# Report on the AAP Review in Oxford

January 6-8, 2010, Oxford, UK

Overview

## Participants:

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(*) apologies received

(**) by phone, part time

## Date & Venue

January 6-8, 2010; Denys Wilkinson Laboratory, Oxford, UK.

## Weather

Existing. Record snowstorm.

## Introduction

The second AAP review dealt exclusively with the Strawman Baseline Proposal SB2009 that had been submitted to the AAP on December 18, 2009, as a written report.

This Proposal was the result of a one-year process directed by the Project Managers, aimed at achieving cost savings and consolidating the design documented in the RDR baseline report. A number of items in that Baseline identified as cost-drivers, items representing a relatively large fraction of the total cost, were studied in detail. The two largest cost-drivers: the cavity field gradient and the total collision energy were excluded from this study, since the latter is a basic physics specification and the former is the subject of continued global development. The remaining cost-drivers are each at most a few per cent of the total cost. Evidently a decrease in total cost can be achieved only by an accumulation of savings in individual items. As the name implies, the Proposal is presented in the form of a possible new baseline, comprising a number of items that while somewhat interconnected could all be adopted at one time.

The AAP members had several opportunities to absorb the material documented in the SB2009 report e.g. in dedicated workshops of the area leaders which were attended by some of the AAP members. When the document was released the AAP members were quickly able to master the contents and to start critical discussions by the beginning of the review. This enabled the presentations to be in good part a response to questions from the AAP, and allowed the AAP members to reach conclusions during two days and report to the Project Managers and Presenters on the third day.

The rapid study of the document by the AAP was made possible by the very well-organized structure of the Proposal by the Project-Managers, and its clear presentation in the Proposal. Links between different areas do exist in some cases and they are clearly described. The AAP was able to address one area at a time, concluding that it was not necessary to recommend action on a whole new Baseline at this time.

## Initial Observations and Principles for the Evaluation

There is a set of main observations that do not refer to individual areas, but apply to the whole project and the strategy for evaluating its cost.

The cost savings laid out in the Proposal sum up to 12.6% of the total cost albeit at the expense of increasing the risk to reaching the luminosity goals. The AAP interpret this valuable conclusion as showing that a close study during one year indicates that no important, large savings have emerged through changes of design and configuration. The immediate conclusion is

*The technically driven RDR design is fairly mature and the cost not so far away from the optimum.*

This is an indication that the cost is driven by the technology and requirements of the linear collider.

Cost savings have been examined addressing modifications of the configuration. The cost of a technical unit itself has not been further studied at this time and inevitably changes (in both directions) will occur. The fact that most savings in an area are at the few per cent level is an important factor characterizing cost reduction, a conclusion that was not at all evident before this study.

The AAP acknowledges that cost containment for the ILC at the level of the RDR estimate is an important goal. As with all large construction projects cost variations amongst major drivers are to be expected and they will vary as a function of time. These variations are the result of both a better understanding of the cost composition, of progress in optimization and of external influences such as the variations in cost of raw material and external services. An important goal of SB2009 is to identify savings that may prepare for cost increases in other areas so as to compensate overall.

*The AAP acknowledges the importance of containing the cost of the ILC at the level of the RDR estimate.*

The proposal does not include a consideration of the running cost, consistent with the approach taken in the RDR. When looking at cost optimization as a whole the AAP observes that the operating costs can be driven up by changes in the design made to reduce construction costs. Reducing luminosity and increasing running time is one example.

*Cost optimizations for design and construction of the ILC must include a consideration of their impact on the running cost. To understand the running costs, a model is needed for the luminosity during the first few years of operation as a function of risk.*

The requirement for cost containment has to be contrasted with the performance requirements laid down in the Parameter Document[1] for the ILC which comprises amongst others energy reach and integrated luminosity.

*The ILC must be able to operate between 200 and 500 GeV.*

*The ILC should be able to supply 500 $fb^{-1}$ in a period of four years.*

While it is conceivable that with more physics guidance from the LHC these goals may be refined it is clear that at this time these assumptions guarantee maximum physics return for the ILC, i.e. a 500 GeV machine. Irrespective of the outcome of such discussions it is not in the purview of the AAP to question these directives.

