ILC Project Implementation Planning

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Contents

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1 Executive Summary

Following the International Committee for Future Accelerators (ICFA) decision to base the design of a global linear collider on superconducting radiofrequency (SCRF) technology, the Global Design Effort (GDE) was created and has carried out the mandate of coordinating the worldwide R&D programme and developing a technical design for a 0.5-TeV linear collider. As a result of physics studies, ICFA gave the GDE guidance for the accelerator performance to be achieved. In carrying out the design presented in this report and in order to make the design as realistic as possible, close attention has been paid to how best to implement such a global project. This has been important for two reasons: 1) it has helped ensure that the design effort adequately took into account the practical aspects of implementing such a global project; and 2) by paying attention to these aspects of the future ILC project, we have developed knowledge and insight into how to implement the ILC. We document here some of what we have learned and concluded in order to help guide future implementation planning.

The **governance** of a large international science project is a very complex endeavour with little precedence for a truly global project without a strong host laboratory. It is crucially important to determine how decisions are made on design and technical issues, who appoints key staff, and the responsibilities of the host when implementing such a project.

For background, we did a study of other recent major projects, including ALMA, ITER and the LHC. Lessons learned from these projects have helped to form what we believe to be key considerations for an effective governance for the ILC. In developing the ILC *Technical Design Report* (TDR), we came to understand the importance of defining the responsibilities of the host, having a well established and agreed-to scheme for in-kind contributions, an adequate common fund, etc. We have presented our understanding and conclusions regarding governance and our key recommendations to FALC, ILCSC and publicly at ICHEP 2010. The key points are discussed in the following section on governance.

We have considered various **funding models** for a globally supported ILC, which was necessary for us to understand how it could be built, the responsibilities of the host, etc. Earlier models for the ILC have been based on equal sharing among the three regions of the world, the Americas, Asia and Europe. Although that may be possible, there is no natural way to organise such a sharing, and instead we favour a funding model similar to that used in both XFEL and ITER, namely a “share” system where the “major” countries or regions should contribute a minimum, perhaps 10%, and other countries would join as members of regional consortia or by making particular contributions. Running and decommissioning costs need to also be considered and agreed to at the time the project is funded.

The responsibilities and the authority of the **project management** and project team need to be determined in advance and must be sufficient to make the team effective. This central management team will be responsible for finalising the design, carrying configuration management, a formal change control process, making technical decisions, maintaining schedules and other responsibilities of project management.

Certain **host responsibilities** are crucial to the success of a global project. The host will need to provide a variety of services similar to what are provided by CERN, a successful example of a multi-country large collaborative laboratory. In addition to the necessary contributions to the infrastructure, construction and operations, the host will be expected to prepare for legal status as an international organisation.

Siting is a major issue, from selecting the site to dealing with the configuration and site-dependent aspects of the design and implementation. Technical issues, such as seismic conditions, will need to be considered and a site-dependent design, taking the conditions of a particular site into consideration, will need to be developed by modifying the original generic design. Matters such as access, providing infrastructure, safety, etc. will need to be considered issue by issue in developing the site-dependent design to be implemented. We envision the design will evolve from the configuration-controlled ILC design produced by the global design team and the site-dependent changes will be done through a formal change control process.

We assume that the major contributions from countries to the ILC will be in the form of **in-kind contributions**. This has the substantial advantage that most resources for the construction can be made within the collaborating countries. This is important for political reasons, as well as to build technical capacity within the collaborating countries. However, this scheme comes with major challenges in terms of managing the different deliverables, integrating them, maintaining schedules, dealing with unforeseen cost increases for specific items, etc.

We have carefully considered this issue, and have studied the various ways to treat such contributions. We suggest that a **flexible** form of in-kind contribution, for example one employing a form of *juste retour*, is preferable (i.e. each member state receives a guaranteed fraction of the industrial contracts). This enables the central management to place the work where it will be the most effective while spreading the work and resources equitably. A very important additional point we learned from other projects is that sufficient central resources must be made available to effectively coordinate and integrate the project through the central management.

The central technology for the ILC, superconducting RF, has many other applications and therefore a worldwide plan for distributing this work is necessary.

An implementation topic unique for the ILC is **the industrialisation and mass production of the SCRF linear accelerator components**. We have developed a model for this production that involves multiple vendors worldwide and a globally distributed model based on the “hub laboratory” concept. Basically, the cost-effective scheme we propose will use industry for what they do best, large-scale manufacturing, and the participating high-energy laboratories for what they do best, integration and carrying the technical risk for performance.

We have considered the overall **project schedule** for ILC construction and commissioning and have found that it is dominated by the time to construct the conventional facilities as well as by the time required to construct, install and commission long-lead time technical components such as the SCRF system. An 8-year construction, installation and commissioning schedule appears feasible.

Finally, we have considered and discuss the **future technical activities** that will help continue to advance the ILC towards construction. Overall, we have used project implementation planning as an integrated element in developing a technical design for the ILC that we believe can be smoothly evolved into a final design and implementation plan to the ILC project once it is approved and funded. Relevant details and conclusions from our project implementation planning process are discussed in what follows.

2 Introduction and General Principles

2.1. In the early 2000s, several study reports [1] were issued by American, Asian and European regional bodies representing the relevant high-energy physics communities on possible organisational structures for the project management of a linear collider (LC). The Consultative Group on High-Energy Physics of the Organisation for Economic Cooperation and Development (OECD) also issued a report [2] on their consensus, concurrently with these regional reports.

2.2. All these reports agreed that a high-energy electron-positron LC should be a next major facility on the roadmap of international high-energy physics, and that this project would require a hitherto unknown scale of global collaboration, calling for special attention by the world's research, administrative and political sectors. Together, these reports laid the foundations for an international organisation for the design and development stage of an LC, leading to establishment of the Global Design Effort (GDE) for the International Linear Collider (ILC).

2.3. These regional and international reports systematically identified most of the organisational, legal, budgetary and political issues associated with construction and management of an LC project. Many of the issues highlighted in the reports stand as valid questions that still need to be resolved.

2.4. However, there is as yet no shared community consensus on the solution model (or models) for addressing the issues mentioned above during project construction and management and an evolutionary path whereby such an organisation can ultimately be put in place. On the technical front, the GDE is presently engaged in producing a *Technical Design Report* (TDR) for the ILC project before the end of 2012 and, synchronously, the detector concept groups are preparing Detailed Baseline Design documents (DBDs) under the leadership of the Research Director. The TDR and the DBDs will be presented to the communities and interested government agencies.

2.5. It is clear that members of the world research community on HEP cannot usurp the role of the legitimate bodies for managing the intergovernmental issues from either administrative or political perspectives. The issues to be managed by these experts must be left in their hands. Therefore, the PIP focusses on making statements from the standpoint of the primary executor of the research and on presenting the community’s preferences from the scientific and technical viewpoints in order to inform the debate as much as possible.

2.6. The following principles guide the approach outlined in the remainder of this document:

2.7. Openness to the world

2.7.1. Large-scale research undertakings cannot be realised without firm commitments by the nations/regions that empower them. However, when the scale of a research project goes beyond what can be readily sustained by a single nation/region, its guiding principles have also to expand. One such principle that needs to be underlined is “openness to the world”. High-energy physics has been characteristically international in nature since its inception. This is connected with its mission to clarify the most fundamental laws of nature and the universe, whereby all discoveries and the results should naturally be deemed as the common assets of people everywhere.

2.7.2. The basic principle is that high-energy physics should be pursued independently of any political, national, ethnic, or other constraints. The opportunity for research has been, and must be, equally open to all scientists in this field, as formulated in the ICFA guidelines, whether such scientists are from nations on the frontier of high-energy physics research or not. The ILC project is a novel and unique opportunity to realise internationalisation and cooperation in our field on a global scale with numerous positive implications for science, technology and education. This is perhaps one of the most important ways in which the ILC can be popularly perceived as making a valuable global contribution.

2.8. Sound legal platform

2.8.1. Several different organisational models are conceivable for managing the construction, commissioning and operation of the ILC. Irrespective of the specific details of such models, a clear legal status needs to be defined for an organisation to manage execution of the ILC project. The adequacy of that organisation and its management needs to be assessed from the standpoint of how its legal structure is expected to address the following points effectively: as a scientific project, it is open to participation by any nation/region that is prepared to make a significant contribution; it is driven by significant shared contributions from multiple participants; solid accountability is ensured in both the scientific/technical and budget/financial aspects.

