Report of the 1st Meeting of the ILC Machine Advisory Committee

FNAL, Apr 6-7/06

Committee: Takaaki Furuya, KEK; Günther Geschonke, CERN; Mike Harrison, BNL; In-Soo Ko, PAL; Philippe Lebrun, CERN; Bernd Loehr, DESY; Shin-ichi Kurokawa, KEK (ex-officio); Dave McGinnis, FNAL; Katsunobu Oide, KEK; Burt Richter, SLAC; Lenny Rivkin, PSI; Claus Rode, TJL; Roy Rubinstein, FNAL (Secretary); John Seeman, SLAC; Ferdinand Willeke, DESY (Chair).

Apologies: Y. Shatunov; BINP, N. Holtkamp, ORNL.

Introduction

A first meeting of the Machine Advisory Committee (MAC) for the design of the International Linear Collider (ILC) was held on April 6-7, 2006 at Fermi National Accelerator Laboratory. The committee was charged to review the baseline configuration (BC) and the corresponding reference design (RD) of the ILC with respect to consistency and soundness of the design, its capability to achieve the performance goals as defined by the requirements of the physics program, and the possibility to upgrade it to higher beam energy. The committee was further asked to review the process of producing the design and to comment on the credibility of the cost estimate. The committee's mandate is appended to this report.

The meeting consisted of two half-days of plenary presentations by Global Design Effort (GDE) members on the status of the design and the design process and concluded with a half-day of executive session. The meeting agenda is appended to this report.

The committee would like to express its regrets that due to the limited time available for this first ILC-MAC meeting, it did not succeed in meeting the entire scope of the demanding charge defined by the International Linear Collider Steering Committee (ILCSC). The committee points out that more time should be allocated for future MAC meetings.

The committee organized its findings, comments and recommendations around the following topics:

- General comments
- Baseline configuration of the ILC
- Choice of the accelerating gradient
- Strategy for upgrading to higher energy
- RF systems
- Change control
- Cost and cost estimation
- Availability aspects
- Civil construction and conventional facilities
- R&D program
- Communication

General Comments

An overview of the ILC baseline configuration and the management structure implemented to transform this configuration into the reference design report (RDR), the corresponding preliminary plans for research and development (R&D) of the required hardware components, as well as the cost estimate procedure to be applied to this design and to be integrated into the RDR, were presented to the committee.

- The committee was very impressed by the detailed and systematic design work already accomplished in a very short amount of time. The committee recognizes that the design work is performed under unusual and difficult circumstances in that the central design team, the GDE, has no authority over the funds and personnel resources needed to carry out the design work and the R&D efforts in the three world regions, and that the design and R&D work is carried out by many groups scattered around the world.

Within the very short period of about one year, the GDE has organized itself to overcome some of the difficulties associated with this configuration by creating several overseeing boards to provide global guidance for the individual regional design teams. The committee observes that a fairly detailed and comprehensive, in most areas quite reasonable, design is being produced as the result of this effort. The baseline configuration uses, in general, technology which can be considered available or within reach. Options for more advanced technologies which might provide advantages in performance or cost savings are kept open whenever they appear to be a not stretched-too-far alternative. The GDE has demonstrated a reasonable balance between forward-looking and pragmatism, driven by the need to provide a first credible cost estimate in the near future, and a moderate optimism by leaving room for innovative solutions.

- The committee endorses this approach and would like to congratulate the GDE for the impressive achievements along the way towards an RDR.

- The committee observes that the ILC design is so far the result of a collection of bottom-up subsystem designs which are at the present stage primarily driven by performance considerations and to a much lesser degree by cost considerations. The committee is concerned about the fact that the design has evolved in a bottom-up fashion and recognizes that complementing this approach by a top-down revision may be a difficult task.

A number of boards have been created to execute guidance and coordination of the design and R&D efforts. These include an executive board, an RDR management board, a change control board, an R&D board and a cost control board.

- The committee notes that these boards are in the process of organizing their work and defining their interactions and competences. The committee acknowledges that attention is also given to the necessity to avoid conflicts and to provide effective interfacing between the subsystems. The committee is looking forward to see these boards evolving quickly into the effective management organization needed to successfully carry out the GDE tasks.