When considering changes to the RDR baseline the AAP paid attention to the readiness of the design towards the end of Technical Phase II in 2012. Components that require considerable R&D with some uncertainty in the outcome should not enter the baseline at this time even if the benefits are seen to be large:

*The work of Technical Design Phases I and II must maintain a viable and hopefully improved solution for the design of the ILC.*

Maintaining this construction readiness is an important element in the worldwide physics strategy discussion at the point in time when the first LHC results will be available.

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[1] ILCSC parameters subcommittee (Chair R Heuer): Parameters for the Linar Collider, Update November 2006, http://www.linearcollider.org/newsline/pdfs/20061207_LC_Parameters_Novfinal.pdf

These principles are consistent with the ones applied during the first review.

## Cost Impact of SB2009

The effort of SB2009 has sensitized and in the end, it seems, has stimulated an overall integration effort for the ILC. It has also produced a cost saving of up to 12.6% over the RDR cost estimate, close to 1bn ILCU. The first benefit of this exercise is a minor update of the RDR cost estimate due to better understanding of the assumptions in the arrangement of some components. A systematic analysis of the cost drivers by accelerator area and component showed that although the absolute magnitude of the cost savings from some components of SB2009, such as Conventional Facilities and Support (CFS), is substantial, the fractional saving with respect to the total cost remain small with the notable exception of the gradient (or equivalently the total energy) and RF power. The total beam power (luminosity) is the second largest single cost driver and will be further considered in this report. The cost savings can be categorized into three groups (1) single tunnel; (2) lower RF power operation; (3) consolidation of the central region.

*Single tunnel*: The consolidation of two tunnels into one for the linac eliminates 28 km of tunnels and introduces a cost savings, however, at a surprisingly low level of about 3%. The civil engineering savings is partially offset by additional cost in RF distribution and cooling. Some aspects of the RF power distribution are coupled to the site geology and hence reflected in the cost estimate in a rather complicated fashion.

> *The cost benefit of the single tunnel solution is at the level of about 2%.*

*Low Power Option*: This change consists of halving the installed RF power with the corresponding cost benefit and of regaining the lost half of the luminosity by better focusing of the beams at essentially no extra cost. This is the largest single cost driver of SB2009.

> *The cost benefit of halving the RF power is about 4%.*

It is reassuring to be aware of this savings potential in the project should it become necessary to stage the project or to provide contingency in the project. Provisions should be made that the ILC baseline design be technically compatible with a half-power installation, irrespective of further evaluation of the Low Power Option.

*Consolidation of the central region*: The number of tunnels and elements that will be housed may be consolidated in a fewer tunnels and fewer elements. This change also places the positron source in the Beam Delivery Section rather than at the 150 GeV point of the main linac.

> *The cost savings related to the Consolidation of the central region are about 1.6%.*

The guiding argument in the discussion of the Central Region is simplicity of the tunnel layout.

*Overall cost impact*: The AAP has studied the cost savings for a machine that fulfills the physics requirements for the ILC. Concerning luminosity these are driven by the goal to accumulate 500 $fb^{-1}$ over a period of four years. The energy range is set to be 200 - 500 GeV. Whilst the peak energy is the single largest cost driver the luminosity requirement is the next big handle on the cost.

## Management Approach to SB2009

SB2009 has been a very valuable process. It has provided a good understanding of the RDR cost drivers and their derivatives with respect to machine performance and risk. The three Project Managers are to be commended for the excellent manner in which they guided and managed the study. The work was of high quality and was completed in a timely manner.

Opportunities for major cost reduction did not emerge from the study. While regrettable, this demonstrates that the RDR cost estimate is mature and comprehensive. Taken as a whole, the configuration changes considered in SB2009 would provide a cost reduction of 12.6%. Individual elements of this cumulative savings are each no more than a few per cent and many either add disproportionate risk or significantly reduce operational flexibility. Accordingly, the AAP recommends against adopting SB2009 as the new baseline. However the AAP did see merit in adopting some of the elements of SB2009 into the baseline and recommends that others be studied further because they look very attractive.

> *The AAP does not recommend adopting SB2009 as a whole as the new baseline.*

When implementing individual changes the AAP recognizes a need for maintaining good cohesion between technical areas and the respective groups. Such cohesion should be instituted in a formal manner under the guidance and leadership of the Project Managers. Hence

> *The AAP recommends that the GDE Management adopt more rigorous configuration control for managing the design effort and that, henceforth, changes to the baseline be processed using the by-now relatively standard change control procedures.*

It should be noted that the original Management Plan of the Engineering and Design Phase, the precursor to the Technical Design Phase, foresaw a Change Review Board on its own. The ideas outlined there should be revisited and adapted to the needs of Technical Phases I and II for the ILC.

