May 1, 2006

Report of the ILC ART Review

The DOE/NSF review of the Americas Regional Team (ART) effort on the International Linear Collider was held at Fermilab on April 4 – 6, 2006. The consultants to the review were Ilan Ben Zvi (BNL), Dixon Bogert (FNAL), Tom Elioff (SLAC), Don Hartill (Cornell), George Mulholland (Applied Cryogenics Technology Inc)., Katsunobu Oide (KEK), Ferdinand Willeke (DESY). (Isadoro Campisi of ORNL was unable to attend). Funding agency representatives included Aesook Byon-Wagner* (DOE), Paul Grannis (DOE), Jon Kotcher (NSF), LK Len (DOE), Randy Ruchti* (NSF) (* : part time).

This first review of ART was intended to examine the FY06 ILC R&D and Reference Design Report (RDR) activities by the ART in the US, to evaluate the plans now in place for work in FY07, and to review the ART management and its relation to the global ILC effort. The charge to the review is appended. The ART Director Gerry Dugan organized the presentations. The review agenda is appended. Talks can be found at https://wiki.lepp.cornell.edu/ilc/bin/view/Public/Americas/ .

Although the review was focused on ART effort in the US, there were Global Design Effort (GDE) observers from Europe and Asia as well as the International Linear Collider Steering Committee. The GDE conducted meetings in parallel with the review and the review was followed by the first meeting of the Machine Advisory Committee. Thus there was opportunity to interact with the GDE on more global issues, and the committee discussed issues of the ART relation to the global effort with the GDE Executive Committee and chairs of the GDE R&D and Design and Cost Boards in a closed session.

This report is drawn from the written comments of the consultants and is organized in terms of the R&D program (Section 1), the work toward the RDR and cost estimate (Section 2) and ART management of the program (Section 3). The consultants were impressed with the rapid progress by the ART in the seven months since it was established. The presentations by ART members outlining the R&D program goals and progress, and the efforts toward completion of the RDR by the end of 2006 were clear, candid and informative. The committee is most appreciative of the excellent work in the preparation for this review by the Americas Regional Team.

1. R&D effort:

R&D programs in FY06 were proposed by participating labs and universities. The ART Director prioritized these and proposed a budget allocation to the DOE for the laboratory portion of the work (DOE and NSF university R&D grants for accelerator R&D had already been made prior to ART formation). This proposal was based on a total budget of $30M, and resulted in an initial financial plan to laboratories, keeping about $2M in reserve for RDR and cost estimate work not yet understood in August 2005, and about

$1.4M for GDE management, common fund and university grants. The NSF contributed about $1.1M for university accelerator R&D and management costs.

MOUs between ART and participating laboratories were executed, detailing FY06 R&D and deliverables and organized with a standard ART/ILC WBS structure. The MOUs included work both for R&D and RDR activities and included expected activities for FY07 work.

The R&D effort review was organized along lines of ILC technical subsystems. Reviewer evaluations by subsystems are summarized in these categories:

Electron and positron sources: Work is underway on the laser for the electron source and testing the undulator/target for polarized photon production. The reviewers found that the work is well conceived, with good inter-regional division of effort. The laser and vacuum systems for the electron source are challenging and will require added attention. The plans to develop a new electron source target material (GaN) or higher voltage electron gun are good. The completed experiment E166 at SLAC will compare both photon and positron polarizations generated in the lab with calculations. The undulator for the positron source, with its large bore and length, is challenging, and could be a good target for expanded inter-regional cooperation.

Damping Rings: The basic damping ring design seems sound. The R&D program on electron cloud instabilities, vacuum, wiggler magnet length is well conceived. The program at the ATF in KEK is central to advancing the damping ring performance and should be sustained. The study of damping ring beam dynamics with realistic fringe fields and non-linear magnetic components should now be undertaken. A realistic estimate of impedances with rf elements, kickers, bellows, valves etc. should be made. The fast kicker magnets are a challenge, and should remain a priority for full scale tests. Reviewers noted the desirability of converting CESR to a positron damping test facility. A phased approach to the positron damping ring might be considered, with one positron damping ring to be constructed first to see if electron cloud effects are adequately suppressed before proceeding to build the second.