- The committee believes that the overall human resources provided for the GDE of about thirty full-time equivalents (FTE) appears to be marginal for coordination of the present stage of the design and R&D effort. Members of the GDE have been chosen based on their technical competence and to a lesser degree for regional balance. The committee would like to endorse this choice.

- The committee discussed the overall organizational structure in which the GDE is embedded and concluded that it constitutes a functioning framework for the GDE to carry out its mission successfully.

Baseline Configuration of the ILC

The baseline configuration and the associated performance goals are driven by the requirements of the physics program, based on a document previously provided by a subcommittee of ILCSC.

- The committee did not see a clear path of how the results of the design effort and the difficulties to achieve the performance goals are fed back to the physics community. This is considered necessary in order to arrive at an optimum design which pushes the correct set of parameters. The committee would like to see a formal procedure which will provide this function and assure that the needs of the physics community are taken into consideration. Such a procedure would also help to avoid ambiguities about the interface of detector and accelerator and it would allow making sure that the evolving physics case is taken into account appropriately in the design specifications and considerations. The committee wishes to point out that the evolution of the physics case will likely be influenced by the physics results of the upcoming Large Hadron Collider (LHC) at CERN.

- The committee did not see clearly where the responsibility for determining the number and configuration of the interaction region(s) lies. While this is not part of the responsibilities of the committee, these decisions affect the beam delivery system and need to be made relatively soon for both the machine and detector designs.

- A well established procedure, as proposed above, would also considerably ease detector performance and cost optimization. An example of a problem to be avoided is a possible miscommunication between accelerator and detector physicists about the specification of beam energy spread during collisions which the committee felt appeared in some of the meeting presentations and discussions.

The basic beam and performance parameters used in the base line configuration occupy a finite volume in parameters space.

- The committee would like to understand in greater detail what the impact on cost and/or possible peak performance are and how much margin and safety is obtained by this expansion of parameter space. The committee deems it important that the GDE understands these trade-offs well.

The committee would like to comment on some specific design features:

- The committee notes that while the electron source of the ILC consists of two parallel RF guns to provide redundancy and enhance availability, they are both driven by a common klystron, which seems inconsistent.

- The committee discussed the change of the RF frequency to 650 MHz in the damping rings. While the committee appreciates that timing considerations may be very important, the committee would like to comment that neither klystrons nor cavities are available for this

operating frequency. While the committee, however, believes that it might be possible to scale existing designs (at 500 MHz or 714 MHz) for this operating frequency with a moderate effort, the committee remains concerned about the impact on the cost.

- The committee takes further note that for timing purposes, a 1.3 km insert is anticipated in the positron linac which might be used for enhanced diagnostics. The committee is uneasy about the balance between benefit and costs. The committee encourages the design teams to keep looking for more elegant and cost effective alternatives.

- The committee wonders whether the timing scheme is compatible with the upgrade to 1 TeV.

Choice of the Accelerating Gradient

The choice of the accelerating gradient of the accelerating structures of the ILC main linac is one of the key parameters of the facility which has a large impact on most aspects of the overall design such as the overall length of the main linac.

The committee was presented with a rationale that the impact of the accelerating gradient on the project cost is relatively small (smaller than 10%) over a wide range between approximately 25 MV/m and 45 MV/m.

- The committee notes that the corresponding cost model does not take into account that higher gradients are more difficult to achieve. This is expected to have a considerable impact on cost due to more elaborate preparation procedures for the accelerating structures including iterations and repetitive applications to narrow the distribution of the achieved gradients to a tolerable level.

- The committee believes that the present choice of a peak accelerating gradient of 35 MV/m and an average accelerating gradient of 31.5 MV/m does not appear at this point as an unreasonable long-term goal. This belief is based on the rather encouraging results on peak performance of TESLA-type superconducting cavities, and the prospects of even higher gradients by using different cavity shapes as evidenced by recent results on single cell superconducting cavities at KEK and Cornell, or the promising results achieved with cavities made of large-grain or single-grain niobium.