## Single tunnel for Main Linac

### Conventional Facilities and Services

The study group for Conventional Facilities and Services (CFS) has carried out a thorough investigation of the seven tunnel configurations that were introduced at the time of the first AAP review. These variants differ in depth and number of tunnels. The studies were carried out in close contact with the various areas groups. Significant progress since the first AAP review is evident.

> *The AAP observes a much improved communication between the CFS group and the technical areas groups.*

SB2009 concentrates on single tunnel configurations which were hence emphasized in the studies. The CFS groups clarified the safety requirements for the single tunnel solution where egress plays a particularly important role. These in-depth studies and discussions with the safety experts show that a single tunnel solution is viable in all three regions. Particular attention must be given to the role of the access shafts.

> *A single tunnel configuration for the ILC will satisfy the safety requirements in all three regions.*

The CFS group responded to the varying regional requirements for the single tunnel, the tunnel diameter being a particular example. The AAP acknowledges that different RF distribution schemes may require different tunnel cross sections or volumes. The AAP is however surprised to see different tunnel diameters used in the different regions for the same RF technology. The range of tunnel diameters from 4.5 m to 5.2 m seemed an unnecessary complication given that the cost varies slower than the tunnel cross section.

*The AAP recommends consolidating the tunnel diameter requirements and to reducing the number of variants to the essential minimum.*

## Overview of RF distribution schemes

The single tunnel poses new requirements on the RF-installation. It was stated that the RDR solution with three cryomodules attached to a 10 MW klystron and modulator is too bulky. The Project Managers showed an implementation of this RDR scheme in a 7.5 m diameter single tunnel. With a larger cross section than the double tunnel RDR implementation this cannot be considered a serious optimization.

There is considerable operational experience from this RF-distribution which should not be abandoned easily. The XFEL, in particular, will supply additional operational experience which could eventually be incorporated into the final design of the ILC.

*The AAP recommends better understanding of the underground requirements for the three cryomodule 10 MW implementation, similar to the RDR baseline until alternate RF distribution techniques have been established.*

Such study affects predominantly the CFS group and is hence largely independent from the development in the RF groups discussed below. It also leaves the operational aspects of this solution unresolved.

The Project Managers decided to concentrate on two RF distribution schemes that have a less bulky footprint in the tunnel. These schemes constitute two extremes: the Distributed RF system goes to small klystrons and modulators to achieve an almost constant density of RF units in the tunnel. The Klystron Cluster scheme concentrates the power sources in a separate (on-surface) building and uses large waveguides to take the RF power to the cryomodules so that there are no active RF components in the tunnel.

## Klystron Cluster RF distribution

The Klystron Cluster RF distribution (KCS) concentrates the klystron and modulators for each 2 x 1.3 km length of cryomodules in a single surface building. The RF power is generated in a gallery of 10 MW klystrons and modulators and fed to the cryomodules in large cross section, over-moded waveguides. Two additional access shafts to the tunnel will be required, however, of only modest diameter to house the waveguides and ancillary supplies.

Variable tap-offs are used to distribute the RF power to the cavities. They are carefully tuned to compensate for the power loss along the waveguide which at 3%/km is small as a result of the chosen propagation mode. The power distribution at the cavities is analogous to the distribution in the RDR and controlled through tuner and input coupler as in the RDR. Excess power is dumped at the respective RF loads at the cavities.

The operational aspects of the KCS system were discussed in the AAP. They are largely the same as for the RDR solution. It is recognized that the KCS system distributes the power to the entire 1.3 km long section of cryomodules. Disabling of power for individual cavities is only possible by diverting the power to the respective loads.

This concept of RF distribution is new and has not been tested in any larger setup. Several hundred MW power will be channeled into the waveguide and finely distributed over the cavities. The distribution luckily is static and passive so that operational failures are not an issue. However, any disruption of the distribution or the excitation of other modes could lead to catastrophic breakdown.

