cryogenic system*, identifies all the tasks to complete the cryogenic system for Horizontal Test Cryostat in FY 07 as well as operational upgrades to the existing MDB cryogenic system. Specifically, it covers improvement to the existing refrigerator and vacuum pump controls, additional cryogenic instrumentation, support contracts, and spare parts.

The WBS element 5.9.7, *ILCTA NML cryo construction*, names all the tasks required to produce 4.5K liquid helium in the ILCTA NML refrigerator room using two Tevatron Satellite refrigerators and to deliver 2K helium at the photoinjector cave. The schedule is contingent on labor availability, CCM removal, cave design and construction, and photoinjector layout in time to design and build distribution transfer line and headers.

The *Compressor and vacuum pump installation* WBS element covers installation of a Kinney/Tuthill KLRC-2100/KMBD-10,000 vacuum pump skid and FRICK RXB39 purifier compressor with associated oil removal system.

The skid was originally designed and fabricated at Thomas Jefferson National Accelerator Facility in 1993 and will be refurbished and altered for helium service. The vacuum skid is composed of a booster pump, a liquid ring pump, an oil pump and numerous water/oil heat exchangers. A new variable frequency drive will be installed on the booster pump to improve electrical efficiency. New helium filled guards will be installed around pump dynamic seals to protect from potential air contamination in leaks.

The FRICK RXB39 purifier compressor needs modification to an existing water-cooling system and a new oil removal system. The new oil removal system will comprise of two coalescers, charcoal absorber and a molecular sieve.

The *Gas storage components* WBS element lists tasks necessary to connect existing gas helium tanks to the ILCTA NML cryogenic system. It includes piping materials, piping contract cost and associated services.

Installation of the second Tevtaron Satellite refrigerator, including valve box, dry and wet engines, u-tubes, valves and instrumentation is covered by the *Coldbox installation* WBS element.

The *Cryogenic storage and distribution system* WBS element identifies all tasks necessary to modify and install an existing liquid helium dewar that will be used for the second refrigerator, cryogenic transfer line from the refrigerator room to the photoinjector cave, bayonet boxes, expansion joints and cryogenic feed points for the photoinjector.

Cryogenic controls and spares, including industrial software and hardware support contracts for the second refrigerator, the photoinjector and the RF unit are covered under the Controls and spares WBS element.

Cryomodule interface equipment (end cans) WBS element covers procurement of Type III ILC cryomodule feed cap, end cap, feed box and associated cryogenic transferline and headers. The design for the feed and end cap used in TTF is the property of DeMaCo, Netherlands. Options include buying identical units from DeMaCo, buying the design from DeMaCo in order to make design modifications as required, or to design similar units in-house. Design and engineering shortages makes the last option least attractive in the short term. The feed box is the ILCTA NML cryogenic system specific component, which has to be engineered, designed and built from an existing concept. A significant modification of the TTF feed box will be required for operation in the NML with the cryogenic system to be used there. There is a high risk that a shortage of cryogenic component designers will affect current schedule.

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

Manpower and Cost Summary:

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond. We expect this activity will require same level of SWF and M&S as we will need additional cryogenics at the New Muon Lab to cool an ILC Cryomodule. There will be additional costs associated with the operation of the cryogenic system.

2.2.5.12 ILC Cryomodule

2.2.5.12.1 ILC Cryomodule Assembly (Type-III+) (WBS X.X.X)

2.2.5.12.2 ILC Cryomodule Design and Fabrication (Type-IV) (WBS 3.9.4 & 3.9.15)

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:

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond. We are planning to start construction of an ILC Cryomodule by the end of FY07.