Ring to Main Linac: The work was judged to be well planned and integrated interregionally, with good milestones and work plan identified.

Main Linac power sources: The absence of a reliable 10 MW klystron was noted by the ART and recognized by the reviewers as a high priority need for near term effort. The inability to react to this problem in FY06 is regrettable. The R&D on the alternate Marx generator modulator was judged appropriate and at the right scale. The rf components for pulse power distribution are expensive, and R&D on alternate components that could simplify the system and reduce costs is appropriate. Power couplers to cavities are presently difficult to condition and have possible failure modes due to multipacting so R&D on better designs is warranted. Reviewers favored the development of higher order mode dampers as BPMs for in-situ measurement of cavity position.

Cavities and Cryomodules: Nearly all reviewers commented that the development of superconducting rf cavities is the major outstanding challenge for the ILC. Only a few cavities have achieved 35 MV/m, and the reproducibility is poor. The variation in achieved gradients is much too large. Preparation of cavities is presently labor-intensive. There was general support for the cavity and cryomodule test facility plan at Fermilab (with a proposed buffered chemical polishing and electropolishing at ANL, and vertical, horizontal and string tests at Fermilab). The proposed level of effort of the FNAL facilities is needed, but not sufficient, for making the transition to high volume production. The progress toward building the facilities in Meson Lab, New Muon and IB1 has been good. The cryogenics infrastructure being put in place will serve the near, but not longer, term needs.

There is no clear plan for cavity testing that is scalable to the pre-production needs. Cavity industrialization effort is needed now; failure to develop the industry capacity early on will cause problems later. The ramp-up of industrial capability may become the pacing item for the ILC R&D program. It will be important to develop a clear time frame for cavity production as this dictates the size of the plant need, and thus the cost.

R&D and prototype cavities using single/large grain niobium may allow significant simplification in cavity processing (potentially eliminating the poorly understood electropolishing step), and thus holds the prospect for cost savings and improvement of yield, reproducibility and operability. The R&D on large grain niobium is welcome; the balance (near-term fabrication of about equal numbers of small and large grain cavities) was felt to be about right.

Multiple R&D facilities building on existing infrastructure at US laboratories should be considered, with one location reserved for high volume pre-production testing.

The proposed 'tight loop' of cavity fabrication, polishing, vertical and horizontal testing, and feedback to industry seems an appropriate strategy. Attention should be focused now on developing comprehensive travelers to document all steps in the fabrication of cavities and cryomodules.

Higher power pulsed-rf power for the vertical test to allow more cavity conditioning would be good.

Although no clear GDE plan exists for worldwide cavity R&D and cavity production, the committee feels that all regions will be needed to participate.

The cryomodule design effort was judged to be appropriately international, with Fermilab lead. ART/GDE should assure that the cryomodule design is compatible across regions.

Some design flexibility could be obtained by sorting cavities according to their gradient and putting them together in separate cryomodules. This could reduce the need to reject poorer cavities, but may require a larger range of power tuning than is planned now.

Higher order mode fields in the TESLA cavities remain a concern. Specification of what is acceptable and tests on existing cavities are needed.

Other test facilities: TTF and ATF are valuable resources that are resource limited, but have some more availability. These facilities should be exploited to the extent possible.

The rf test facility at SLAC is a necessary and useful effort. The committee asked if it would be possible to use the SNS linac to gain some operational experience? Beam instrumentation development is a good candidate for university R&D work.

Linac optics, low emittance transport: The progress in understanding the low emittance preserving optics has been good, with an appropriate balance of effort in different regions. There are several simulation codes that attack similar problems. Although one should watch for unnecessary duplication, the codes specialize in different sectors. Using code that is familiar also tends to raise the efficiency of individual groups. Benchmarking of the codes against each other has progressed, but there is need to compare some of the codes to actual accelerator experience, perhaps at the DESY VUV-FEL. Attention should be given to cavity higher order mode effects; to BPM specification and in the case of the higher order mode dampers, the sensitivity to dark current; to simulations in the presence of component position variations; and to diagnostics specifications.