*The AAP recognizes the benefits of the KCS RF scheme and encourages the planned R&D. Handling of the high power levels is a risk and it is acknowledged that a demonstration is needed. A systematic analysis of possible failure modes should be carried out.*

*The acceptance criteria should be defined by the Project Management to understand whether KCS could become the baseline RF distribution. The R&D on this option should be continued.*

## Distributed RF system

The Distributed RF system (DRFS) has been predominantly studied in Japan where the geography does not easily support a concentration of the klystron power in surface buildings. Based on 700 kW klystrons such a scheme fits into a 5.2 m diameter tunnel. The number of klystrons increases by a factor of thirteen. Lifetime of klystrons is consequently a serious concern. The proponents claim that klystrons that are not driven at peak power and with a smaller cathode current density will reach lifetimes of 110000 h or more; a factor of three improvement over the assumed lifetime of the RDR 10 MW klystron. Even with such an improvement the klystrons will fail at a large rate. Downtime can be minimized by preemptive maintenance since the degradation of klystrons is often recognized beforehand.

Such klystrons do not exist yet. There is considerable experience from the 300 kW CW klystrons for KEK-B which have a remarkable track record. The extrapolation to 700 kW pulsed units is hence not too far. Nonetheless it will take a considerable effort to develop these klystrons and in particular to prove that they show the expected lifetime performance. If the lifetime requirements cannot be met a correspondingly larger overhead will be required.

*The AAP recognizes that the fine distribution of RF power generation is a viable solution for the ILC if the performance and cost parameters can be met. R&D into this scheme should continue. However, it is observed that the DRFS scheme imposes operational constraints on the ILC to meet the availability/ luminosity goals.*

## Availability

The AAP very much welcomed an availability study of the single tunnel configurations based on the Monte Carlo code *availsim*. The code takes into account a list of lifetimes of components derived from the experience in various laboratories. In addition to the failure of components it addresses the repair logistics and the time to recovery. Constraints for the recovery arise from the availability of upstream components.

Key elements of this study were the transition to a single tunnel with the 10 MW klystrons in the tunnel, the DRFS scheme and the KCS. Other variants have been examined and the first observation is

*All three variants can be made to work at energies below the peak energy, provided the improvements in magnet power supply and other lifetimes can be met.*

They differ largely in the availability at the peak energy, i.e. the required energy overhead to enable running at the highest energy: the KCS has all high-power RF installations accessible in a separate building with extra hot swappable klystrons so that no downtime is expected from these components that will be repaired as they fail. The DRFS system has many components in the tunnel so that a high failure rate can be expected. However, the impact of a single klystron failure is small (2 to 4 cavities) so that operation may continue. In addition, the DRFS group showed from the experience at KEK-B that an emerging klystron failure is often indicated by the performance of klystrons so that a directed scheme of preemptive maintenance becomes possible. The DRFS group hence relies on a semi-weekly access to the RF components for maintenance.

With such a scheme the availability studies showed that the impact of RF failures at the highest energies can be controlled. The KCS and DRFS schemes are content with 3.5%

and 5% energy overheads respectively, a relatively small difference. The RDR 10 MW solution imposes a larger energy overhead of 10% in the single tunnel operation, a number indicating that there has been no attempt to add redundancy or improve mean time between failure of components.

*The impact of the RF distribution schemes on availability arises only at the highest energies. The KCS and DRFS satisfy these requirements with small energy overhead, albeit the latter imposes additional constraints on the operation of the ILC to satisfy the maintenance.*

*With appropriate overhead all three RF distribution schemes meet the luminosity requirements.*

### Single Tunnel

The cost reductions for the single tunnel solution are comparatively small. Additional arguments favoring a single tunnel are ease of construction and of some aspects of installation. The AAP welcomes these elements of simplification.

The RF distribution in the RDR is based on 10 MW klystrons and corresponding modulators located in the tunnel. An installation of such a scheme together with the beam line necessitates a larger tunnel diameter or alcoves to house the infrastructure. Such a scheme has not been worked out.

The transition to a single tunnel is hence coupled with the development of new RF distribution schemes.

*The AAP supports the transition to a single tunnel provided that at least one of the RF distribution schemes can be demonstrated to work.*

*A change control process should be put in place that will define the acceptance criteria for either RF solution and examine the side effects before adopting the single tunnel solution as the new baseline. The R&D for the RF distribution schemes should be adapted accordingly.*

*The CFS implications of the single tunnel solution should be fully explored and should include an assessment of the installation procedure.*

## Low Power Option

The Low Power Option is a plan to reduce the number of bunches per bunch train and hence the average beam power by a factor of two. This option halves the number of klystrons and modulators saving considerable money. It also allows the circumference of the DR to be halved while leaving all DR risks essentially unchanged.

