international linear collider

ILC-Americas
FY10 Mid-Year Work Package Technical Progress Report

Work scope period: 10/1/09 to 3/31/10
Work Package WBS Number: 1.1
Work Package Title: SLAC Program Management
Work Package Leader: Nan Phinney
Laboratory: SLAC
Date: 10-May-2010

WBS and budget overview

Work Package	FY10 budget full cost (k$)	FY10 actuals including indirects (k$)
1.1.1 GDE & ART Program management	326	214
1.1.2 National Lab Program management	670	211
1.1	996	425

The GDE & ART management work package covers the System Integration effort at SLAC including participation in the GDE Executive Committee. In FY10, work continued on establishing a re-optimized configuration for the ILC, likely including clustered klystrons and a low power parameter set. Availability simulations for the new baseline continued into FY10. Now that Ewan Paterson has retired, there will be little further costs in this area.

The National Lab work package covers management of the SLAC ILC effort, including all GDE travel. For the TDP, SLAC physicists are the Area Group leaders for the e-Source, Linac Systems and BDS areas. SLAC physicists also lead the Damping Ring ecloud task force and serve as deputy HLRF technical leader. Spending on this WBS item was somewhat reduced in the first half of FY10 because of conflicts for key personnel. About 20 SLAC physicists and engineers attended the ALCPG meeting in Albuquerque in October. About 12 SLAC physicists attended the GDE meeting in Beijing in March.

Work scope period: 10/1/09 to 3/31/10
Work Package WBS Number: 1.2
Work Package Title: Electron Source
Work Package Leader: J. C. Sheppard
Laboratory: SLAC
Date: 13-May-2010

WBS and budget overview

Work Package	FY10 budget full cost (k$)	FY10 actuals including indirects (k$)
1.2.1 Electron Source	893	131
1.2	893	131

The Electron Source R&D ART work package at SLAC includes laser, cathode, and gun development with the goal of demonstrating an ILC specification polarized electron source by the end of FY12.

In FY10, ongoing work includes the efforts to develop the final stage laser amplification systems for the ILC bunch pattern and investigations of the effects of the doping profile on QE, polarization, and charge limitation in GaAS-type cathodes. A pair of 18W, 515 nm pump lasers will be ordered for the final stage amplifier in replacement of an ELS laser system which does not perform to the specifications. The new lasers are expected in Q3 FY10. A visit is planned to JLab to develop a work plan through the end of FY12 for combining the SLAC ILC laser system with a JLab HV gun to demonstrate an ILC electron source prototype.

Work scope period: 10/01/09 to 3/31/10
Work Package WBS Number: 1.4.1
Work Package Title: Electron Cloud
Work Package Leader: Mauro Pivi
Laboratory: SLAC
Date: 20-April-2010

WBS and budget overview

Work Package	FY10 budget full cost (k$)	FY10 Q2 actuals (k$)
1.4.1 DR Electron cloud experiments	491	201

This work package covers the aspects of the Electron Cloud R&D effort on simulations and experiments for the ILC Damping Ring at SLAC, including support for CesrTA.

1.4.1 Damping Ring Electron Cloud experiments

During the first half of FY10, electron cloud mitigation tests in wigglers continued in KEKB in collaboration with SLAC. Different mitigations, including grooves, have already shown very promising results. Then, with KEK colleagues, we designed an insertion with smaller 2.5mm grooves depth and worked on improving the TiN coating at SLAC. As a result, the latest tests made in FY10 show that the electron cloud current in the groove section is further reduced by an additional factor of 2. The plan is to manufacture smaller grooves, apply coating by vapor deposition and manufacture a 4m long test beam pipe with grooves. At SLAC, simulations continue in support of the tests.

SLAC is collaborating and supporting simulations for the CesrTA experiment with a number of codes that are in use at Cornell: *CMAD, CLOUDLAND* and *POSINST*. These codes were developed at SLAC and LBNL. In particular, SLAC is benchmarking the data for the electron cloud build-up in wiggler and quadrupole regions of CesrTA. We developed the parallel code *CMAD* to allow advanced simulations of head-tail instability and emittance growth below the instability threshold, which is the focus of the second phase of simulations at CesrTA. This work provides a crucial benchmarking of the available codes against experimental data to scale the results to the ILC DR instability threshold. SLAC is actively participating to the commissioning of the CesrTA operations, to the experiments and to the simulation effort with a number of trips to Cornell.