- The committee however wishes to point out that this performance is by no means in hand at present. If the gradient value taken for the RD was to be chosen more in line with the general design principles (as observed above), the design accelerating gradient would be significantly lower.

- The committee encourages the design team to be prepared to take a fresh look at what the optimum design accelerating gradient should be as soon as more information from the R&D program becomes available.

- The committee believes that a very aggressive, world-wide, well-coordinated, R&D program is necessary to defend the case of an accelerating gradient as large as 35 MV/m. The committee recommends that this R&D effort have a very high priority in the overall ILC R&D plan. The committee would like to learn about the plan at its next meeting.

The committee notes that some spread in the anticipated cavity performance has already been taken into account in the choice of the average accelerating gradient value.

- Sorting of accelerating structures or phasing offset may be considered as methods to cope with a larger spread in accelerating gradient, thereby avoiding the effort of reprocessing weak accelerating structures and loosening the specification on the required minimum performance of individual resonators. This naturally would require a correction of the anticipated ratio of peak to average performance.

- The committee endorses the effort to achieve a higher accelerating gradient by optimization of the cavity shape and the effort to reduce the cavity preparation effort by the use of new materials such as large grain niobium, given that these efforts are appropriately prioritized in view of the more important issue of providing reliably high gradient cavities based on the TESLA type cavities and the well established processing methods. A worldwide coordination of the cavity innovation program is strongly encouraged.

Strategy for upgrading to higher energy

The ILC baseline design for a center of mass energy E_{cm} of 500 GeV includes the capability and a roadmap for upgrading the facility to E_{cm} = 1 TeV. The main element of the upgrade plan is that the geometry of the beam delivery system (BDS) allows an upgrade to 1 TeV (by replacing and adding beam transport elements in the BDS) and by extending at some future time both the electron and the positron tunnels at their low energy ends to provide the space for additional accelerating structures and RF systems.

- The committee can see why the GDE considers the provision of additional tunnel in the first stage of the project for the purpose of upgrading to higher energy at a later time as unattractive, despite the fact that the overall cost for the 1TeV machine is expected to be lower if one would proceed that way.

- The committee remarks that the GDE is aware that this upgrade strategy implies that the industrialization program and the learning curve in industrial production of cryostats, cavities and modulators will have to be repeated, that the cost impact of this way of performing the upgrade has not yet been estimated.

- The committee did not converge to a clear recommendation concerning alternative upgrade strategies. It wants to point out however, that a possible strategy exists which consists in starting with a longer tunnel and a lower gradient for the 500 GeV machine. According to the cost versus gradient curve shown to the committee, this is expected to have only relatively little impact on the cost for gradients as low as 25 MV/m, especially if one takes into account that this curve may be too optimistic for the high gradient range. The 1 TeV option could then be implemented by upgrading the RF power and would rely on further progress in reliably producing cavities with larger gradients at no additional cost before cavity mass production starts. Proceeding this way does not exclude the option to pursue the present upgrade plan with no extra penalty if high gradients cannot be achieved. The advantage of this procedure would be (provided that all these assumptions can be verified) to combine a reduced risk of missing the desired performance of the 500 GeV main linacs with the option for a presumably significantly less costly upgrade to 1 TeV. The committee thus wants to make sure that this option is discussed and well understood by the GDE.

RF Systems

The status of the design of the main linac RF systems was presented to the committee. The baseline design consists of TESLA type cavities and cryostat with minor modifications and adaptations. The option for alternative cavity shape and alternative cavity material is kept open and will be developed in the R&D program. Modifications and improvements with respect to the TESLA design are also anticipated in the coupler and tuner systems.

The baseline for the pulsed RF high voltage supply consists of a bouncer-circuit modulator, which is an established technology.

An R&D program is underway to develop a modulator with a modular architecture consisting of Marx generator cards which allow a parallel charging and a serial discharging of the electrical power into the klystron. This design promises a considerable cost reduction due to mass-producibility and enhanced availability due to the ease of providing margin by just adding cards. The system is also quite compact which should help to economize space in the tunnel.