2.9. Long-term stability, short-term agility

2.9.1. The organisation needs to be able to implement a mechanism that provides long-term stability in terms of maintaining the productivity and continuity of the project, together with the agility to address short-term problems in project execution, in both technical and financial contexts.

2.9.2. The ILC project will go through a number of evolutionary steps towards construction and operation (see above). The early stage of the ILC organisation cannot be completely static because the participating countries/regions may or may not be able to negotiate the necessary approval processes in complete synchronisation. The ILC project, including construction, will have a life span of 20 years or longer. Successful project execution requires a predictable budget with good stability.

2.10. Intellectual property

Article 8 in the "MoU for Establishment of a Technical Design Phase of the Global Design Effort Concerning the International Linear Collider" [3] sets forth the established agreement on intellectual property issues for the current stage of the GDE. Investigation is required of whether these principles remain valid for the construction and operation phases of the ILC or, if they need revisions, how these should be formulated.

2.11. Maintaining the vitality of both participating and other HEP institutes

Collaboration on a major project requires the maintenance and fostering of the scientific cultures of all participating institutions, as well as the visibility and vitality of each of the partners. The ILC project should be executed in this same spirit and be managed in a manner that allows the participating parties to accumulate certain technical competence, knowledge bases and positive economic impacts, as a return to society at large.

Physics experiments at major HEP accelerators are currently managed in accordance with the ICFA Guidelines for the Interregional Utilization of Major Regional Experimental Facilities for Particle Physics Research [4].

The ICFA Guidelines have served quite successfully for execution of international research programmes at large accelerator facilities. Recently, with the expectation of global projects in mind, the ICFA guidelines in regard to operating costs were modified to state:

"Operating laboratories should not require experimental groups to contribute to the running costs of the accelerators or colliding beam machines nor to the operating costs of their associated experimental areas. However, in particular for a large global facility, allocation of operating costs should be agreed by the project partners before project approval, while still allowing open access for experimental groups."

It is expected that the ILC laboratory will adhere to these guidelines.

2.12. The subjects outlined above are best analysed assuming a specific timeline. This is particularly important given the evolutionary nature of the ongoing R&D and the steps to follow when a laboratory organisation for the ILC is formed; some must be done in parallel, some in series, some in national and others in international contexts. Figure 1 shows a rough overview of a possible timeline towards realisation of the ILC.

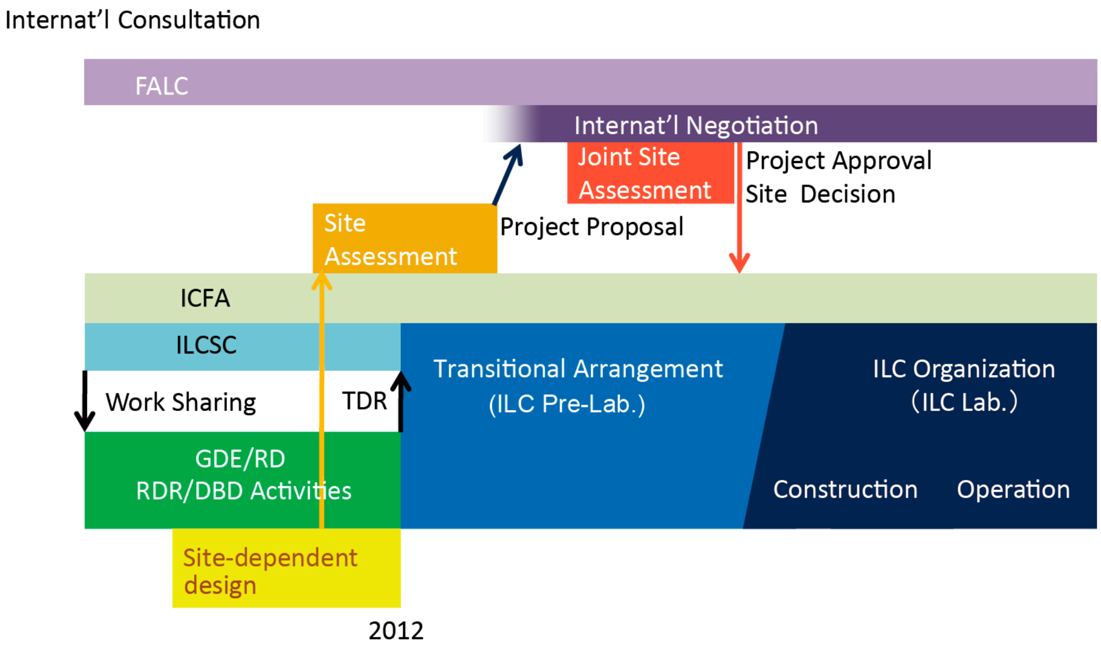

Figure 1 Possible roadmap towards realisation of the ILC

2.13. One important consideration that should be noted is the separation of technical/scientific and political aspects. Without doubt, the final negotiations and decisions concerning the legal agreements, budget sharing and site selection for the ILC will have to be made by suitable, relevant government agencies of the interested nations/regions. On the other hand, the technical contexts and resultant boundary conditions or specifications for the project (such as the base performance parameters and/or the technical specifications for possible sites) should be dictated by the scientific merits, and this aspect must be protected from arbitrary political compromises.

2.14. Therefore, systematic efforts are made to identify “where the responsibilities of scientists end, and where those of the government officers and statesmen begin” and develop the analysis accordingly.

2.15. In the area of government-level discussion, or at least sharing of information regarding the ILC’s future development, the Funding Agencies for Large Colliders (FALC) is holding regular meetings. Once the project is ready to be formally proposed a suitable forum under the OECD could be formed, which, in fact, earlier served as a precursor body for launching FALC.

2.16. One of the most important, problematic and difficult areas is the transition between the current GDE organisation and a fully fledged ILC laboratory with an agreed site, specification and budget. In order to separate these considerations, which necessarily change rapidly with time, from the more general principles that pertain to a final organisation, only the structure of the final ILC laboratory is discussed further in this document. The necessary transition arrangements and possible procedures for site selection will be published separately by the International Linear Collider Steering Committee.

3 Governance

Overview

3.1. The International Linear Collider (ILC) is a unique endeavour in particle physics; fully international from the outset, it currently has no “host laboratory” to provide infrastructure and support. The realisation of this project therefore presents unique challenges in scientific, technical and political arenas. It is important that we propose at an early stage a workable and efficient scheme to structure the project so that it can be effectively managed and so that it provides the requisite accountability to funding authorities. This section (and the following one) suggest both general principles and outline a specific model for ILC governance. Many of these issues will be of considerable importance to funding authorities and governments, which will inevitably bring other considerations into play.

3.2. In the following sections, specific analyses and a possible organisational model for the ILC and its time evolution are presented. Note that there is overlap in some of the issues discussed, with section 8 of the Project Implementation Planning (PIP) also dealing with in-kind contributions.

Working methods

3.3. Although the ILC is unprecedented in particle physics, a great deal of experience has been built up on the governance of other projects of substantial size and wide international involvement. However, perhaps only ITER is really comparable in both these aspects and even here there are substantial differences. This means that it is impossible simply to take over wholesale prescriptions that worked well in previous particle physics projects or in the current generation of large international facilities. This does not imply that lessons cannot be learnt from them; on the contrary, our approach has been systematically to investigate the governance arrangements for many international projects and to organise the data to facilitate comparison. In addition to reading the proposal and other documents produced by these projects, several meetings and discussions have been held with senior members of many of the projects, in which experience and ideas have been exchanged and refined.

3.4. The projects that have been investigated are: ALMA, ESS, FAIR, ITER, LHC, SKA and XFEL. Both ESS and SKA were at an early stage of development when the investigations were carried out and therefore did not necessarily yet have fixed proposals for governance. Nevertheless we have examined and discussed what is available and incorporated it into our considerations. There are many similarities between FAIR and XFEL. We have concentrated on the proposals for XFEL but where FAIR has differing features they have been taken explicitly into consideration.