The plan includes the entire infrastructure for nominal operation (AC power distribution and water cooling and space) so that the RF can be added back in later with total cost for this nominal power option being little increased from implementing it in the first place. That is, the Low Power Option can be thought of as a staged construction where the peak luminosity that can be reached is halved until the upgrade is done.

*The plans for halving the installed RF power in the Low Power Option look technically sound.*

The Low Power Option as presented includes improvements in the specific luminosity (traveling focus or smaller $\beta^*$) to bring the luminosity back to the value specified by the Parameter Document. The plans for stronger focusing entail a stronger disruption of the beam with adverse effects on the beamstrahlung. The traveling focus is a scheme not yet demonstrated technically. While appealing it needs to be demonstrated (initially by detailed simulations) that the benefits can be maintained given the margins of longitudinal charge distribution in the bunch, variations of the bunch length itself and e.g. effects on the beam-beam steering algorithms.

The AAP had the impression that the neither the effects themselves nor the implications on the detectors had been thoroughly understood.

Hence, at this time

> *AAP views the Low Power Option as a reduction of a factor of two in the luminosity.*

This conclusion hinges on the observation that the flexibility in the operational parameters for the ILC seems small. A serious investigation will be required.

> *The AAP recommends that the specific luminosity improvements (traveling focus or smaller β*) should be pursued in earnest. Such improvements are independent of the Low Power Option.*

> *The AAP also recommends pursuing other ways to increase the specific luminosity that leave the layout largely unaffected. As an example, the possibilities of luminosity enhancements by shortening the bunch length should be considered.*

The AAP is guided to this conclusion by the requirement of achieving the specified integrated luminosity as laid down in the Parameter Document. The total cost of construction and running to achieve this goal should be minimized. So even though the Low Power Option reduces construction cost (especially if the savings from the DR circumference reduction are included), the running time at half luminosity is considerably increased[2]. Consequently

> *The AAP does not recommend the adoption of the Low Power Option.*

## Parameter space for linac operation

An integral part of the RDR discussion was the parameter space for ILC operation. Except for very special cases the chosen operating point for the baseline does not correspond to the theoretically achievable peak luminosity. It is rather an operating point that leaves sufficient margins to adjust parameters and achieve the required performance given the uncertainty of success for some of the luminosity increasing options. Flexibility in the parameter space, i.e. choice of number of bunches, bunch charge and dimension etc., is hence a risk mitigating measure that must be properly understood and budgeted since it does not come for free.

Recent experience from highly performing colliders, in particular the B-factories, shows that none of the machines operate at the originally planned point in parameter space. Flexibility was required to achieve nominal luminosity and even exceed it. Even though the simulation tools have vastly improved (and so have the standards of expectation) the machines needed adjustments. Hence the notion of a parameter plane has been defined. It is the projection in parameter space that achieve constant (design) luminosity.

> *The establishment of a realistic and finite parameter plane to achieve the advertised performance of the ILC is paramount to the success of the design. However, too large a parameter plane should be avoided as it increases the costs.*

The traveling focus scheme is not viewed to be at the level that one count on it for a luminosity boost.

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[2] Note that the running time may not be actually doubled as full current will take some time to achieve even in the nominal-power case.

## Central Campus Integration

### 3.2 km Damping ring with 6 mm bunch length

Since the time of the RDR a new optics layout has been developed for the damping ring. This scheme is based on a racetrack layout and gives more flexibility for the placement of wigglers and combines injection and extraction region in one location. The advertised features look very attractive and hence

> *The AAP welcomes the transition to a racetrack damping ring.*

The AAP would welcome a detailed description of the features, calculations, and simulations supporting this choice of design.

In SB2009 it is also suggested to halve the damping ring circumference to 3.2 km. With the Low Power Option the performance requirements on the ring and the extraction kickers would be essentially unchanged (same spacing of charges, same current). However, a 3.2 km damping ring may not be able to provide the full number of bunches as is necessary for nominal power operation.

> *In the light of the recommendation to not commit to the low beam power option the AAP recommends staying with 6 ns bunch distance and the full number of bunches, consistent with the previous statement of the AAP in April 2009.*

The AAP acknowledges that fast kicker operation has been demonstrated in the laboratory. Much better information will be obtained from ATF at KEK where the 3 ns kicker is an integral part of the extraction scheme. Representative operations data will hence be available soon such that kicker stability, orbit stability and pulser timing jitter can be examined.