Work scope period: 10/01/09 to 3/31/10
Work Package WBS Number: 1.6
Work Package Title: Beam Delivery System
Work Package Leader: Andrei Seryi
Laboratory: SLAC
Date: 12-May-2010

WBS and budget overview

Work Package	FY09 budget full cost (k$)	FY09 actuals including indirects (k$)
1.6.1 BDS design	1159	118
1.6.2 ATF2	1220	556
1.6.3 DR kicker	293	40
1.6 Total	2672	715

The BDS R&D ART work package covers the effort at SLAC on the design of the beam delivery system and on commissioning and operation of the ATF2 test facility.

The BDS design efforts were focused on optimization of parameters and integration studies in support of SB2009. A Physics Question Committee was established, co-chaired by representative of BDS, to work in coordination with SB2009 Committee chaired by

Detector colleague. The former has developed and provided answers on physic and luminosity questions of the latter.

A particular concern was identified by the SB2009 Committee – rapid reduction of luminosity at low energy, due to collimation effects and due to reduced positron production. The Beam Delivery group has initiated studies, engaging other groups (Damping ring, Sources, Linac, etc), to evaluate possibility of doubled repetition rate at low energy. The study has resulted in a positive outcome, and the double rep rate will likely be considered for the baseline.

The SLAC team has actively participated in every run of ATF2. The commissioning continued through 2009, and by early 2010 most of hardware was installed and commissioned. In early 2010, SLAC team has delivered and installed new electronics for a dozen of stripline BPMs in the extraction line, which will allow accurate measurements with self-calibration and minimized current dependence. Together with IFIC, Spain, SLAC has produced the multi-OTR system that is undergoing final assembly and test steps, and will be installed at ATF2 at the end of May.

The work on beam dump design has continued, under collaboration of SLAC with BARC (India). The recent work was focused on analysis of materials for the vessel, simulation of window and wall heating, evaluation of the impact of double rep-rate.

Work scope period: 10/1/09 to 3/31/10
Work Package WBS Number: 1.8
Work Package Title: Global Controls
Work Package Leader: Ray Larsen
Laboratory: SLAC
Date: 10-May-2010

WBS and budget overview

Work Package	FY10 budget full cost (k$)	FY10 actuals including indirects (k$)
1.8.1 Global Controls	425	234

1.8.1 MicroTCA Demonstration – Marx P2 Interlocks

The Marx P2 interlock design is in the stage of defining requirements. It has two levels, one inside of each cell by fast-acting hardware interlocks, and one external for the entire klystron-modulator system. This item is focused on the latter.

The conceptual design of interlocks on MTCA has made good progress. This is tightly dependent on the new extensions for MTCA by the PICMG xTCA for Physics standards program in which the MTCA industrial solutions are now in prototyping and testing.

The new standard hardware includes a double-wide Advanced Mezzanine Card (AMC), matching Rear Transition module (RTM), fast timing/ triggering line extensions and special bus lines for fast feedback vector summing and fast programmable interlock summing over the gigabit serial backplane.

The plan is to convert the functions of the 3-module F3 interlock system currently operating in ESB onto an MTCA platform with a single AMC and RTM. The new approach will eliminate a large amount of external signal conditioning which becomes embedded into a mixed technology analog-digital chip.

This project is also important to the SLAC linac upgrade plan involving 240 RF stations.

<u>Progress:</u> The project is behind schedule for completion by Q4 due to lateness in assigning engineering. A Controls hardware engineer has just been assigned. Estimated completion dates are now:

Design:	Q4 FY10
Operational:	Q2 FY11

1.8.2 ATCA VME Adapter Demonstration

The VME ATCA Adapter project was under a contract with SAIC until early in the year and then the partially tested prototype board was taken over by SLAC once a software engineer was available. Testing was resumed at SLAC and numerous hardware and software problems were encountered and solved. The boards have proven unreliable due to very tight layout and intermittent connections. Two boards were loaded and only with a lot of effort can either one be kept running. The original test bed for the adapter was intended to be the P2 interlocks, but as described in 1.8.1, due to the success of the standards development a much more efficient and cost-effective solution can be made in MicroTCA. The combination of new F3 boards and adapters is not cost-effective.

The conclusion is that the rapid progress in supplanting VME enables us to move directly to the new solution, so we propose that the Adapter effort be suspended. We can take advantage of the power and intelligent platform management parts of the design to use in future layouts of ATCA modules, and the software tools we have built up are also usable.

<u>Progress:</u> The project is behind schedule due to intermittent circuit boards and some component failures that required circuit patches.