- The committee believes that this is a worthwhile development and wants to encourage further R&D effort.

The committee notes that a satisfactory solution for the10 MW klystron is not yet at hand.

- The committee notes that an appropriate R&D program which follows several paths at this point is underway to arrive at an improved version of an L-band klystron. The committee endorses and encourages these R&D activities.

The committee notes that the RF control is very challenging.

- It is unclear to the committee why amplitude variation at flat-top needs to be limited to 0.1%.

While there is a baseline RF distribution scheme with circulators to handle the reflected RF power, alternative RF distribution schemes without circulators with presumably lower costs are being considered.

- The committee would like to encourage this effort.

Change Control

The mission, the working model, and the first actions of the change control board were presented to the committee as one of the important management tools to maintain consistent baseline design while the elements of the design are evolving as the result of the ongoing effort to improve on performance, consistency and cost.

- The committee is pleased to see that this important design instrument has already started its activities. However, the committee is concerned with the implementation of present change control and believes that significant difficulties could arise once a large number of design changes is requested along the way to the RDR, including those resulting from R&D programs.

- The committee would like to recommend establishing clear rules of authorization of change requests. This way, some filtering of the change requests is already achieved before the board has to deal with them.

- The committee takes note that no impact criteria have been defined. Once impact criteria have been established, clear rules for escalation and communication of change requests are encouraged as well. The interface between the RDR management board and the change control board must be defined clearly.

- The committee would like to emphasize that CCB decisions must be prepared and communicated with all the technical groups. Each group must be informed of a change request and asked for its impact on their system.

- The committee proposes further the consideration of differentiating between the acceptance procedure for requested changes and the execution and implementation of changes while maintaining a consistent design. The latter task cannot be provided by a committee but requires considerable technical and engineering support.

- The committee is concerned with the present level of version control. In order to maintain a series of reference designs to be able to perform consistent calculations, simulations and comparisons, a higher level of formality and the use of more sophisticated tools is probably necessary.

- The committee encourages the GDE to make cost considerations an important element in the change control procedure. The committee is not sure that some recent change requests would have been accepted by CCB if cost considerations had been included in the acceptance criteria. (Possible examples are the change to 650 MHz in damping ring RF frequency and the 1.3 km insert in the positron main linac tunnel for timing purposes).

Cost and Cost Estimation

A detailed description of the cost models and methodology for the RDR cost estimate was presented to the committee.

- The committee endorses plans to provide a region-independent cost estimate and the rules for translating the cost, or part of the cost, into cost estimates according to the rules in each region.

The committee did not see any plans on how to execute cost control on the evolving design.

- Since the design effort so far has been primarily driven by performance considerations, the committee is concerned that the resulting design will resist attempts of cost reduction. The committee feels that the GDE should be prepared for larger design changes to arrive at a concept which is robust with respect to cost reduction.

- The committee heard little about the methods to encourage or enforce cost consciousness in the design process. The committee is moreover somewhat concerned about the concept of producing first a performance driven design and then introducing cost consideration in a second stage. In order to arrive at a substantial cost reduction in the second stage, very painful design changes might be necessary which may be unfeasible to implement at this later time. The committee

encourages the GDE to introduce cost consciousness immediately as an integral part of the design

- The committee finds it difficult to offer direct advice on how to encourage and assure cost consciousness throughout the design team. The committee, however, feels that this task can not primarily rest on the shoulders of the area and system managers but has the opinion that it is a primary responsibility of the GDE. Cost reviews have been mentioned as a possible instrument of cost control in the design phase. The committee suggests charging the RDR Management Board explicitly with the task of providing guidance for cost conscious design, the encouragement of cost-saving design decisions and the rejection of costly design approaches. The committee notes that this task naturally has to overcome the resistance of the area and system providers which feel primarily responsible to deliver a working design which will meet the performance goals. It will be vitally important to strengthen the authority of the Board (if this is the body which will be assigned to make cost-based decisions) to assure a successful outcome of this task.

- The committee also would like to suggest including cost consideration at an early stage in the industrialization process. The industrialization process for any technical system or major component should not be started up without a clear view of how much responsibility for achieving the performance goals is deferred to industry (the decision of build-to-print or build-to-performance).