3.5. The information on the projects was organised wherever possible into a common format in pro formas. The headings under which information was organised were:

a. Legal status
b. Management structure
c. Representation and voting structure in governing body
d. Duration of agreement
e. Attribution of in-kind contributions, value engineering, etc.
f. Running costs & decommissioning
g. Budgetary control & personnel policy

3.6. The pro formas were discussed and evaluated in several meetings of the ILC working groups in order to reach a series of recommendations for each of the sections of the pro formas. These are outlined below, where the italic text following the recommendations is a commentary on that recommendation, adducing reasons and observations on the conclusion. It should be emphasised that, while there were often strong reasons to reach a particular recommendation, there were also sometimes several possible conclusions with no strong preference for any particular one; the recommendation of a particular path does not mean that other choices would not work.

Recommendations on Governance

3.7. **Legal status**. The ILC should be set up as an international treaty organisation similar to ITER, taking advantage of zero VAT rating and similar privileges.

Projects examined include three currently utilised models for legal status: no legal entity with institutional-level agreements or MoUs, limited company and treaty organisation. Since the MoU-based organisation is not as familiar as the others, a more detailed description of the important characteristics is shown in Appendix A. We strongly recommend that the ILC must have its own legal identity. Experience from XFEL and FAIR shows that the foundation of a limited-liability company is no easier, quicker or less complex than a treaty organisation. A treaty organisation with a finite duration is stronger and more flexible than a limited company. A vitally important part of the treaty is to guarantee access to the ILC laboratory to all *interested parties. The circumstances of the US with regard to treaties can be accommodated by the same arrangement as used for ITER. Participation of individual countries in the ILC can be through regional organisations, e.g. CERN, and use can be made of existing research infrastructure frameworks, e.g. ERIC in the European Union, where appropriate. While preferring a treaty, other solutions such as a limited company or institutional-level agreements could be made to work.*

3.8. **Management structure**. The ILC should have a strong Council as the ultimate governance body. Council delegates should be of sufficient standing to make decisions in a timely fashion. The ILC should have a Director General and a Directorate, proposed for Council ratification by the DG. The DG should have significant delegated authority from the Council, allowing him or her to act decisively without continual need to refer back to Council. We expect that the Council would wish to set up high-level advisory bodies on scientific policy, and on the design, construction and operation of the accelerator, but it is not necessary to specify details at this stage.

All projects examined have Councils representing the member states; some are stronger than others. Council should meet at least twice a year. It is essential that a DG should be appointed in whom Council has confidence and whom it trusts to manage the laboratory and project. He or she must have suitable delegated authority to keep the project on track. The level of delegated authority in ITER, for example, does not seem to us sufficient to manage the project optimally.

3.9. **Representation and voting structure in governing body**. Each Council member state should have 2 official delegates and a maximum of 2 advisors. One of the two delegates should be a particle physicist. There should be the option, every few years, of Ministerial Council meetings in which delegates are the relevant government ministers.

Council should decide questions not of a financial nature by simple majority; financial questions should be decided by a qualified majority voting decided by a majority of financial contributions plus a majority of individual member states.

It seems important to keep the Council meetings as small as possible, consistent with ensuring that each member state has a delegate representing the government and another to give a scientific perspective on the work of the ILC laboratory. This recommendation is modelled on the CERN experience. CERN Council does not explicitly have Ministerial sessions in contrast to, for example, ESA. Appropriate Ministerial involvement with the organisation is important when major strategic decisions are required. The option of having such meetings on a regular basis is important.

Most of the projects examined have a weighted voting system, with a tendency to reach decisions by requiring a higher weight of financial contributions than required at the CERN Finance Committee. It is unnecessary to specify the details of the voting system here but the pattern of a majority of financial contributions and/or a majority of members seems a good one.

3.10. **Duration of the ILC agreement**. The ILC agreement should be fixed term, a construction period of ~8 years plus 20 years of operation. It should be extendable by agreement of Council in periods of 5 years. Withdrawal would not be allowed until a minimum of 10 years after the agreement comes into force and then only after 1 full year after notice of withdrawal.

All projects have a fixed term that can be extended after agreement by all members. The construction period as described in section 8 represents a reasonable best guess from the ILC civil construction experts including necessary initial tool-up time after the construction agreement is signed. The physics programme of the ILC would extend over at least 20 years and would include an energy upgrade to 1 TeV as well as possible technology changes to reach even higher energies. It is essential for international organisations to have stability of membership in order to plan sensibly; hence withdrawal should be inhibited by considerable barriers.

3.11. **Attribution of in-kind contributions, value engineering, etc.** The ILC construction project should be based on a work breakdown structure (WBS) system. In-kind contributions will be likely to form the majority of contributions to the project's infrastructure. An agreed register of WBS items should be set up and a committee constituted to consider bids for WBS items from member states. Cost engineering should be used in defining the "value" to the project of each WBS item. There should be an adequate Common Fund (of at least 20%) in order to give management enough flexibility.

Use of WBS is now standard in all major projects, as is value engineering to optimise the performance/cost ratio and thereby determine the size of financial contributions attributed to WBS items. The value estimate must be based on the close-to-final design and the industrial procurement model. The committee to adjudicate the award of WBS items will need optimally to match the expertise and track-record of the bidding manufacturers, the financial contribution of the member state and the requirements of the project.

Some WBS elements do not lend themselves to in-kind contributions. The most obvious example of this kind of item would be installation and testing. Support for the Project Team during hardware commissioning (pre-operations) also does not readily *fit into the in-kind contribution model. These and other similar costs will be supported via a Project Common Fund contributed directly in cash by the Member States. It is important that the project has a correctly scoped Common Fund so that the management team is sufficiently capable to react to and minimise delays from time-critical areas of the project and manage problems as the project progresses. Experience from ITER would suggest that a Common Fund larger than 12% is required. The appropriate size requires detailed estimation at the time of project approval.*

3.12. **Personnel policy**. There are two main options for the personnel policy for an ILC laboratory, the pros and cons of which are outlined below:

3.12.1. Seconded personnel from participating institutions

Benefits: Employment benefits, social security, pension plans and re-employment of the seconded personnel would be dealt with by the participating organisations that provide those seconded personnel to the central ILC organisation, which, in turn, would be freed from such duties. Participating organisations would be allowed to develop their own long-term human resource plans with the seconded personnel in the ILC organisation as part of their resource pool. If managed adequately, this should contribute to securing mobility of experts between the branches at the ILC site and the member organisations.

Drawbacks: A member of the central team would come under dual command chains, one being the central team itself and the other the member-lab to which he or she belongs. Seconded personnel could experience difficulties in receiving fair personal reviews by their home institutions since they will inevitably become divorced and out of touch with the home laboratory as their research priorities substantially change over time.

3.12.2. Direct employment

Benefits: Providing an adequate budget is secured, direct employment would enable a stable supply of human resources during the project lifecycle. Formation of a strong and stable central team under a straightforward and simple management chain could be realised.

Drawbacks: The central ILC organisation will have to develop and operate an adequate pension plan. An imbalance in the expert population could result. For instance, the number of experts at participating organisations could be depleted during the project construction and operation phase. Likewise, there could be an expert surplus in the job market as the project nears completion and shutdown.

The ILC laboratory is a fixed-term organisation whose lifetime is highly likely to be shorter than careers of many of its staff. It is therefore natural to recommend a personnel policy that is predominantly based on seconding staff from participating institutions. The exceptions would be the Director and his/her senior staff, who would be employed directly.

3.13. **Contingency:** If and when needed, the Council should have the authority to call on a central contingency budget with a maximum of perhaps10% of the total project cost and to allocate it as appropriate. Increases in costs to produce a WBS item should be borne by the country with responsibility for that item; thus Member States are recommended to have an internal contingency consistent with their own practices for their in-kind contributions. It is important to avoid double counting between the central contingency and a country's internal contingency in arriving at the overall project costing which should include the former but not the latter. Project contingency would be principally expected to cover only those cost increases related to the common fund activities and unanticipated design changes, i.e. Project Team responsibilities. Exhaustion of the central contingency should lead to appropriate descoping of the project to be decided by management with Council's agreement.