2.2.5.13 RF Unit Test: ILCTA_NML Facility Infrastructure (WBS 5.9.6)

The ILCTA_NML will host the photo-injector and 1 ILC RF unit. Fermilab is working to improve the infrastructure at ILCTA_NML. The FY07 goals are:

1. Build cave for the test of the ILC RF unit with photo-injector.

   a. A detailed shielding study will provide the requirements for the shielding of the photo-injector and down stream ILC RF units. The shielding will consist of concrete shield blocks typically used at Fermilab for this purpose. In the event sufficient blocks of the size needed do not exist, new blocks can be procured.
   b. A modular room will have to be purchased, or a suitable room built, to provide the environment needed for the Laser used to generate electrons from the photocathode. This room will need excellent temperature stability, clean AC power distribution, and vibrational isolation.
   c. A control room suitable for machine operation will have to be furnished and outfitted.
   d. The photo-injector will need an upgraded modulator to provide the RF at a repetition rate specified by the project physicist.

2. Interlocks and electrical infrastructure.

   a. The accelerator will need personnel and machine protection systems. The personnel systems need to address both radiation and oxygen deficiency hazards. An interlock system for the machine will need to provide protection for normal occurrences like beam losses, module quenches or RF system sparks.
   b. The building being used to house this facility is being converted from a former fixed target experiment. The AC power and HVAC systems will need to be modified to support the new systems. The main AC power system was upgraded in '06 by the addition of a 1500KVA substation. The power will need to be distributed to the various hardware elements on the experimental floor.

3. Move loading dock and build beam dump.

   a. The existing loading dock is located in the North West corner of the hall. This location places the loading dock directly over the proposed beam dump location making the construction of the dump more difficult. Additionally the existing dock is marginal in length for easy delivery of the cryomodules. The plan is to move the loading dock one bay to the East and extend its length to facilitate module and equipment delivery. The beam dump and associated instrumentation will have to be designed and built.

4. Temporary Beamline extension from the end of the cryomodule to the dump.

   a. Due to the phased construction of the facility, a temporary beamline extension will have to be provided to transport the beam from the end of the last cryomodule to the beam dump. The transport beamline will require simple, beamline magnets and the associated power supplies. As the accelerator has additional cryomodules added to it, the transport line will be shortened and eventually removed entirely.

2.2.5.14 **Electron Source for ILC Cryomodule Testing (WBS 5.9.8)**

Goal: 1) Provide electron beam for cryomodule testing by end of FY06. 2) Upgrade the injector to provide ILC quality beam.

Our plan is to use the Fermilab NICADD photo-injector (FNPL) as an electron source for testing the cryomodule. In FY05 we acquired a 30 MV/m cavity from DESY for use as a high gradient capture cavity. Work continued on a 3.9 GHz accelerating cavity and associated RF power for the FNPL upgrade, this work will continue into FY07. All of these new components will be installed with the FNPL when it is moved to the New Muon Lab in early FY07. Further upgrades of the FNPL will be required to more closely match its beam qualities to that of ILC for beam studies.

The table compares the present FNPL parameter to that of ILC.

Parameters	units	Goal ILCTA_NM	Achieved at FNPL/A0 (06/2005)
RF Pulse Length	msec	1.5	0.5
Pulse Rate	Hz	5	1
Beam Pulse Length	msec	1.0	0.5
Electrons per Bunch		2e10	1e11
Bunch Spacing	Ns	337	1000
Charge stability	%	5 (rms)	5 (rms)

Required parameters for ILC = goal for ILCTA_NM versus achieved parameter at FNPL/A0. (red: not achieved, green achieved, black: no problem to achieve but not yet tested)

Present limitations of FNPL:

A new photocathode-drive laser oscillator was procured and the charge fluctuation now matches the ILC/SMTF requirements[1]. The laser, in its present configuration, can in principle provide bunch trains with repetition rate of 3 MHz; test will be done soon.

The main limitations are coming from the rf hardware:

- L1: The rf-pulse on the rf-gun is limited to 0.6 msec
- L2: The rf-pulse rate is limited to 5 Hz
- L3: There are significant doubt that the rf-gun can withstand the 1 ms / 5 Hz rf format, the rf-gun seems to be limited to about 0.2 msec due to vacuum breakdown

The proposed upgrade plan

- L1&L2: require modification of the Pulse Forming Network (PFN) + current transformer.