The ILC has launched an investigation of the electron cloud effect which could become a serious obstacle for positrons in the 3 ns operation mode required to accommodate the whole pulse of the nominal parameter set. Several mitigation techniques for the electron cloud effect already have been studied and others will be tested in Cesr-TA. The results from Cesr-TA on the 6 ns operation will be available this spring. Eventually such observations will be cross-related to other damping ring configurations using sophisticated simulation tools. Once 6 ns operations have been fully established and the mitigation techniques have been implemented in the design (and cost) the 3 ns mode should be revisited. However, the electron cloud effect is a threshold effect and extrapolations are difficult.

> *The AAP would be pleased to see the demonstration that 3 ns operation is viable after the viability of the 6 ns operation has been established.*

The AAP observes that the 6 ns bunch distance can be maintained in a 3.2 km tunnel with two positron rings from which positrons would be consecutively extracted. The AAP debated whether for such a tunnel solution the electrons could be cooled in a single or two rings depending on whether they would be affected by collective effects such as fast ion instabilities etc.

> *The AAP observes that the requirements set above may be realized in a 3.2 km tunnel. A cost/benefits analysis with up to four rings in a single tunnel as opposed to two rings in a 6.4 km tunnel should help determine the best configuration.*

### Single stage bunch compressor

SB2009 abandons the second stage of the bunch compressor of the RDR. This is possible since with the new layout of the damping ring a 6 mm bunch can be produced in the damping ring, down from 9 mm in the RDR. The two-stage compressor of the RDR had a flexible compression ratio up to a factor of 45. The design presented in SB2009 achieves a factor of 20 in a single stage.

*The AAP welcomes the simplification that arises from a single stage bunch compressor.*

The AAP did not understand the real limitations of the proposed design. How much flexibility is left in the choice of optimal damping ring parameters and better compression in the single bunch compressor? Further compression might increase the luminosity and if so should be considered.

*The AAP recommends exploring the shortest possible bunch operation with a single stage compressor and the current or even further optimized damping ring layout.*

### Beam Delivery System

The Beam Delivery System itself has seen only few changes. The AAP did not raise any issues.

### Positron Source

The RDR employs an undulator at the 150 GeV position along the length of the electron linac to generate photons that impinge on a thin target for positron production. In SB2009 the undulator is moved to the end of the linac to the 250 GeV position dramatically boosting the photon yield at design energy. Even when using the less efficient Quarter Wave Transformer the required positron yield at 250 GeV is exceeded by a factor five. In practice a fair number of undulators would be turned off during high energy running. SB2009 chose 150 GeV beam energy with the undulator at the end of the linac to define the maximum length for the undulator. At this energy the positron yield is adequate (with a 50% safety margin, i.e. 1.5 $e^+/e^-$). Likewise the undulator induced beam spread is largest at this energy.

*The AAP welcomes the boost in positron intensity for operation at the highest energy.*

The AAP observes that the energy spread at 150 GeV increases because of the excessive length of undulator required by the adoption of the Quarter Wave Transformer in the baseline. The AAP also notices that the intensity demands on the target itself increase with worse collection efficiency.

*The AAP encourages research to return to the Flux Concentrator for positron collection.*

The AAP notices that the research in the feasibility of the target has not sufficiently advanced due to lack of funding. There are concerns about the load and the forces on the rotating target, the stress on the vacuum seals, etc. These limitations have to be explored or replacement technologies such as a liquid lead target have to be put in place.

*The AAP encourages intensification of the R&D on the positron target.*

Energies below 150 GeV (300 GeV CM) are difficult to serve in this scheme. Given current physics expectations these energies may be particularly interesting. A light Higgs boson is best examined at a CM energy of 230 GeV, i.e. a beam energy of 115 GeV. The positron yield falls quickly with beam energy. While there is some flexibility in the choice of viable production threshold energy (length of undulator, flux concentrator etc.) it will be difficult to lower it all the way to 100 GeV beam energy (to continue where LEP II ended).

SB2009 recognized this deficiency and devoted half the number of trains to high energy acceleration to satisfy the positron yield. The other half (2.5 Hz) would be used for collision at the nominal energy. Such a scheme is possible since the quality requirements to the beam for positron production would be relaxed and the beam could use the same optics as the low energy beam. Except for a kicker to dump the high energy beam and the different acceleration the changes in the control are minimal. – Nevertheless such a scheme entails a factor of two loss in luminosity because of the smaller rate.