General instrumentation: The systematic approach to controls, power supplies, monitoring was appreciated. The card level diagnostics program follows industry trends and is good. There is a rational interregional plan for work over the next 3 years, with useful tests at the ATF and TTF.

Beam delivery, machine detector interface and dumps: There has been progress in design of the beam delivery systems for the two IRs with crossing angles between 2 and 20 mrad. The MW-level synchrotron radiation at the IRs represents a significant challenge for detector design and the IR optics. The beam power of ~20MW is large, and imposes severe constraints on the beam dumps and machine protection system. The current design of water dumps should be carefully examined soon for radiological and tritium production issues that may affect the civil construction design.

Availability: The availability assessment seems not to have progressed substantially for over a year. Many key decisions are influenced by these simulations (one vs. two tunnels, one vs. two bunch compressors, modulators on surface vs. in service tunnel, etc). There was a worry that the input mean-time-between-failure numbers may not reflect existing experience in some cases. The errors on the availability estimates may be underestimated. More work with revised input numbers, perhaps with a new code for cross checking, would be useful since many key decisions are being strongly influenced by this analysis. Benchmarking the code against existing accelerator availability remains to be done.

Civil Construction: The civil construction effort is well integrated inter-regionally, and design planning is going well. The information for the US site is still relatively minimal and progress requires settling on the specific footprint. Evaluation of competing tunneling techniques should be made. There should be a careful review of contractual methodologies used in large commercial projects, with attention given to strategies for mitigating contractor claims on the basis of actual rock conditions encountered during construction. Concerns regarding the stability of the rock after blasting shafts or tunnels should be addressed.

The reviewers found the US ILC R&D program to be well conceived and directed to the important goals for preparing a credible ILC design. The coordination with activities abroad was good in many areas, though in some areas, the worldwide programs would benefit by more explicit coordination. It may be possible to better apportion some activities across the world ILC laboratories to avoid covering all topics in the US. In the primary area of need for demonstrating the ILC design – the fabrication of reliable high gradient superconducting cavities – the US activity is well formulated but still far from sufficient to demonstrate the maturity of this technology. In some areas, notably the research on a high power klystron, increased effort is needed.

2. Reference Design and Cost Estimate:

The baseline configuration now established by GDE is the basis for the RDR and the cost estimate. Generally the conceptual design was seen to be sound and to provide an adequate basis for costing, but the choices made at this stage are typically conservative in many subsystems, since the alternate choices have not yet been shown to be realizable. The conservatism results to some degree from the fact that the design is a bottoms-up effort with individual subsystem designers building in safety margins. Some reviewers argued for a less conservative specification in order to reduce costs. This may be partly achieved by a more top-down approach that emphasizes cost-consciousness overall. We hope that the migration to less conservative options can be validated in the next year or two as the R&D effort matures.

The baseline design envisions a parameter 'plane' in which parameters such as bunch charge, train length, beam power, or emittance can be varied to give operational flexibility. Four representative operational points are chosen with differing degrees of stress upon individual subsystems, each with luminosity of $2x10^{34}$ $cm^{-2}s^{-1}$. Pushing all the parameters to their limit would give over $5x10^{34}$ $cm^{-2}s^{-1}$. While the reviewers liked the parameter range concept, they were skeptical that ratio of the maximum luminosity and that on the design plane needs to be so large. The cost associated with providing this degree of safety margin should be investigated.