Generally speaking, the provision of in-kind contributions carries with it a responsibility for the contracting Member State to bear any cost overruns incurred in providing the WBS item. However, it is possible that some items may well incur cost increases because of factors beyond the control of the provider, or involving some other exceptional factor. An example would be if the growth in cost were substantially related to design changes in other areas of the project. Experience with other projects teaches that it is necessary to deal flexibly with increases in cost for particular WBS items. The expectation should be that countries assigned a WBS item should normally be responsible for any cost increases incurred in providing it. However, it is necessary to recognise that there may be exceptional circumstances where this is not appropriate and to put in place mechanisms to adjudicate such cases. The size of the central contingency proposed is in line with that adopted by other large projects.

Recent experience in budgetary growth for large international projects has not been encouraging. In order to reassure governments that the ILC project, once approved, will not spiral into major cost overruns, we believe that it is necessary to give assurances that descoping the project is possible in order to contain costs if this is the decision of the ILC Council. The ILC, being highly modular, can be much more easily descoped than, for example, a project such as ITER. The most obvious *method of descoping is to reduce the energy reach of the machine by installing fewer superconducting cavities.*

4 Funding Models

Construction costs

4.1. Earlier reports on governance [1] generally favoured a regional approach to funding, e.g. the host region providing 50% of the overall cost and the non-host regions 25% each. Developments since the date of these reports increasingly call into question the viability of such models. The rapid industrialisation of in particular China and India and their increasing expenditures on science have changed the face of science in Asia. Japan no longer dominates the scene, although it is still by far the strongest participant in particle physics. Still, both India and China have greatly increased activity. Since, unlike the situation in Europe, there is no strong coordinating institution similar to the EU, it is difficult to see how an Asian contribution to the ILC could be apportioned without complex multilateral negotiations in an undefined forum. Similarly, the relative commitment of the US to particle physics has declined to the extent that it does not seem likely that the Department of Energy would be willing to invest 25% of the ILC cost in a facility overseas.

4.2. The 50:25:25 model of regional contributions is more or less a GDP-related model, similar to that used by CERN, though it uses Net National Income (NNI) rather than GDP. A model for the ILC based on that used by CERN could be considered; it has a saturation feature that no one country can contribute more that 25% of the total CERN budget. Unfortunately as remarked above, it seems unlikely that the US would be willing to contribute 25% of the project cost, which is the amount that its GDP would dictate under the CERN-like arrangement.

4.3. These considerations lead towards a funding model similar to that used in both XFEL and ITER, namely a ‘share’ system in which countries can indicate the share of the project they believe they can contribute. There would be an expectation that “major” countries or regions should contribute a minimum, perhaps 10%, and that other countries would sign up either as members of a regional consortium that would grow until it could contribute the minimum 10%, or for particular activities or deliverables.

4.4. All models must include a substantial “host premium” by which the host pays a significantly larger share of the project than would otherwise be expected. This takes into account the well documented fact that very substantial economic benefits accrue to the area in which such a leading scientific facility is sited. The size of such a premium should not be fixed to an arbitrary amount, such as 50%, but instead should be agreed between the major partners at the start of the project. Another subject for discussion and agreement would be the form of the host premium; traditionally the host has been responsible for providing all the civil engineering but it may be attractive to other states to fund their own civil engineering firms to provide significant fractions of the civil infrastructure. In addition, the host may prefer to provide a larger fraction of "high-tech" equipment.

4.5. These considerations lead us to conclude that **the ILC funding model should be based on a substantial host premium together with a "share model" in which participants contribute an agreed share of the project not naively proportional to GDP or other measures of economic wealth.**

Running costs and decommissioning

4.6. The ICFA guidelines in regard to running expenses have recently been modified to permit operating costs to be shared among the project participants. Since there are evident economic benefits to hosting a major scientific facility some sort of host premium seems appropriate. It is important not to double count the benefits of hosting, leading to a premium in both construction and running, unless this is really justified by the economic analysis. It seems to us that a reasonable compromise would be to divide running costs proportional to the contributions to the capital cost. However we recognise that this is contentious and so we recommend that **running costs should be evaluated at the time of setting up the organisation and a suitable algorithm agreed to**. **A commonly chosen algorithm is that running costs should be distributed roughly proportional to capital contributions**.

4.7. **Decommissioning should be the responsibility of the state that provided that WBS item; the host should have residual responsibility, including if necessary returning the site to the condition before the project was constructed.**

Although, in the above models, the host bears a premium in construction and operating costs, numerous government studies of global science projects indicate that there are many direct and indirect offsetting financial benefits to the local economy. A significant fraction of commissioning, operation and maintenance costs, as well as payroll, are boosts to the area economy. Also a major new science facility would attract new businesses, some of which could be high-technology spinoffs and would be additional boosts to the local and regional economies. In addition to the prestige surrounding hosting a new global science project, there are potential long-term economic benefits in the hosting region.

5 Project Management

Framework

5.1. The tacit assumption in this section is that the governance of the Linear Collider will resemble that described in section 3. The consortium responsible for construction of the linear collider would consist of a central Project Team, a host, together with several collaborating entities designated Member States. The location of the Linear Collider will determine the host. While this appears to be a straightforward concept defining the major entities of the project, the position of the host is unique. Although there are only a limited number of large international science projects to serve as role models, the most successful (e.g. LHC) have managed to provide a special role for the Host in the project management structure. This is *de facto* recognition that with a significantly larger contribution to the project than anyone else, hosts have when necessary provided fiscal and/or technical stability beyond their nominal position in the management structure. An example that recommends itself is the XFEL model where DESY (representing Germany) has a ~50% budgetary responsibility but in addition takes the lead in terms of design and technical specification. This organisational structure looks similar to the US lead-lab model for national projects involving collaborations of its national labs. The Spallation Neutron Source at Oak Ridge National Laboratory is a good example of this approach. In what follows in this section, what could be termed a strong-host model is tacitly assumed, whereby the host will have a significant role in the Project Team although such a role is not explicitly highlighted and the Host and Project Team are treated as two separate entities. A strong-host model seeks to closely align the interests of the Project and the Host while maintaining the essential collaborative nature of the endeavour.

Management Roles and Responsibilities: Project Team

The concept behind the Project Team is that this is the group of people who are responsible for the technical design, component specifications, high-level Q/A, installation, commissioning, and management of the project-related functions in support of the above. The Project Team reports to the Council.

5.2. The final design of the collider will be dependent to a certain extent on the specific features of the chosen site. The Project Team will be responsible for finalising this design together with its configuration management. A formal change control process will be used to maintain the baseline.

5.3. The Project Team will set the interface specifications, which control the technical requirements of the in-kind contributions of the Member States. Design reviews to validate that the in-kind contributions meet these interface specifications will be conducted jointly by the Project Team and the corresponding team from the Member State. Formal acceptance of in-kind contributions will be the responsibility of the Project Team. Thus, ultimate responsibility for the successful performance of the collider resides with the Project Team.

5.4. The overall project schedule will be set and managed by the Project Team. The main technical elements driving a construction schedule are discussed in section 9. The detailed schedule however will be formulated by the Project Team in consultation with the other members of the collaboration. Once established, the Project Team will then manage this high-level schedule.

5.5. The use of the common fund will be determined and managed by the Project Team within the ground rules established for this funding as discussed in section 2 above.

5.6. Installation and facility commissioning will be the responsibility of the Project Team. There are significant components of a project that do not lend themselves to in-kind contributions. Two such activities are installation and commissioning, both of which are required to be performed, wholly or substantially, at the site. For a large project such as the ILC there will be a significant overlap of the two activities. Commissioning of the lower-energy machine elements (such as the damping rings) will take place while component installation in the main linac is still underway. Only the Project Team can provide the detailed integrated planning needed to complete such tasks efficiently.

Management roles and responsibilities: Member States

The Member States are collaborators who agree to provide project support through both in-kind hardware and cash. They will follow the lead of the Project Team in terms of schedule, component specifications and acceptance. Member States are represented on the governing Council.

5.7. The Member States shall be responsible for providing their in-kind hardware contributions. Once the scope of in-kind contributions has been established, the member states become responsible for the total costs associated with their contributions as well as the agreed-upon delivery schedules. Cost increases to Member States resulting from any design changes requested by the Project Team shall be the responsibility of the Project Team.