The AAP is concerned about the loss of luminosity in an energy region that is particularly interesting. The smooth scanning in the energy range from LEP II to the highest energies is hampered.

> *The AAP recommends finding a solution that matches the requirements of the "Parameters for the Linear Collider" Document for positron production for all beam energies.*

The AAP is aware that further specification for the low energy running must be sought from the physics groups. In addition to the luminosity itself the luminosity within a small fraction of the nominal CM energy may be the driving factor. This guidance is currently missing and would help the optimization.

The AAP observes that the RDR implementation at the 150 GeV energy position may be marginal. This location was chosen to allow deceleration of the beam to 50 GeV for a Z-factory. This requirement is not part of the Parameter Document and could be dropped. Consequently the undulator could move to a higher energy position, e.g. 175 GeV, and still satisfy the demands on the energy range. Such position would increase the intensity and create either an extra margin or allow for further reduction of the undulator length.

### Keep Alive Source

The Keep Alive Source (KAS) will be used for standalone positron production when electrons are not available. SB2009 co-locates the KAS in the electron arm so that the undulator and the KAS use the same target for positron production. The positron transport lines are also shared.

> *The AAP recognizes the advantages of co-locating the undulator and Keep Alive Source.*

The AAP recognizes that the access to the end of the electron linac and the BDS region running the transport lines will thus be restricted when positrons are being commissioned.

Since electrons are less efficient than photons to produce positrons the power load on the target for the same number of positrons produced is increased. The thin photon target is not optimized for positron yield from a 500 MeV electron beam. In addition, the positron collection needs to be separately investigated. SB2009 assumed a Keep Alive Source of a few per cent intensity. The AAP observes that the intensity of the KAS must be sufficient to be useful for machine development. Diagnostics on the beam should still have their full resolution and not have significant intensity dependent offsets.

> *The AAP recommends that the intensity of the Keep Alive Source and the beam diagnostics sensitivities be adequately matched to most machine development activities.*

Significant R&D may become necessary if the intensity requirements for the Keep Alive Source turn out to be high.

## SRF progress and strategy for gradient decision

The SRF gradient was not the key topic for this meeting. The AAP hence only made a few observations and suggestions. An in-depth discussion of SRF may take place at a later stage.

> *The AAP acknowledges the good progress on the S0 goals. The AAP is pleased to see a clear definition of TDP I process yield.*

The results on improving the process yield are encouraging for Technical Phase I goals, although there is still a long way to go. To continue to make progress, it would be helpful to understand the nature of the present yield limitations, for example by comparing the yield limitations due to field emission versus yield limitations due to quench at the various gradient levels for the usable data. If it is mostly due to field emission, then the cleanliness during preparation and assembly needs to be addressed. If it is mostly due to quench, then material and fabrication issues deserve focus of future attention.

If the few degradations observed during re-processing are due to field emission, it is less serious than degradations due to a new quench because the cause of the new field emission is understood to be a fault in the preparation. But if a re-processing degradation is due to quench, then it raises the more difficult possibility of a material defect exposure with increased depth of material removal or worsening of a small pit, etc.

There now exists a proof-of-principle for the S1 goal of 31.5 MV/m. This is very encouraging. A study should be made to compare vertical and horizontal test cavity gradient preservation. There exists good data on some DESY cryomodules, 5, 6, 7 etc. This should give some basis for future sorting strategies to maximize the average operating CM gradient, coupled with excess RF power.

There also has been progress on S2 which was not reported. This should not be ignored.

The gradients for the cavities going into the S1 global module are respectable, but the realistic goals of the S1 global activity have not yet been clearly described. The AAP made such a request in the previous report.

The issue of maintaining the plug-compatibility option for the long-term (ILC production, assembly, installation…) has not been touched upon. It would be good to put this issue to rest by having a review of experts as recommended in previous AAP reviews.

Based on the continued progress in gradients for S0, S1 and S2, there is no reason to change the gradient specification at this stage. This issue can always be re-visited if and when exciting results from LHC push the ILC to the forefront.

## Conclusion

The AAP welcomes the thorough study and the many new ideas contained in SB2009. The Project Managers are to be commended for carrying out this project in a short amount of time and with the solid engagement of the respective experts.