The cost methodology was outlined. The estimate will be done in 'ILC Value Units' consisting of M&S direct costs and FTE labor broken into three broad categories (physicist and engineers, technicians, and administrative). The basic WBS for costing is at level 3 or 4 (e.g. superconducting quadrupoles, klystrons, cryo transfer lines) but individual estimators may need to go to deeper levels to develop their costs. M&S costs will be based on the best quote worldwide that achieves necessary quality. For large quantity elements, learning curves will be assessed using standard industry algorithms. A cost probability distribution will be prepared for each WBS level 3 system that would replace the usual US estimate of contingency based on the solidity of information going into the cost estimate. In this way, contingency could be assessed separately in different regions using different guidelines. The cost of the R&D and PED activities, pre-operations, operations and decommissioning should be separately estimated, and added as

desired regionally. No escalation will be put in explicitly, but can be added where needed. The cost estimate will be based on a seven year construction timetable – the fastest that is deemed technically achievable.

The GDE plans to develop a value cost estimate that can be translated to any national accounting system for real costs in that nation, based on the assumption of the specific work packages assigned to each region. These translations to real national costs should be available at the time of the cost estimate release. Preliminary cost estimates will be kept private within GDE until the final release. ART and the reviewers emphasized the need to make the first public cost estimate as clear as possible since that cost number will be remembered and highly quoted. Delivering a cost number that has many caveats and fine print to describe its meaning will create dangers of misinterpretation.

The committee generally agreed that the advertised cost methodology was appropriate and if achieved could satisfy the needs of funding agencies. It is a large task and will be challenging to achieve. The committee thought the cost probability method of approaching contingency would be workable.

In some regions, cost information from industry is confidential. The GDE believes that this confidential information should be available for cost review committees on a non-disclosure basis, but this needs to be verified. The reviewers emphasized the need for this information to be made available to appropriate review panels.

The GDE plans to make a preliminary cost by the July meeting in Vancouver so that adjustment of baseline and optimization of the cost could be done.

The Baseline Configuration appears to be a sound basis for the RDR and cost estimating process. The configuration on which the RDR will be costed is, probably necessarily, rather conservative in most choices. The committee urges that the assumptions leading to these choices be vigorously addressed by the continuing R&D program, and re-evaluated over the R&D phase of the ILC effort The costing methodology seems to be sound, but will be challenging to achieve by the end of the year. The ART/GDE should make every effort to make the basis of the cost estimate transparent to the funding agencies that will review it and to provide all the information needed to translate the value-based estimate into existing national cost bases. The committee asks, if the preliminary cost identified in the summer 2006 roll-up is deemed too high, what methodology will be used to modify the RDR reduce the cost.

3. Management and planning

The consultants generally were quite complimentary about the progress made in less than a year in formulating and managing the R&D and RDR effort. The ART director has done a good job putting the US ILC program on a firm footing and in prioritizing and directing the effort. There were however several concerns and suggestions. In some respects these questions address both the ART and the GDE.

1. There is as yet little overall control of the global ILC R&D effort. The GDE receives proposals or statements of what each nation or region will do but has no direct authority over national or regional R&D decisions. This could cause some degree of duplication of effort, or gaps in the R&D coverage. The committee recognized that not all duplication is bad, particularly in high risk areas, or in those systems where the volume of production is so high that all regions will need to contribute. Nevertheless, the global ILC R&D effort does not yet resemble a project as typically defined in the US, with clear lines of authority and fiscal control.

2. There is no clear US R&D roadmap with milestones and estimated budgets. The GDE R&D board has recently issued a list of all needed R&D (globally) with priorities attached. This will be useful in establishing where US funding might best be applied for FY07 and beyond. However, there is not yet an attempt to specify how work might be shared among regions.

The committee calls for the development of an integrated multiyear R&D plan in the US showing resource needs and milestones, using significant input from the GDE.

3. The sum of Laboratory requests for FY07 significantly exceeds the expected budget. The committee was concerned about how the priority decisions would be made to select the optimal program for FY07. Establishing the relative priority for subsystem R&D and the development of test facilities and contracts with industry for cavity and cryomodule related work will be a critical choice facing the budget allocations for FY07 and beyond. Although the development of test facilities and the planning of national industrialization efforts can be seen as part of national aspirations aimed at hosting the ILC, the major facilities and industrial capacity for superconducting rf systems are so central to the success of the ILC that it seems inevitable that the GDE must be integrally engaged with these activities.