5.8. Quality assurance, including hardware testing, necessary to ensure that in-kind contributions meet the technical acceptance criteria will be the responsibility of the Member State. Appropriate acceptance criteria will be determined jointly by the Project Team and the Member State team in question. This also applies to component or system "final delivery to site" schedules, which satisfy the overall installation schedule.

5.9. Component designs that do not change the agreed interface specification will be the responsibility of the Member States. A Member State will be allowed to propose a more cost-effective solution to that described in the baseline design provided the interface specifications are unchanged and subject to acceptance by an appropriately constituted technical review. Any proposal to modify the interface specifications will require the concurrence of both parties.

5.10. It is expected that Member State contributions will include Project Team manpower. The intellectual resources needed to successfully accomplish a project of the complexity of a linear collider reside within the Member States. It will be important to provide a mechanism to allow optimal use of these human resources.

Management roles and responsibilities: Host

The experience of previous projects, both in high-energy physics and elsewhere, shows that the existence of a strong host laboratory is a vital ingredient for success. There are many factors that contribute to this, of which the most important is the large pool of expertise and experience in large projects and their construction that is available in the leading laboratories. The most recent example of the role of such a host laboratory is the relationship between DESY and the European XFEL. DESY has essentially been contracted by the XFEL Laboratory to build the XFEL accelerator and beam lines. While not wishing to specify the exact form of such a relationship and how it might be constructed for the ILC, it is important to bear in mind that, if the host has a major national laboratory not too far from the ILC site, the project would be greatly strengthened if the ILC laboratory builds a close and synergistic relationship with this major laboratory. The host bears special responsibilities towards (and receives additional benefits from) the Project. As discussed earlier, the host is expected to have a significant backup and underpinning role in the Project Team.

5.11. The host shall be responsible for all land acquisition needed for the Project (see section 6)

5.12. The host will coordinate the conventional construction and is likely to be responsible for providing most of it. The nature of conventional construction is such that it is difficult to provide in-kind contributions: the work is site-specific as are planning, safety and environmental regulations. This reality has been recognised in all major international projects.

5.13. The Project will adopt the safety standards of the host. Ultimately the host safety authorities will be required to authorise operation and, since safety regulations vary from country to country, it is necessary that all facets of the Project be conducted in compliance with the host regulations. Certification of components from a non-Host source will require host concurrence. The LHC provides an existence proof that this is feasible.

5.14. The host shall assume similar responsibilities to those of a Member State in regard to in-kind contributions. The scope of the host undertaking will not be limited to conventional construction.

Project Tools

5.15. The management practices used for large science projects are relatively well established and will be followed for the ILC. The scope of work necessary to complete the Project will be formulated in a WBS. The WBS will be the responsibility of the Project Team and will form the basis of the Project status.

5.16. Cost and schedule tracking will determine project progress. The status of the Project will evaluated on an agreed-upon schedule, which will include variance reporting at both the Project and Member State level. There are many existing software programs that provide these kinds of management tools. All collaborating entities will be expected to use the same software tools to interact with the Project Team.

6 Host Responsibilities

6.1. In addition to the site infrastructure and civil-construction requirements outlined in the section 6, the host will need to foster en environment conducive to the success of the ILC as a major international research facility. CERN provides an example of good practice in these areas.

6.2. It is expected that the size of the total population of the researchers and laboratory employees with their families will be on the scale of, for example, a small town of 10,000 persons. Even if the site is not a green-field location, the increase of the local population will require adequate social facilities such as houses, schools, and medical facilities. Ensuring the availability of this type of social infrastructure will be one of the responsibilities of the host.

6.3. In addition to permanent staff there will be a significant number of visiting researchers of a long-term (several years), a short-term (a few weeks), and a virtual nature. Allowances for all will be necessary. A sizable fraction of the long-term visitors will have families and will require access to schools, potentially of an international character, flexible enough to accommodate both multiple short-term and long-term stays. Rental housing of a medium-term nature will need to be available. Families imply working spouses and some accelerated medium-term work-permit availability will be required.

6.4. Short-term visitors have a different set of requirements. It is preferable that entry to the host state does not require complex or protracted visa applications to enter the country. Should this not prove possible then it will be necessary to provide for multiple entry visas to minimise administrative overhead in regard to site access. Housing for short-term visitors will be of a hotel or on-site hostel type.

6.5. Increasingly the use of virtual access is changing the nature of large-scale scientific collaborations. Since this field continues to evolve rapidly, it is difficult to be precise about what will be required in this regard. However, a very high-bandwidth network connection and unfettered web access to scientific sites from the host are minimum requirements.

6.6. The host must prepare for the legal condition as an international organisation. Section 2 suggests that a treaty organisation with tax-exempt status is the preferred approach in this regard. With significant in-kind contributions envisaged for the Project, relief from import duties is certainly required. A whole host of legal issues regarding the staff, employees and visitors, including such aspects as insurance, pension contributions and resident status, will need to be negotiated between the various parties.

7 Siting

7.1. If it is decided to move ahead with the ILC project, a formal ILC Site Selection Process will begin. It is not the purpose of the ILC Project Implementation Planning to describe how this process will be conducted or how the final site will be selected. The PIP highlights certain information to any entity considering a proposal to host the ILC project. This information is a subset of the criteria that should be considered in the identification of a specific site proposal. These criteria were developed originally to support the selection of the reference design sample sites, but they continue to be valid criteria and will provide a comprehensive measure of the suitability of a specific site to the construction and operation of the International Linear Collider.

7.2. Some of the criteria will be identified as prerequisites for any site to be considered, such as overall site length and width and electrical power availability. The majority of the criteria however, will measure the degree to which the proposed site provides conditions that support and are otherwise favourable to the ILC construction and operation.

Configuration

7.3. The topography and geology of a site influences machine configuration, tunnel alignment, tunnel depth, tunnel access and penetrations as well as the flexibility for design optimisation options. Potential host proposals will need to be able to characterise their proposed site.

7.4. Usable Length and Width - The overall length of the ILC Project site for the initial phase of the machine at the tunnel depth is approximately 30 km, however the proposed site must be able to accommodate a planned machine upgrade to an ultimate length of 50 km (36 mi). The overall width required at the tunnel depth varies along the length of the Machine. At the start of each Main Linac, a turnaround loop in the tunnel will require an area of approximately 100 m2. Along the e- and e+ Main Linacs only a single tunnel width is required. In the central Region of the machine to accommodate the Interaction Region and adjacent Damping Ring tunnel, an area of ~1km wide and ~2 km long will be required Requirements for the accommodation of technical machine support facilities and conventional support facilities will vary with specific site conditions.

With relatively uniform surface conditions that allow for vertical access shafts to the tunnel complex below, surface structures may be used to house these facilities. In mountainous regions which utilize horizontal access to the tunnel complex, underground caverns may be used to house some or all of the machine support equipment. Requirements for administrative space, general laboratory support and user office space will also be subject to specific site conditions.

7.5. Flexibility for adjustment of alignment. The e- and e+ main linac portions of the machine (each initially approximately 10 km long) can be constructed in an enclosure that follows the curvature of earth. However, the beam delivery systems that deliver the e- and e+ beams to the interaction region must be constructed in an enclosure that is laser straight. The proposed site geology must be able to accommodate these alignment requirements.

7.6. Depth of tunnel and depth of interaction region. At a minimum, the e- and e+ main linacs and beam delivery system enclosures require 8 m of earth or rock shielding for radiation purposes. However all of the sample sites that were considered for the *Reference Design Report* positioned the enclosures in stable rock geology at a minimum depth of 100 m in relatively flat terrain and at varying depths greater than this in mountainous regions.

7.7. Accessibility to tunnels and enclosures. Access to the underground complex is required for personnel safety and egress, ventilation, equipment installation and removal and technical and conventional utility support. This accessibility is also very dependent on the topography of the proposed site. In relatively flat terrain, vertical shafts are appropriate for access to the underground enclosures. However in mountainous regions, horizontal tunnels, though longer, may be the preferred method to access the underground enclosures.

Vibration and stability

7.8. Micro-seismic ground motion and cultural noise (man-made vibrations) can affect the operations of the entire facility with the most demanding tolerances in and around the beam collision region. A quiet site that has low levels of micro-seismicity and cultural noise will minimise the need for passive or active damping systems to achieve required stability during operation. Potential host proposals should consider and identify the vibration and stability characteristics of any site under consideration. The baseline design assumes no active damping in the main linac tunnel but active feedback systems in the collision region. Most existing major accelerator sites have been characterised and would prove acceptable for the ILC so that, while excessive vibration should be avoided, significant limitations from this source are not expected.