- L3: A **new rf-gun** should be designed and procured. We are in discussion with Dubna to collaborate on this item.

We need provision for general beamline hardware (vacuum pump, screens, BPM, ICT, vacuum parts, magnets); approximately 10 meters of beam line will be needed in addition to what we have at A0 (since in phase A the rf-gun will be located 28 m upstream from the TESLA-module).

- A new optical table (18'x4') should be procured before the move to NM. This will enable the entire laser to fit on a single table and reduce jitter due to vibrations.

- The photocathode drive-laser is one of the most critical components of FNPL. It was built by University of Rochester in 1995 and needs to be upgraded. Recently it was partially upgraded (new seed oscillator) and the performance was enhanced (charge stability is now < 5 %). We should have provision to continue this upgrade, and we would like to eventually upgrade the amplification scheme to include diode-pumped amplifiers to replace the multi-pass and two-pass amplifiers. We plan to do the upgrade while moving to NM. The new laser system will not need water cooling (since diode-pumped amplifier/oscillator are air-cooled). The upgrade could be:
    - Upgrade multi-pass amplifier to diode-pumped
    - Upgrade 2 two-pass amplifiers to diode-pumped

2.2.7 <u>Beam Delivery System (WBS 3.10.6)</u>

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

<u>Description:</u> Feasibility study of beam loss, energy deposition and radiation in beam delivery system (BDS) and extraction beam-lines, detector backgrounds and mitigation measures.

<u>FY07 goals:</u>

- Further refine built in FY06 the front-end STRUCT-MARS15-GEANT4 model of BDS, IP and extraction lines.

- Include into the model realistic detector description (SiD and possibly others), detector and machine beam diagnostics, two experimental halls with their transitions to the BDS tunnels, detailed extraction line and beam dump descriptions.
- Further investigate the BDS-related backgrounds, corresponding detector responses and mitigation measures.
- Perform optimization studies of the BDS apertures, collimators, synchrotron masks, muon spoilers, machine-detector interface (tunnel plugs, two-hall separation, masks, quads at IP, detector), extraction beam-lines with their collimators and beam dumps at the end for 2, 14 and 20-mrad crossings.
- Calculate radiation loads, prompt and residual radiation levels in the BDS, IP and extraction components; investigate and evaluate possible ways to mitigate beam-induced deleterious effects.
- Calculate impact of BDS radiation on environment and second experiment.

Milestones and deliverables: The scope of this work needs to evolve during the RDR and TDR process.

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

Key Personnel: Nikolai Mokhov,

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

Expectations for FY08 and beyond: This work is expected to continue in FY08 and beyond. We expect this activity will increase to 3 FTE as more accelerator physicists and engineers get involved with the design and engineering of the beam delivery system.

2.8 ILC Magnet R&D (WBS 3.2.11)

Scope: Design, fabrication and test prototype magnets for various ILC applications
FY07 Goals:

Description: In FY07 we propose to start the design, fabrication and test prototype of several ILC magnets.

1. Main Linac Low Gradient Superconducting Quadrupole: Design and fabricate an iron dominated (aka "superferric") low gradient superconducting quadrupole for the low energy portion of the Main Linac.

2. Main Linac Dipole Corrector: Design and fabricate superconducting dipole steering coil assembly (x and y correctors) to be used with the focussing quadrupoles for the Main Linac. May include skew quadrupole winding.

   Superconductor Material: Conductor for magnet fabrication; samples for magnetization studies, short sample characterization.

3. Low Gradient Large Bore Conventional Quadrupoles: Design, fabricate and test prototypes of conventional quadrupole magnets of the type required in the e+ source transfer line.

4. Stretched wire test stand: Precision measurements of quadrupole axes are critical to determining stability; an improved stretched wire measurement system with thermal and vibration damping will be developed. An existing granite table will form the base.

5. Low Fringe Field measurement test stand: Exteremely low fringe fields from quadrupoles near superconducting RD cavities are required to avoid degrading the cavity performance. Procurement of magneto resistive sensors and development of a very low field measurement system for initial studies at room temperatures.