<u>Recommendation:</u> Terminate the program and apply results and effort to new designs,

Since our rapid progress in the standards area has outstripped the need for this module we propose to apply the resources to completing infrastructure for xTCA reference board designs for engineering and in parallel pursue the new interlock design on MTCA. The proposed new milestones are as follows:

1.8.3 MicroTCA Standards Infrastructure Development

New Goals:

1. Procure new standard crate and board components for evaluation and prototyping.
2. Procure or develop reference design including power system and IPMI for new standard AMC, RTM boards
3. Complete design of MTCA interlock AMC, RTM modules

New Milestone Summary:

1.8.1	MicroTCA Demonstration – Marx P2 Interlocks design of new modules in MTCA	SLAC	Q4
1.8.2	ATCA VME Adapter Demonstration	SLAC	Term-inate
1.8.3	MicroTCA Standards Infrastructure Development		
1.8.3.1	Procure evaluation 12-slot crates, AMC & RTM modules from 2 or more industry partners	SLAC	Q4
1.8.3.2	Complete engineering reference designs AMC, RTM modules	SLAC	Q4

Work scope period: 10/1/10 to 3/31/10
Work Package WBS Number: 1.5.1, 1.9.x and 1.10.10
Work Package Title: Main Linac RF Systems and Integration
Work Package Leader: Chris Adolphsen
Laboratory: SLAC
Date: 01-May-2010

These work packages cover all aspects of the Main Linac RF source development efforts at SLAC, including program management, rf design, modulator, klystron, rf distribution and coupler development and L-band facility operation and maintenance at End Station B

(ESB). They also encompass work in support of the GDE Main Linac Integration effort, including wakefield studies.

ML Design

Covers work by Chris Adolphsen to oversee rf system R&D efforts and Main Linac Integration (MLI) studies (Chris heads the GDE MLI group). It also covers some of Chris Nantista's rf design work relating to general rf system development and MLI activities (Chris Nantista become deputy head of the ILC HLRF effort during Q2-FY10)

Wakefields and Main Linac Integration

This program includes the following tasks.

1) Examine LLRF signals recorded during operation of the FLASH cavities at DESY without and with beam. The goal is to understand the sources of pulse-to-pulse gradient jitter in order to estimate the rf overhead needed at ILC, and to model the energy errors that will occur along the linac for various LLRF feedback schemes.

In Q2, analyzed beam-on LLRF signal data taken during the Fall-09 FLASH '9 mA' program. Found the feedback systems do well to suppress gradient jitter caused by pulse-to-pulse beam current variations. The remaining jitter is similar to that observed in beam off and feedback off data, which is dominated by the detuning effect of microphonics (i.e., few Hz cavity frequency variations that result from vibrations induced by helium pressure fluctuations in the cryogenic system).

2) Evaluate the effectiveness of the cryomodule 70 K HOM absorbers in preventing a significant fraction of the beam induced, higher order mode (HOM) energy from being dissipated in the 2 K beam line (in particular in the non-superconducting beam pipe sections between the cavities).

For this purpose, bunch-induced longitudinal wakefields were computed in the time domain for a series of 2D cavities, but the available computing power proved inadequate to obtain meaningful results. Instead, the propagation of the HOMs are being examined individually at sample frequencies. The S-matrixes for TM0n modes are first determined for the cavity and absorber and then cascaded with periodic boundary conditions to determine the absorption profile along the linac.

This work is nearly complete and the results predict that 5-10% of the HOM energy on average in the 4-20 GHz frequency range ends up in the 2K cryogenic system, which will require increasing its capacity by a comparable fraction. In rare cases, at certain frequencies and cavity spacings, the mode pattern has a null near the absorbers that leads to much higher relative beam pipe losses, but the absolute losses are small. Data on beam induced heating of the absorbers is being taken at the FLASH to verify these and other estimates of the heat loads.

3) With the hire of a staff physicist (Yipeng Sun) in Q2 to do linac beam dynamics studies, a program was started to examine the impact on the linac beams of the proposed Klystron Cluster Scheme (KCS) for distributing the rf power. This scheme has a much courser energy control than that in the baseline design, so there is a concern that the resulting beam energy errors will produce unacceptable beam emittance growth. So far, a beam transport program has been written that includes the expected random and systematic energy errors, and a quadrupole alignment algorithm is being incorporated to simulate the effect of the residual dispersion after the magnets are aligned.

Marx Modulator

The ILC Linac klystron modulator specifications call for 120 kV, 140 A, 1.6-ms pulses at 5 Hz. SLAC is pursuing a Marx-topology modulator to fulfill these requirements. A full-scale prototype, the SLAC P1 Marx, has been designed, fabricated, and is currently undergoing lifetime testing. Thus far, it has driven a 10 MW Toshiba Multi-Beam Klystron (MBK) for about 1500 hours and there have been no chronic modulator or klystron problems (the MBK is only the second one built by Toshiba – this multi-beam approach is the ILC baseline choice).