- The committee understands that it is very important to make use of the large momentum which has been developed since the ILC design effort has started, and the committee would not like to see this effort slowing down. Given the large amount of work to be done and given the anticipated accuracy of the cost estimate of 20%, however, the committee is concerned that it might be difficult to succeed with this task by the current goal of the end of 2006.

Availability Aspects

The committee takes note that the decision for a double tunnel is based primarily on availability considerations.

- The committee would like to make sure that other considerations such as safety have been taken into account in the layout of the tunnels.

- The committee is concerned that some of the assumed improvements in component reliability might be unrealistic. The committee would like to hear more details in the future.

Civil Construction and Conventional Facilities

A review of technical site considerations and planning for conventional facilities based on evaluations of three site examples was presented to the committee. One of the important conclusions from the assessment is that a deep tunnel will have a number of advantages.

- The committee considers these activities well underway, and recommends that sufficient attention is paid to, and a considerable effort is devoted to, the issues associated with conventional facilities.

The committee was informed about a bid-to-host activity within the US in order to provide the technical preparation of the US site proposal.

- The committee is unsure whether now is the optimum time to proceed with these activities. The committee is aware that these activities are not within the responsibility of the GDE or the Americas Regional Team (ART) R&D program.

R&D Program

The activities of the R&D board of the GDE were presented to the committee. The difficult task of the R&D board is to coordinate the worldwide R&D activities for the ILC without any direct authority over R&D funds. The first activities of the board are to work out a prioritization of the ongoing and planned R&D activities, and avoid unnecessary duplication.

- The committee did not see an overall R&D plan with milestones. The committee would like to encourage the GDE to aggressively pursue its plans to develop an explicit R&D plan including milestones.

- The committee wants to point out that the communication between the R&D activities in the regions and the GDE must be improved. The regional directors bear the primary responsibility for this.

- Formal relations between the ILC R&D program in the US and the GDE R&D board are being established, which is expected to provide considerable progress towards a well coordinated R&D program. The committee welcomes this as an important step towards better overall coordination. The possibilities for the GDE to influence the ongoing and planned R&D activities in Europe and Asia, however, are quite limited and so far not very successful. The committee believes that the regional directors must take action in order to ensure better overall coordination.

- At this point, the committee rates the overall coordination and the overall focus of the R&D program as unsatisfactory. The committee did not see effective instruments being developed to provide the overall coordination and the focus. The regional directors should work with the regional ILC sub-system technical coordinators as a group to develop a focused program in each technical area.

- The committee is thus very concerned about the present status of the worldwide R&D program. Given the large amount of work to be performed in order to prepare for construction of the ILC, the present lack of sufficient R&D funds, and the current regional imbalance in those available will, if they persist, create a serious problem for the ILC.

Communication

Communications among the GDE members and between GDE and the design and R&D teams was raised as one area of concern by the director of GDE to the ILCMAC. The committee noticed that some progress has been made recently to overcome the difficulties with world-wide distributed design and R&D efforts. Besides the use of email, telephone and video conferences, there is a centralized agenda server located at CERN, there are new communications tools in use such as WEBEX, and a central database for the ILC provided by DESY is in preparation.

- The committee feels that perhaps some of the communication problems are related to the regional control of the funds to carry out R&D and design work, to different regional interests, and to different views on the relationship of ILC activities to other activities in a region.

- The committee recognizes the special responsibility of the regional directors to avoid misunderstanding and misinterpretation between GDE and regional activities. It is important that relevant information on ILC related activities in the regions is brought to the attention of the GDE and be coordinated with initiatives of the GDE. The committee would like to point out that it should also be the responsibility of the ILCSC to make use of its influence in the regions on these matters.

- As noted earlier, the committee further suggests that the communications with the detector and the physics community of the ILC should be strengthened by more formal relationships and regular communications. Well-organized communication between GDE and the ILC physics community is important especially to reach consensus on the design issues that have significant impact on physics capabilities. The committee believes that well established communication between GDE and the ILC physics community should be institutionalized, and that ILCSC should give some guidance in this area.