Site infrastructure

7.9. Economies in construction cost and operational cost over the lifetime of the ILC can be achieved if the site is sufficiently close to existing facilities of some sort. Such support infrastructure might include industrial shops, office buildings, computer resources, and the skills of physicists, scientists, engineers and technicians. Site proposals should identify existing facilities that can be used to fulfil the requirements for conventional facilities identified for the ILC Project.

7.10. Within reason there are no special factors to consider in regard to climate conditions. Extremes in winter or summer temperatures may have an impact on water cooling systems for some accelerator components and these impacts should be understood.

7.11. A project of the scale and size of the ILC will place a substantial additional demand on the capacity of the regional utility infrastructure. Electrical power requirements for example will be in the range of 250-300 MW. The laboratory could employ ~2,000 permanent personnel with ~1,000 visiting scientists and users at any one time. The capacity of all conventional support utilities including electrical power distribution, domestic and industrial cooling water supplies, sanitary and waste disposal systems and fuel resources such as oil and natural gas should be reviewed in order to demonstrate and supply the necessary capacity to the laboratory site.

7.12. The majority of equipment, materials and components needed to construct the ILC will be transported to the site by trucks or customised transport vehicles. It is likely that some equipment or components could be as large 50 tonnes. Within the ILC project site, access and transport roads and conventional utility distribution will be installed as part of the construction process and eventual laboratory operation. However, required upgrades to improve existing roadways for access to the ILC Project site from existing highway systems should also be considered if existing roadways are not capable of supporting loads of this nature. Rail access to a proposed ILC site would also be considered a positive aspect of existing infrastructure support.

Land acquisition

7.13. The ILC footprint ultimately will require a site that is nominally 50 km long and up to one km wide in places. The specific surface requirements will be customised and influenced by the method of construction. It is assumed that any proposed site will have no major limitations arising from specific local conditions.

Environmental impacts

7.14. Sites will need to be evaluated for environmental issues that could place restrictions or limitations on the construction of the ILC. Issues of this kind could require future modifications to the design. Existing accelerator facilities have proven capable of fulfilling all the necessary environmental requirements in sites around the world in many different types of settings ranging from rural to urban. There is nothing in the design of the ILC that will create any special issues of this kind. Radiation will be minimal and localised in the beam dump equipment where well proven protocols can be used to ensure safe operation. Since the bulk of the ILC enclosures will be underground, consideration will also be needed with respect to removal and disposition of the rock and soils removed to construct the underground enclosures with respect to local environmental requirements.

7.15. With regard to general environmental considerations, the ILC construction requirements are straightforward and pose no additional aspects than those taken into consideration in any other large construction project.

Safety and health

7.16. There are no special issues associated with the ILC construction in regard to safety and health. All local regulations will be followed during the ILC construction (and operation). The construction and operation of an accelerator facility with both above-ground buildings and below-ground enclosures does require a formalised approach to below-ground access and control. However, numerous accelerator facilities worldwide provide working models that can easily be adopted for use at the ILC site.

7.17. Internal laboratory support and emergency response capability as well as local municipal emergency capabilities are both important components of a comprehensive approach to safety and health. These include local fire and emergency response availability, medical and ambulance response and local emergency medical facilities and hospitals including distances and response times to the ILC project site.

Regional infrastructure support

7.18. The existing infrastructure in the proximity of a proposed site will affect both the construction and operations cost of the ILC. Supply, availability, reliability, and cost of the various utility services that are required will be considered. Since a significant amount of equipment will be shipped from many disparate locations, convenient access to a seaport, airport and overland transportation of oversized and heavy objects is desirable to transport scientific and support apparatus to the site.

7.19. While the collider is in operation a constant flux of personnel is anticipated. Easy access to a major international airport is essential.

Risk factors

7.20. Although accelerators have proven relatively robust, natural and man-made disturbances have the potential to disrupt facility operations with possible damage to accelerator components. Given the precise alignment required for optimal operation, then, it would appear sensible to avoid known seismic fault lines.

7.21. Lightning strikes and/or electrical power outages are also disruptive. Locations that minimise such incidents are preferable.

7.22. With the accelerator enclosure in a tunnel of some depth, the possibility for flooding exists and could be catastrophic in a severe scenario. Flood plains should therefore be avoided.

Project and Host responsibilities

7.23. Currently, several options are being considered for the ultimate governance and management model for the ILC Project. While many of the details and implications of the eventual plan are currently under discussion, a model for the conventional facilities construction has been developed. This model divides all of the work required to construct the conventional facilities and infrastructure, both above and below ground, needed for the International Linear Collider Project into three basic categories:

a) Equipment or materials required for the conventional construction that can be readily procured by competitive bidding on an international basis and are currently included in the ILC conventional facilities cost estimate. Examples of such equipment or materials include electrical transformers, pumps, piping and mechanical equipment, and cranes. This category currently represents approximately 40% of the total conventional facilities cost estimate.

b) Permanent facilities, infrastructure and improvements that will remain as part of the host country or region after the life cycle of the ILC Project. Examples of such facilities are surface buildings, underground tunnels and enclosures and on-site utility distribution and roadways. This category currently represents approximately 60% of the total conventional facilities cost estimate.

c) All costs that are considered to be the responsibility of a host country or region to demonstrate their commitment to host the ILC Project. Examples of such costs include land acquisition for the ILC site, all required permitting and easement fees, required roadway and utility improvements up to the ILC site boundary, public relations and governmental and societal approval. Currently these costs have not been estimated and are not included in the total conventional facilities cost estimate due to the site-specific nature of these costs and the fact that they should be entirely borne by the host state.

7.24. The percentages of cost indicated above are based on a preliminary cost estimate for the sample sites that were described above. This is meant to provide an indication of costs that need to be considered by a country or region that may consider hosting the ILC Project. Conditions including land costs, construction methods and specific site design, may alter the percentages indicated.

7.25. At this time it is assumed that category 1 costs could form the basis of Member State (or Common Fund) contributions. Category 2 would be likely to fall predominantly to the host and would be counted as contributions to the Project. Category 3 costs would also be a host responsibility but would not be counted as part of the Project.

8 In-Kind Contribution Models

Introduction

8.1. The concept of in-kind contributions for large-scale international science projects now appears to be the accepted norm. The majority of the projects studied in preparation for this report rely on funding schemes either partially or completely based on some form of in-kind contributions. It is assumed that keeping cash investment within the participating countries (or regions) makes contributing to an offshore project more attractive: a more direct and tangible benefit to governments can be demonstrated in the development of local infrastructure, technical expertise and intellectual knowledge. A further benefit – and one of direct importance to any future ILC laboratory – is the continued support of national laboratories and universities, which will form the cornerstone of any future collaboration.

8.2. Despite these advantages, the difficulties associated with in-kind contribution schemes should not be overlooked. Experience from projects like ITER and the European XFEL have shown that managing such enterprises adds an additional layer of complexity to the project. Furthermore, without central control of the total funding and resources by the project, the risk to cost and schedule is increased and has proven difficult to manage. In many cases it has fallen to the host nation (as the largest shareholder) to provide *ad hoc* additional contingency funding to solve critical construction problems

One possible scheme for implementing a more flexible form of in-kind contribution employs a form of *juste retour*. *Juste retour* denotes a system in which each member state of an organisation receives a guaranteed fraction of industrial contracts placed by that organisation. This fraction is equal to its fractional contribution to the overall organisation budget. An example of the use of *juste retour* is the European Space Agency. While there are obvious advantages and some sort of equity for the member states, it is widely accepted that pure *juste retour* inevitably pushes up the costs of an organisation, since the cheapest qualifying bid is not always accepted.