The P1 Marx includes sixteen, 11 kV cells and a single "Vernier" Marx cell. The triggering sequence of the main Marx cells is designed to promptly turn-on eleven cells, then stagger turn-on the remaining five cells to coarsely compensate the storage capacitor droop. The Vernier Marx (with cells charged to ~ 1 kV) staggers its turn-on and turn-off to further regulate the output to the specified +/-0.5%. The HV waveforms that are produced result in an overall flat 10 MW klystron rf pulse that has a ~ 3% saw-tooth modulation (30 us period), which would have a negligible effect on gradient flatness of the low bandwidth ILC cavities.

Building upon the success of the P1 Marx, the SLAC P2 Marx is currently in the final stages of design. It has 32, 3.75 kV cells where each cell individually regulates its output. There is no arraying of solid-state switches within a cell, simplifying the control and protection schemes, and the layout is redesigned to have single-side access.

Sheet-Beam Klystron (SBK)

The original plan was to develop the SBK by building a Beam Tester to verify that a flat beam (40:1 beam aspect ratio) can be generated just after the gun, and designing a full scale klystron in parallel. This SBK would utilize permanent magnet focusing, making it smaller and much lighter than the MBK, for which it is plug-compatible and has a comparable efficiency.

The Beam Tester has been assembled and successfully run at full power (120 kV, 140 A) with 1-us-long pulses. A movable probe is used to map out the beam profile so a comparison can be made to the gun simulation program MICHELLE (unfortunately, the carbon in the probe shield appears to poison the cathode unless the gun is pulsed at a very low rate). A vertical asymmetry was observed in the measured current density profile that was partially corrected using a 900 V and 0 V bias on the upper and lower focus electrodes, respectively The resulting current density still has significant unevenness (+/- 15%) on the flattop portion although the general elliptical shape is close to that predicted.

The klystron rf and beam transport design were nearly complete when it was realized that without the up-down symmetry that had been assumed to expedite MAGIC PIC code simulations, strongly beam-coupled transverse modes (0.7-4 GHz) appear between the klystron cavities that can drive the beam into the drift tube walls in tens of ns. Addressing this problem has been the main focus of the SBK program for the past year. After trying many methods to suppress the modes, the drift tube height was doubled to decrease cavity coupling, and stronger, solenoidal (~ 1 kG) focusing (relative to that with permanent magnets) was used to achieve stability in the simulations. A two-cavity oscillation device using the Beam Tester gun and existing permanent magnets has been built to verify the predicted regions of stability versus field strength (and so validate the MAGIC PIC code). The plan is to test this device by the end of FY10, and perhaps test a second gun cathode that has already been fabricated.

A half-day SBK program review was conducted at SLAC in April, 2010 that included a summary of the work to date, a reassessment of the relative merits of a SBK versus MBK, and a presentation of cost and schedule estimates to complete a full klystron. Given the long development time still required, and the smaller cost saving and weight reduction with the switch to solenoidal focusing, it was formally decided to end the ILC funding of this program after FY10. RF engineers from two local klystron manufacturing companies were invited to the review to learn from this four year effort and provide suggestions for other possible applications of the sheet-beam klystron approach.

Global RF Distribution

To reduce the ILC cost, two rf distribution schemes are being considered that would allow the elimination of the Main Linac service tunnel. In one option, the Klystron Cluster Scheme (KCS), power from 10 MW klystrons that are located in surface buildings are combined in circular waveguide and transported down to and along the beam accelerator tunnel. The klystrons are grouped in clusters of ~35 and the combined power feeds a 1.25 km linac section. At 38 m intervals along the linac, 10 MW is tapped off from the circular waveguide to feed three cryomodules, just as in the baseline design. The high power is transmitted in the low-loss TE01 mode in 0.48 m diameter waveguide where the average power loss is about 7%. Coaxial Tap-Offs (CTOs) have been designed to transfer power in to or out of the TE01 waveguide without perturbing the axial symmetry of the inner, high power region.

At SLAC ESB, a KCS test bed is under construction in which 10 m of aluminum waveguide will be resonantly charged through a single CTO to the field-equivalent of a 350 MW travelling wave. Tests will be done both under vacuum and in nitrogen at two bar absolute pressure to see which environment is less prone to rf breakdown (note there are no surface electric fields in the main pipe and coaxial gap region of the CTO).