2.9 **US Bid to Host (WBS 7.3)**

2.9.1 **US Bit to Host Management (WBS 7.3.1)**

2.9.2 **Fermilab site Specific Accelerator Design (WBS 7.3.2)**

Goal: Fermilab is proposing to build ILC using the existing site as much as possible. We propose to modify the ILC baseline design for Fermilab site.

Description: Accelerator physics and engineering design and simulation work will be needed to for the Fermilab site specific ILC. The work done under this category will be the same as done in the Accelerator design for RDR and TDR. We would be requesting help from collaborating institutes in this design work.

2.9.2.1 Damping Ring and RTML Design (WBS 7.3.2.1)

Described in WBS 2.5.2

2.9.2.2 Main Linac Design (WBS 7.3.2.2)

Described in WBS 2.7.3

2.9.3 **ILC Industrial Development in US (WBS 7.2.1)**

Goal: ILC industrial development will be focused towards developing the SRF components of the Main Linac in collaboration with US industries.

Description: Although the detailed plans of the industrial development needs to be made, the aim of the US industrialization efforts could be

- Production of ~1% components of SRF Main Linac (Cavity, Couplers, Tuners, Cryomodule assembly and RF components) using US industries
- Build industrial infrastructure at or near Fermilab (This requires detailed studies) to achieve 1% production rate needed for ILC Main Linac components.

- The industrialization study will help provide a detailed production cost and schedule.

These studies need to be carried out in several phases. In the initial phase we propose to carryout industrial studies on

- Cavity manufacturing, processing and testing
- Cryomodule Assembly
- Coupler manufacturing, processing and testing
- RF Component development (SLAC)

These studies will be carried out by US industry in collaboration with Fermilab for SRF components, SLAC for RF components. The study will provide a road map of the US industrial development to meet the above goals.

We will use the study report generated in the first phase to make an industrialization plan. The budget presented for the subsequent three years is an estimate of what it will be required to build an infrastructure to achieve a production rate of 1% of the final production rate needed for the ILC and produce 1% of the SRF component. In this planning it is assumed that the industry is allowed to use the national laboratory infrastructure where ever possible and is cost effective, for example in cryogenic testing. The budget presented is a very rough estimate and needs to be developed.

Fermilab budget does not include industrialization of the RF components. We are proposing SLAC to take a lead in this area.

2.9.4 <u>Conventional Facilities (WBS 7.1.1)</u>

<u>FNAL Site Specific technical drawings and machine layouts:</u> Developing configuration of the Systems Areas to make use of the existing land, infrastructure, and structures on the Fermilab site to provide added value to the project while maintaining or exceeding the specified physic goal of the project will be studied.

<u>Characterize local surface and geotechnical site:</u> There are numerous considerations both on the surface and the geological setting that need to be examined in detail in order to determine the most optimum routing for the ILC at Fermilab. This effort will concentrate on the route that traverses the Fermilab site, but will also consider a site to the west.

<u>Optimize design and perform site specific cost estimates in conjunction with A&E Consultants:</u> Through the normal course of design development, engineered plans and designs that are more refined and detailed that those provided in the RDR will be produced. Major design issues will be identified and solution provided. Cost estimate will be refined to the level of the design development.

2.9.5 <u>Public Outreach (WBS 7.3.1.4)</u>

Fermilab Public Affairs office will work with the ILC management, US-GDE, Linear Collider Forum of Americas and others to build support for bid-to host ILC at Fermilab. The top level goals for this activity is communication at local, state, national level

ILC Community Advisory Board: With the help of The Perspectives Group, Fermilab will build on the success of the Community Task Force by forming an ILC Community Task Force, representing all important segments of the community. Fermilab activity on this front is getting noticed by local media. From recent Chicago Sun Times Article: "Fermilab directors learned a lesson [from the SSC experience]. Again, the far west suburban center is bidding for a big new machine. This time, it has neighboring residents involved, including appointing Craig Jones, a leading opponent in 1988, to its Community Task Force on Public Participation. "The situation is completely different," says Jones. "They're very interested in making this as fair a process as possible and are treating people like they're human beings, rather than fodder for their project."