The SB2009 exercise was carried out to save cost and consolidate the design. The cost savings in SB2009 amount to 12.6% and are composed of several savings at the few per cent level. The AAP recognizes that a cushion of savings at this level will have to be identified to contain the cost of the project which is likely to change because of both a better understanding of the cost composition, of progress in optimization and of external influences such as the variations in cost of raw material and external services until the end of Technical Phase II.

The requirements for the ILC have been laid out in the Parameter Document of the ILCSC, which the AAP took as the authoritative guideline. In doing so the AAP does not exclude that these requirements could be changed and in particular adapted as e.g. results from LHC give further guidance. However, a modification of the requirements is not in the purview of the AAP.

The AAP hence analyzed the Proposal by dividing it into three largely independent themes, which were individually considered and confronted with the above guidelines. When the requirements were incompatible the AAP typically chose to maintain the physics performance.

The AAP hence concluded for the *Single Tunnel*

*The AAP supports the transition to a single tunnel provided that at least one of the RF distribution schemes can be demonstrated to work;*

for the *Low Power Option*

*The AAP does not recommend the adoption of the Low Power Option;*

and for the *Central Campus Integration*

*The AAP recommends staying with 6 ns bunch distance and the full number of bunches for the ILC Damping Ring until experimental research and simulation tools demonstrate the viability of a short bunch distance.*

*The AAP recommends finding a solution for the source that matches the requirements of the "Parameters for the Linear Collider" Document for positron production for all beam energies. – The AAP encourages further R&D on the positron source.*

## Agenda of the Meeting

| | | | |
|---|---|---|---|
| Jan 6, 2010 | | Wednesday | |
| 09:00 | 00:30 | Executive Session | AAP & BB |
| 09:30 | 00:30 | Management of SB2009 | M Ross |
| 10:00 | 00:30 | Introduction to SB2009 | N Walker |
| 10:30 | 00:30 | Discussion of SB2009 | PMs |
| 11:00 | 00:15 | Break | |
| 11:15 | 01:00 | Cost impact of SB2009 | P Garbincius |
| 12:15 | 01:15 | Executive lunch | |
| 13:30 | 00:30 | Single tunnel, CFS aspects | V Kuchler |
| 14:00 | 00:30 | Cooling and AC Power requirements | V Kuchler |
| 14:30 | 00:15 | RDR HLRF scheme in single tunnel/XFEL | M Ross & A Yamamoto |
| 14:45 | 00:30 | Distributed RF System (DRFS) | S Fukuda |
| 15:15 | 00:30 | Klystron Cluster (KCS) | C Adolphsen |
| 15:45 | 00:15 | Break | |
| 16:00 | 00:30 | Availability | J Carwardine |
| 16:30 | 00:30 | Discussion tunnel and RF schemes | AAP |
| 17:00 | 01:00 | Executive Session | |
| 18:00 | | | |

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|---|---|---|---|
| Jan 7, 2010 | | Thursday | |
| 08:45 | 00:15 | Executive Session | AAP & BB |
| 09:00 | 01:00 | Low power option | C Adolphsen & A seryi |
| 10:00 | 00:30 | Single stage bunch compressor | N Solyak |
| 10:30 | 00:30 | break | |
| 11:00 | 00:30 | 3.2 km damping ring with 6mm bunch length | S Guiducci |
| 11:30 | 01:00 | Integration of e+ e. source into central region with BDS | E Paterson, A Seryi & J Clarke |
| 12:30 | 01:00 | Executive lunch | |
| 13:30 | 01:00 | Effect of changes for running at lower energies | B Foster & J Clarke |
| 14:30 | 01:00 | SRF progress and strategy for gradient decision | J Geng, J Kerby & A Yamamoto |
| 15:30 | 00:15 | Break | |
| 15:45 | 01:00 | Discussion of SB2009 | PMs et al |
| 16:45 | 00:45 | Executive Session | AAP |
| 17:30 | 00:30 | Observations and prel. Conclusions | AAP & BB |
| 18:00 | | | |

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|---|---|---|---|
| Jan 8, 2010 | | Friday | |
| 08:30 | 01:30 | Executive Session | AAP |
| 10:00 | 00:15 | Break | |
| 10:15 | 01:30 | Executive Session | AAP |
| 11:45 | 00:30 | Closeout | AAP & all |
| 12:15 | 01:00 | Lunch | |
| 13:15 | | adjourn | |

Total 18:15 + 02:15 (Executive lunch)