- The committee would like to mention that communication is a serious issue as such and needs attention and resources. The committee suggests that the ILC communication group should also look into possible problems of communications within GDE and the ILC design and R&D teams. Replacements for the unscheduled exchange of information that takes place within a laboratory must be provided. The committee wants to point out that these problems are taken rather seriously by private industry, and professional support in these matters is available and can be made use of.

Topics to be addressed at the next MAC meeting

The committee would like to GDE to provide more technical and detailed information at the next ILCMAC meeting. In particular, the committee would like to learn in more detail about

- Availability, safety and machine protection aspects.

- Detailed information on the progress of the configuration and the cost estimate.

- The damping rings are three rings of Tevatron (or HERA) size. MAC would like more information on their design at the next meeting.

- R&D program on superconducting RF cavity development.

- Low Level RF Control

Next MAC Meeting

The next ILC-MAC meeting is foreseen on Sept 20/21/22 2006 (2 ½ days).
The location is yet to be decided.

22 March 06

ILC Machine Advisory Committee (MAC) Mandate

1. The oversight of Global Design Effort (GDE) activities is by the International Linear Collider Steering Committee (ILCSC); MAC will assist ILCSC in one of ILCSC's oversight functions.
2. MAC will meet two or three times per year until ILCSC and the International Committee for Future Accelerators (ICFA) approve the Reference Design Report (RDR).
3. MAC will review GDE accelerator activities; it will report to ILCSC.
4. MAC will review the following aspects of the Baseline Configuration Document (BCD):

a) Is the conclusion of BCD reasonable and consistent with the overall ILC system? Is the BCD design consistent? Is it optimized to produce maximum physics output? Is the plan to upgrade the machine to 1 TeV appropriate?
b) Are there any BCD items that MAC feels should be reconsidered?
c) Are there any issues that MAC thinks should be discussed in a broader context by ILCSC?

5. MAC will review the process that will lead to the RDR:

a) Is the organization of GDE appropriate for this activity?
b) Is the accelerator design process appropriate?
c) Is the cost estimate process appropriate?
d) Are the milestones envisioned in the RDR appropriate and realistic?

6. In addition, MAC will review the RDR for the following:

a) Is the RDR design reasonable and consistent with the overall ILC system? Is the RDR design consistent? Is it optimized to produce maximum physics output? Is the plan to upgrade the machine to 1 TeV appropriate?
b) Is the estimated cost reasonable?
c) Is the envisioned project schedule reasonable?

AGENDA

Thursday 06 April 2006

Review of the BCD (13:30->17:30)

13:50	**Overview** (30') (Slides) `Process and Highlights`	Barry Barish (*Caltech*)
14:20	**Technical Features of the BCD** (1h00') (Slides)	Tor Raubenheimer (*SLAC*)
15:20	break	
15:50	**The Main Linac** (45') (Slides)	Chris Adolphsen (*SLAC*)
16:35	**Conventional Facilities** (45') (Slides)	Victor Kuchler (*Fermilab*)
17:20	**Change Control Board (CCB) Report** (30') (Slides)	Nobu Toge (*KEK*)

Friday 07 April 2006

Efforts on the Reference Design Report and R&D Program towards the TDR (08:50->12:20)

08:50	**Overview** (30') (Slides) `Organization, Schedule, Approach and Goals`	Barry Barish (*Caltech*)
09:20	**Design Cost Board (DCB) Report** (30') (Slides)	Peter Garbincius (*FNAL*)
09:50	**RDR Management Accelerator Design Towards the RDR** (30') (Slides)	Nicholas Walker (*DESY*)
10:20	break	
10:50	**Global R&D Board** (30') (Slides)	William J. Willis (*Columbia*)
11:20	**European Regional Program** (20') (Slides)	Brian Foster (*University of Oxford*)
11:40	**Asian Regional Program** (20') (Slides)	Kaoru Yokoya (*KEK*)
12:00	**Americas Regional Program** (20') (Slides)	Gerald Dugan (*Cornell University*)