8.3. Better value for money for the project, as well as improved management oversight and control, could *be achieved* by *modifying* the in-kind scheme to introduce the flexibility of a total cash model driven by market forces while retaining the ability for countries to provide parts of the project as deliverables in-kind in a modified *juste retour*. Section 3.11 d*iscussed the* mechanism by which WBS items could be allocated to bidders. Member states should be strongly urged to make bids for *all* WBS packages for which t*hey have the* technical competence to deliver, totalling well beyond their intended financial contribution. The project management can then allocate packages so as to maximise the value for money and minimise the risk for the project, up to the maximum contribution offered by each member state. If a country is particularly keen to be allocated a given package, it may even be willing to bid less than the nominal value in the formal cost estimate, thereby reducing the cost of the project. This introduces an element of market competition into a substantially in-kind model. It may help to understand this proposal to note that, in the limit that all countries only bid for the minimum number of projects to saturate their agreed financial contribution, this model reduces to the standard in-kind procedure. In the limit that all member states bid for all parts of the project, it is essentially a cash model with complete *juste retour*.

8.4. Developing the final model for in-kind contributions will rely heavily on other aspects of the Project Implementation Planning such as governance, project management and funding models. For example:

- which legal entities make the primary binding agreements (funding agencies or institutes)?
- how much is a potential collaborator willing to contribute?
- does the responsibility of the collaborator end with delivery and installation (life-cycle dependency)?
- how is the technical risk distributed and managed?
- what mechanisms should be adopted to deal with cost and schedule issues?

8.5. Since many of the above questions will only be finally resolved during project approval negotiations, it is difficult to define a single model for in-kind contributions. The remainder of this section will attempt to give an overview of the ways in which the construction project could be divided. A key conclusion is the need to maintain flexibility within any adopted model, since each potential contributor (large or small) will likely present different circumstances: no ‘one model’ will fit all contributors. What can be shared?

8.6. The total construction cost of the ILC can roughly be divided into three categories:

Superconducting RF (SCRF) linac technology (35%). This includes the complete cryomodule and the RF power sources (klystrons, modulators and distribution system).

Civil engineering and conventional facilities (48%). This includes water cooling, AC power distribution and the cryogenic plants.

Accelerator systems (17%). This is magnets, power supplies, vacuum systems, beam dumps, instrumentation, controls etc.

8.7. The SCRF remains a special case. It is generally assumed that this sub-system represents the 'high-tech' component of the project that will appeal to funding agencies, given synergies of the technology with other applications. Mass production of these components (especially the SCRF niobium cavities) may eventually demand some form of global distribution to achieve the desired production schedule. It is therefore relatively straightforward to consider these components as strong candidates for in-kind contribution. Given the scale of the cost (35%), this will likely represent a contribution from a major stakeholder (10% level or more in value), although there is still potential for smaller contributions at the sub-component level. The cost of the SCRF technology depends strongly on how the production is divided (as described in section 9).

8.8. The accelerator systems category represents the more traditional technology associated with modern accelerators (storage rings for light sources etc.). While there are specific examples where R&D is required, most of these systems can already be produced by existing industry. The largest fraction of the value associated with this category corresponds to the roughly 30,000 conventional magnets and power supplies, which are unlikely to come from a single contributor. Accelerator systems therefore offer potential for in-kind contributions at smaller levels than the SCRF technology, and may be attractive for minor shareholders.

8.9. Accelerator systems also offer the possibility of a different model for in-kind contribution: that of integrated systems. It is possible that a Member State proposes to deliver one or more of the damping rings (6%) or the beam-delivery system (2%) as complete systems. This has an attractive feature of being able to clearly identify 'ownership' of a complete sub-system of the ILC, which may go beyond construction and include operations. Providing such a complete sub-system may also prove more intellectually appealing to national labs and institutes.

8.10. Of the three categories, civil construction and conventional facilities may prove the most difficult to deal with in terms of in-kind contributions. This is because it contains those costs that are historically assumed to be the host nation’s responsibility (for example civil engineering). In general, in-kind contributions lend themselves to technical components that can be easily shipped. In principle a large fraction of the conventional facilities cost can be divided up in this way. For example, the large cryogenic plants are a good candidate for in-kind contribution. Other possible examples are AC power and water-cooling infrastructure. However these represent off-the-shelf industrial contributions, which should be tendered on a free-market basis.

8.11. This situation represents a possible dilemma for the host nation. At almost half the estimated project cost, the conventional facilities would represent a major burden on the host, which would leave little room for contributions in the more-attractive high-tech areas. It is therefore of great importance to attempt to share these costs as far as possible.

8.12. One possible in-kind contribution not explicitly mentioned above is manpower. During construction (and indeed operations) it is likely that personnel from the collaborating institutes will be required, and these can also be considered as a potential in-kind contribution. As an example, personnel are being supplied by one cold-linac consortium member for the European XFEL for testing the superconducting cavities. Other examples are integration engineering, alignment and survey and installation.

Technical interfaces and the level of Work Breakdown Structure

8.13. Careful definition of interfaces is required to manage technical in-kind contributions efficiently. This normally takes the form of a WBS with many levels of detail. The technical boundaries and responsibilities for an in-kind contribution will be defined at a certain level within this WBS. The level of detail at which the contribution is defined will have impact on the way the overall project is managed, and ultimately the cost and schedule (risk).

8.14. Defining the interfaces at a relatively high level will ease management and integration issues, and is therefore probably desirable from the point of view of the central lab management. Examples could be integrated systems (e.g. damping rings) or complete integrated cryomodules. The interfaces are fewer and potentially easier to define, as are the Member State and Project Team responsibilities.

8.15. Lower-level interfaces will conversely create more interface definitions, and increase the role of the Project Team as ‘integrator’. This will inevitably increase the required resources for the central integration engineering and design team, and add more complexity to the overall central project management. An additional feature is a shift in the risk responsibility away from the Member State to the central project management.

8.16. Clearly neither of these approaches will be adopted wholesale, and reality is likely to be a mixture of the two. Again, flexibility is key in accommodating potential contributors to the project. It is however important to include these technically detailed considerations early in the negotiation process, in particular to define clearly the responsibility (and therefore the required resources) of the central management team.

8.17. There is also a special consideration for ‘high volume’ components, of which cryomodules and RF sources are an obvious, but certainly not the only, examples. These are likely to be shared across several contributors, and this raises the possibility of design diversity, which could have repercussions on spares and maintenance (and ultimately cost). While a certain level of diversity can and should be accommodated, the level should be minimised. Careful choice of the detail level and definition of interfaces and specifications will certainly help in this respect.

In summary

8.18. A large fraction of the total cost of the project lends itself to component-level in-kind contribution. Since these contributions are negotiated between prospective partners at the time of project approval, it is difficult to produce a model now that would suite all contingencies. A flexible approach within the framework provided by appropriate technical interfaces should be adopted. Provision needs to be made for supporting both large and small stakeholder contributions. Particular care should be taken in packaging contributions to make them attractive to potential bidders. High-volume components are likely to be divided up between contributors, with the SCRF being the most attractive technology. Possible contributions in the form of integrated systems (e.g. damping rings) should not be excluded. While it is assumed that the civil engineering will ultimately be the host’s responsibility, it is highly desirable to attempt to distribute responsibility for the infrastructure to reduce the host burden, although it is acknowledged that this is likely to be difficult. Finally, during the negotiation phase, it is important to clearly define the technical interfaces and responsibilities and the implications thereof for the central integrating and design team (host lab) resources.

9 Industrialisation and Mass Production of the SCRF Linac Components

Introduction

9.1 A project the size of the ILC will rely heavily on industry to provide cost-effective production of large-volume components. The primary challenge and the current focus of the GDE activities is the construction of the SCRF linacs – a significant cost driver. The ILC will require the manufacture of approximately 16,000 1.3-GHz nine-cell niobium resonators (cavities) assembled into some 1,700 cryomodules. The SCRF cavity is a high-tech state-of-the-art component, requiring careful preparation and assembly of the subcomponents (deep-drawn half cells) using electron-beam welding, application of carefully controlled chemical polishing techniques, high-pressure rinsing and baking, all in clean or semi-clean room environments. The assembly of the complete cavities into the cryomodules likewise requires clean-room environments and adherence to well defined procedures. Much of the last decade of R&D into SCRF technology has been in refining these procedures and transferring the technology to industry, with a goal to reproducibly produce high-performance cavities (~35 MV/m with a Q_0 of $>8x10^9$) in a cost-effective manner.