The committee would welcome bringing the needs for test facilities and US industrialization into the ART budget request process.

4. The US funds being expended on the ILC R&D under ART guidance are already large ($30M DOE in FY06) and are expected to grow substantially in future years. Management of this large outlay of public funding requires careful and intensive oversight, particularly in the areas of developing plans for funding, manpower, and infrastructure for the duration of the R&D phase, establishing milestones for the R&D work and monitoring the effort and expenditure progress toward meeting them, and providing timely reports of expenditures and progress to the funding agencies.

The committee suggests that the ART staffing be increased by about two people in the near term, in view of the need to provide budget, planning and administrative support. It is likely that this need will grow as the ART R&D program develops, particularly at the rapid pace that is anticipated. The committee recommends that the first phase be in place by the start of fiscal year 2007, and that the funding agencies and ART work together to define this expanded near- and longer-term oversight role.

January 20, 2006

Dr. Gerald Dugan
Director, Americas Regional Team
Laboratory for Elementary Particle Physics
Cornell University
Ithaca, NY 14853-5001

Dear Gerry:

The first review of the US R&D program for the International Linear Collider (ILC) by the Department of Energy and the National Science Foundation will be held April 4 – 6, 2006 at Fermilab. This review will serve as DOE and NSF's primary peer review of the US portion of the ILC R&D activities. Our goal is to evaluate the scope and quality of the accelerator research and development activities, the prioritization of activities within the budgetary advice, the planning for the next few years, the efficacy of the management of the effort by the Americas Regional Team (ART), and the integration of the US work into the larger ILC Global Design Effort (GDE) effort.

We ask that the review addresses the ongoing ILC R&D program, covering the major areas of US activity including:

- ART organization and its integration into the larger GDE effort
- US R&D program and deliverables in FY06
- Expected program activities and milestones for FY07
- Machine availability and risk assessment studies
- US role in plans for world-wide ILC test facilities
- US effort in preparation of the Reference Design Report, site studies and cost estimate

In each of these areas, the review should address both the laboratory and university efforts as appropriate, and should present the plans for developing the appropriate industrial engagement. We also ask that the intended development of the activities in each area over the next several years be indicated, and that the collaborative connections with research groups outside the US be noted.

The ILC detector R&D effort in US will be covered in a separate review.

We will ask the consultants to advise us on all aspects of the US component of the GDE/ART activities. We will ask them to provide feedback to ART during the closeout of the review. We also request confidential statements from the consultants that will serve as the basis for written evaluation of the program by the DOE and NSF. The questions for the consultants to consider in making their evaluations are appended.

Paul Grannis will chair the review and serve as the primary contact for the review. Jon Kotcher will be the primary NSF liaison to the review. Together, Grannis and Kotcher will prepare the final program evaluation.

We ask that talks and supporting materials be made available through a web site prior to the review to aid the preparation by our consultants. This is particularly important for this first-ever ART review so as to provide the basis for our consultants to gain a broad overview this new program.

We look forward to this first formal review of the US R&D program for the ILC, and hope, in addition to providing the basis for the DOE and NSF evaluation, that it will give a useful opportunity for ART to make its own evaluation at this formative juncture.

Sincerely,

Robin Staffin
Associate Director
DOE Office of High Energy Physics

Joseph Dehmer
Director
NSF Division of Physics

Questions for Consultants

This is the first DOE/NSF review of the Americas Regional Team effort on the ILC R&D program, so it is appropriate to take a broad view of the US ILC activities. We ask that the consultants examine the overall structure of the ART effort as it is being initiated, to help guide its organization as well as commenting on the quality of the R&D efforts. Listed below are some questions on which we seek advice, but the consultants are encouraged to expand on these as they see fit.