Four, 2.4-m-long sections of the “big pipe” waveguide are ready for installation. Each pipe consists of two aluminum plates that were rolled, welded longitudinally and then precision machined (to ~ 1 mm for the inner diameter). The rf specifications for roundness were met, and all passed hydro-testing for operation under pressure. Double grooves on one face of each flange joint allow for pressure/vacuum sealing with a rubber O-ring and rf sealing with a canted coil gasket. A perforated vacuum pump-out insert is near completion as are two step tapers from 0.48 m to 0.35 m diameter for interfacing with the CTO.

For the high power test, the desired CTO coupling will be achieved by shorting one end with the proper length waveguide, and the resonance condition will be achieved by shorting the far end of the waveguide at an appropriate length. RF windows on the CTO rectangular ports isolate the test system from the input rectangular waveguide.
Future work includes developing and testing a high-power waveguide bend, demonstrating the matched tap-off function of the CTO and combining of two or more sources into the large TE01 mode waveguide. At noted above, the beam physics issues related to this rf distribution approach are being studied.

Local RF Distribution

At SLAC, a system for distributing up to 3.3 MW of rf power to eight SC cavities was built for the first cryomodule that will be tested at FNAL. This system makes use of a novel, adjustable directional coupler called the Variable Tap-Off (VTO), which, by means of mode rotation, allows tailoring of the power distribution among pairs of cavities. This functionality is desireable given the wide range of sustainable cavity gradients (+/- 20%) that will be accepted to increase the production yield for ILC.

A second such distribution system with a different power tailoring scheme is being prepared for FNAL’s next cryomodule. The VTO requires loosening two large bolted flanges to make coupling changes, which is fine for the ILC where such adjustements should be rare. For an R&D facility, however, a system that can be adjusted more quickly is perferred. For this purpose, the equivalent of a remotely controllable VTO will be provided by a pair of folded magic-T’s connected by a pair of motorized U-bend phase shifters. Each of the phase shifters contains an inner waveguide turn-around inside a pressurizable outer shell, movable by means of motorized feed-throughs. The broadwall edges of the inner U-bend are shorted to the outer WR650 by stainless steel finger-stock. A prototype has been tested up to 2 MW, and eight more are in fabrication. All the other parts required for this system have been purchased. A FNAL-based ARRA account is being used to fund this work.

Couplers

One FY10 goal is to finish the preparation of the 12 TTF3-style cavity power couplers that were purchased from CPI by FNAL in FY08. The process involves inspecting the parts, cleaning and assembling them in a Class-10 cleanroom, pumping them down, baking them at 150 degC in a nitrogen filled oven, and then rf processing pairs of them using the 5 MW L-band station at ESB. For this purpose, a dedicated cleanroom was built at SLAC based on the coupler assembly facility at Orsay. It was commissioned in early 2009, and since then, four coupler pairs have been prepared and shipped to FNAL, and a fifth pair is in process.

In Q2, two orders were placed for more couplers: 10 using SLAC ILC funds and 22 using FNAL-based ARRA funds. Both contracts were awarded to CPI. In June 2010, representatives from FNAL and SLAC will visit CPI to inspect some of the coupler parts that have been fabricated for the order of 10 to ensure that CPI has implemented a better QC program than was in place when the previous 12 couplers were fabricated.

Another goal of this program is to make the coupler fabrication less expensive. The CPI-built couplers require many e-beam welds, which limits the companies that can do this work. As an alternative, TIG welding and induction brazing are being evaluated by the SLAC Klystron Department. The plan is to build a coupler 'cold' section in FY10 with such techniques. The drawings have been completed and construction has started using ARRA funds. These funds will also be used to build such couplers in industry once the fabrication technique has been proven.

L-Band Test Stands at ESB

At ESB, the original L-band test stand, which is powered by an SNS-style modulator and a commercial 5 MW klystron, continued to be used for various component tests. In particular, the couplers are rf processed with this system, and it is used to evaluate waveguide parts for the rf distribution program.

In parallel, a new test stand consisting of the P1 Marx modulator and a 10 MW Toshiba MBK began 24/7 operation in Q1-FY10 to evaluate the long term reliability of the system. Thus far it has run about 1500 hours, and while there have been several faults (e.g., waveguide/window arcs) and items that needed upgraded (e.g., resistors were added to equalize the voltages on the capacitors that are combined in series), the modulator and klystron designs appear to be robust. The fault analysis is aided by the slow and fast waveform data that are recorded every time a fault occurs (and periodically as a reference).