Consultant (Perspectives Group): A comprehensive communication program with the local community and Illinois state officials will go into high gear in FY2007. The Perspectives Group will provide key expertise and support services to make this effort a success

Build local support for ILC at FNAL: The Fermilab Office of Public Affairs will produce a series of print and electronic materials designed to build community support for and strengthen public participation in the US bid to host the ILC at Fermilab. Community outreach at many levels including use of envoys, speakers bureau, community organizations and media campaign

The Fermilab Office of Public Affairs will work lead the effort to develop a local envoy program analogous to the community-wide national program; to strengthen and train the Laboratory Speakers' Bureau to convey the ILC message to the community; to meet consistently with local government and civic organizations; and to engage local media.

2.10 Crab Cavity (3.9 GHz) Development for the BDS (WBS 3.9.17)

Motivation: Design and build a 3.9 GHz Crab cavity prototype for the Beam Delivery system. It is expected that such a cavity will considerably enhance the luminosity performance of the ILC.

Description: In FY06 Fermilab developed the design of a transverse mode 3.9 GHz cavity that it developed for the CKM experiment. Several single cell and four 3 cell prototypes have been fabricated. Fermilab has enough Niobium and additional half cells to fabricate a 13 cell prototype. We did not allocate any funds in FY06 for this work.

In FY07 we are proposing to fabricate and test a 13 cell 3.9 GHz Crab Cavity using existing FNAL design. The cavity will be processed and tested at Fermilab using the existing 3.9 GHz facilities that we have put together for 3.9 GHz accelerating cavities.

2.11 Cryomodule (4 Cavities 3.9 GHz) for DESY-TTF (WBS 3.9.16)

In FY07 it is the goal of the 3.9 GHz effort to deliver a 4-cavity cryomodule to DESY for use as a third harmonic cavity in the Tesla Test Facility linac. Simulations indicate that successful incorporation of this third harmonic cavity is necessary to achieve lasing at 6 nm. A total of eight cavities are being fabricated, four at Fermilab and the others by Jefferson Lab. The four with the best performance characteristics will comprise the string in the cryomodule, two will be retained as spares. The following steps are required to complete this effort in the first half of FY07.

– Vertical testing of the 3.9 GHz cavity: All bare cavities will require cold testing in a vertical dewar to evaluate their performance when cold. As a minimum the gradient will be measured as well as the cavity Q and resonant frequency as a function of temperature (1.4K – 4.2K).

– 3.9 GHz Coupler conditioning: The main input couplers are conditioned to be able to accept up to 80 kW peak power at a maximum pulse length of 1300 □s and with minimal reflected power. Two couplers will be conditioned at a time. It is estimate to require two weeks to complete assembly and testing of each pair.

– Horizontal test of the 3.9 GHz cavities at ILCTA_MDB : Testing and evaluation of complete 'dressed' cavities in a horizontal dewar will occur at the ILC test area ni the Meson detector building. Dressed implies cavities outfitted with a blade tuner and couplers contained in a helium vessel. Each cavity is tested in this manner to check tuner and cavity tuning stability, test the main input power and HOM couplers, as well as verify cavity performance and limitations. These tests will also permit checkout of the Low Level RF and a long-term system check.

– Complete assembly of 4 cavities in a cryomodule: Complete assembly of the cryomodule entails assembly of four dressed cavities into a single string, fit up of the cold mass assembly including the cavity string, magnetic shielding, cryogenic and vacuum piping, electrical and instrumentation connections, etc. into the vacuum vessel.

– Deliver to and assemble at DESY: Once assembly has been completed and verified leak tight the vessel will be disassembled, packaged, and shipped to DESY for installation into the TTF linac. 3.9 GHz personnel will be present at DESY to aid in reassembly and preparation for installation.

3. Proposed plans for FY08 and beyond

In this section we briefly describe the R&D program we propose to carry out in FY08. 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.

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