Goals: Are the R&D goals for ART appropriate given the world-wide ILC planning? Is the effort on preparation of the Reference Design Report/cost estimate and the future development of a technical design report appropriate? Do the goals meet the stated desire to propose a bid to host within the US?

Scope and quality of the R&D: Is the scope of US ILC R&D appropriately matched to the GDE needs? Are the R&D objectives and milestones well formulated? Are the groups conducting the work well matched to carry out the program? Are the plans for industrialization of components well formulated?

Resources: Are the planned resources adequate to carry out the planned program? Are the resource allocations to the individual areas in the ILC R&D program appropriately balanced? Are there areas where there should be expanded or reduced effort?

Management: Is ART organized so as to guide the US ILC R&D effectively? Is the integration of the ART organization into the broader GDE functioning well? Are the management roles and tools well defined and well matched to the effort. Are the mechanisms for establishing priorities and conducting proposal reviews suitable.

DRAFT AGENDA -- ILC AMERICAS REGIONAL TEAM REVIEW

April 4-6, Fermilab

April 4				WBS	Speaker
		Duration			
8:30 AM	9:00 AM	0:30	Closed session		
9:00 AM	10:00 AM	1:00	Overview of GDE efforts; ART organization and international context, FY06 overview; FY07 planning	1.x	Dugan (GDE/Cornell)
talks on R&D program, also outlining the effort supporting RDR design issues -------					|
10:00 AM	10:30 AM	0:30	Reference design effort overview	2.1, 3.1	Raubenheimer (SLAC)
10:30 AM	11:00 AM	0:30	Break		|
11:00 AM	11:30 AM	0:30	electron and positron source R&D	2.3, 3.3, 2.4, 3.4	Sheppard (SLAC)
11:30 AM	12:15 PM	0:45	damping rings R&D	2.5, 3.5	K. J. Kim (ANL)
12:15 PM	1:15 PM	1:00	lunch		
1:15 PM	1:45 PM	0:30	ring to main linac R&D	2.6, 3.6	P. Tenenbaum (SLAC)
1:45 PM	2:45 PM	1:00	cavity and cryomodule R&D	2.9, 3.9	Mishra (Fermilab)
2:45 PM	3:25 PM	0:40	rf systems R&D	2.8, 3.8	Adolphsen (SLAC)
3:25 PM	3:55 PM	0:30	Break		|
3:55 PM	4:45 PM	0:50	Beam delivery and MDI R&D, and ESA facility	2.10, 3.10, 5.10.2	Seryi (SLAC)
4:45 PM	6:00 PM	1:15	Closed session		
6:30 PM			Dinner for presenters, consultants, observers		
April 5					
8:30 AM	9:00 AM	0:30	Global systems	2.2, 3.2	Larsen (SLAC)
9:00 AM	9:30 AM	0:30	LET, ML optics, instumentation	2.7, 3.7	Solyak (Fermilab)
9:30 AM	10:15 AM	0:45	Infrastructure and test facilities in US (ILCTA, ESB)	5.8, 5.9	Kephart (Fermilab)
10:15 AM	10:45 AM	0:30	Break		
10:45 AM	11:15 AM	0:30	R&D at international test facilities (TTF, ATF, ATF2)	5.5, 5.10.1	Ross (SLAC)
11:15 AM	12:00 PM	0:45	Cost estimation studies	4.x	Garbincius (Fermilab)
12:00 PM	1:00 PM	1:00	lunch		
1:00 PM	1:30 PM	0:30	Availability and operations	2.2.1	Himel (SLAC)
1:30 PM	2:00 PM	0:30	Civil engineering, site development	2.11,3.11	Kuchler (Fermilab)
2:00 PM	3:00 PM	1:00	Open time for consultants to work with ART experts		
3:00 PM	4:00 PM	1:00	ART wrap up, answers to questions, discussion		Dugan, all
4:00 PM	6:00 PM	2:00	closed session for discussion by consultants		
April 6					
8:30 AM	9:15 AM	0:45	closed session		
9:15 AM	10:00 AM	0:45	Closeout with ART		
			End of review		