9.2 When considering mass production of such high-technology components, much can be learnt from the experience of the LHC dipole manufacture and the current production of ~80 SCRF cryomodules (~640 cavities) for the European XFEL. The XFEL currently represents the largest deployment of the technology and is being constructed by a European consortium of laboratories and industrial partners. In particular two vendors are responsible for the complete assembly and surface preparation of the cavities and three vendors are responsible for supplying the semi-finished niobium and niobium-titanium material. The expected peak production rate for the XFEL requires the cavity vendors to supply four cavities per week. By comparison, the ILC will require a total rate of ~8 cavities per day for a production period of 6 years. Fortunately this industrial capacity now exists globally given the development of qualified cavity vendors during the GDE Technical Design Phase. A model of five vendors each providing an average of 20% of the total required over six years represents a modest and achievable extrapolation to the XFEL production rate.

9.3 A primary goal of any approach to mass production is the reduction of the unit cost to the lowest practical level. Understanding the impact of various approaches and models on the final unit costs is therefore mandatory. In addition the actual approach to mass production is likely to be influenced by governance issues and the way the project is funded, which are difficult to predict in advance. It is generally assumed that SCRF technology is an attractive in-kind contribution to the project, and hence the production of the linac components will likely be divided globally. The industrial models proposed for the project must therefore be flexible enough to scale to any possible scenario, and any possible impact on costs also needs to be quantified.

9.4 Based on both LHC and European XFEL experience, several key points have emerged to handling cost-effective manufacture:

- The risk to the vendors must be reduced to an acceptable minimum. In general, for high-tech components like cavities, this means no final performance guarantees should be specified beyond those parameters than can be well defined and mechanically measured.
- A consequence of the above is that the ILC Project and its partner laboratories must assume responsibility for managing the risk associated with achieving expected performance. This is done by carefully specifying the production process (so-called “build-to-print”), and requiring sufficient documentation and sign-off on each step of the process.
- Final and full testing of the cavities and cryomodules must be done by the responsible laboratories, who will need to host the necessary test infrastructure.

9.5 In terms of unit cost reduction, additional factors should be considered:

- In general there is a cost reduction associated with large-volume production, where investment in additional infrastructure and application of aggressive mass-production techniques may become cost-effective. Such possible cost savings would favour a smaller number of industrial producers (larger-volume production), but this must be balanced against the risk to the project associated with too-few suppliers.
- Allowing some flexibility in the design of the components will allow scope for vendors (working with the laboratories) to develop lower-cost and/or better-quality techniques through the adoption of well-defined interfaces. This must be balanced against the advantages of a common design.
- Having the participating laboratories provide some or all of the production facilities would reduce the risk associated with large infrastructure investment by industry.

Above all, it is important to make maximum use of competition between vendors to maintain the lowest reasonable price.

A globally distributed model based on the “hub laboratory” concept

9.6 Figure 2 shows the concept of a possible globally distributed cryomodule production based on the concept of regional partner “hub laboratories”.

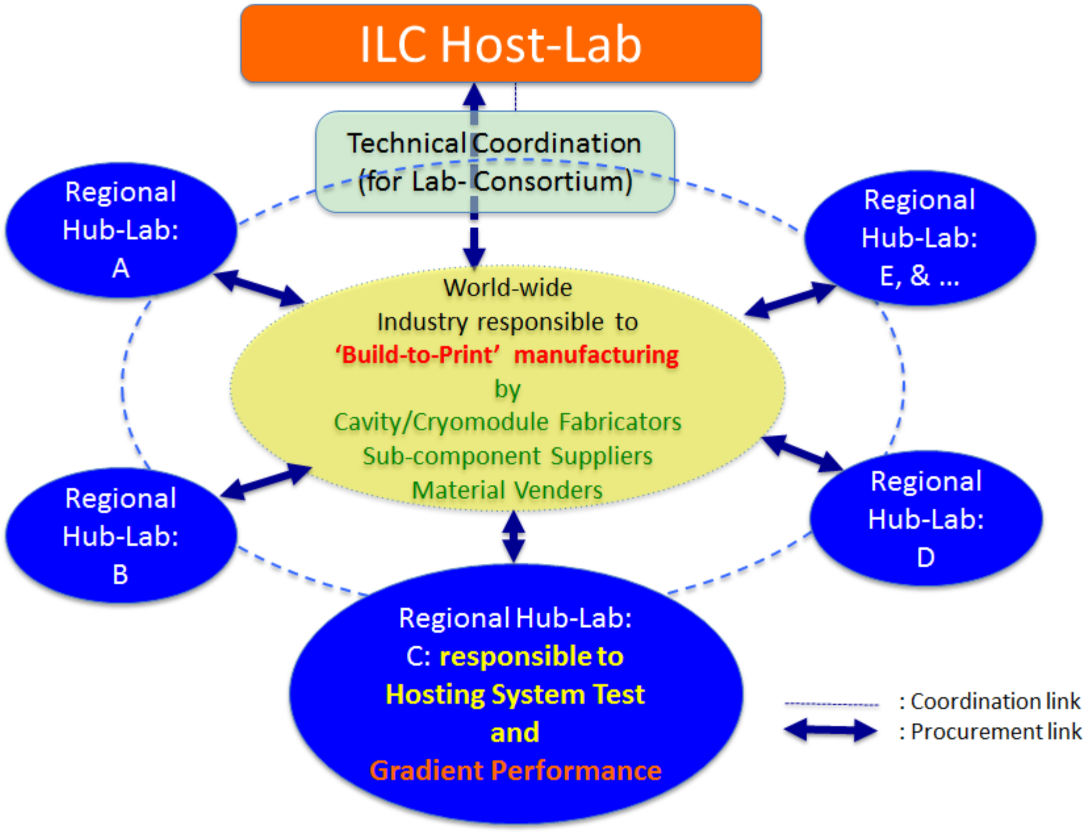

Figure 2 Globally distributed cryomodule mass-production based on the hub laboratory concept

This model represents a direct extrapolation from the LHC dipole and XFEL cryomodule production based on the principles outlined in the introduction. The assumption is that cryomodule final assembly and test will be divided up across the three regions.

The role of the hub laboratories

9.7 As its name suggests, the hub laboratory is the central coordinating laboratory for the regional cryomodule production. The hub laboratories form a strong collaboration with the ILC laboratory (ILC Project) via the adopted governance mechanism. The hub laboratory’s key responsibilities are to:

- demonstrate that the performance of the cryomodules shipped to the ILC Laboratory are meet ILC specifications;
- provide the necessary centralised cold testing infrastructure (for both cavities and complete cryomodules);
- manage and supervise the industrial contracts, including tendering, for those cryomodules it is responsible for;
- provide quality control and assurance of the “build-to-print” industrial contracts (risk management).

In addition to the above, it is quite likely that the hub laboratories will:

- procure and qualify the niobium material, which will then be delivered to the cavity vendors;
- host the string and cryomodule assembly facility which could be run under contract with industry.

A further scenario would see the hub laboratory providing manufacturing infrastructure for cavity production, for example, relieving industry of the need to invest in large amounts of new infrastructure.

Industrial contracts (vendors)

9.8 In this model it is the hub laboratories that manage the industrial tendering process and eventually supervise the contracts with the component vendors. It is assumed that such large-volume orders will be tendered and placed with the lowest reasonable bidder, thus maintaining a competitive market. The number of vendor contracts for a given component or sub-assembly will be a balance between mitigating the supply risk (risk to the project), available (or cost-effective) vendor capacity and the desire to keep the number of vendors to a minimum, both to reduce the contract management overhead to the hub laboratory and to potentially gain the maximum cost reduction through high-volume production.

9.9 Types of components foreseen for industrial production of the complete cryomodules are cavities, high-power and higher-order mode couplers, tuners, cryostat, superconducting quadrupole, and various instrumentation and cryogenic components. In addition, string and cryomodule assembly will likely be outsourced to industry (but possibly hosted by the hub laboratory as described in the previous section).

9.10 Cavity production is effectively an assembly process and could be broken down into sub-components, whose manufacture could also be directly managed by the hub laboratory. Contracts could be placed, for example, for production of the half-cells, end-group components and assembly into cavities (electron-beam welding); subsequent surface treatment could be outsourced independently. Such an approach would increase the role of the hub laboratories as ‘integrators’.

General remarks on the distributed hub laboratory model

9.11 The concept of regionally distributed cryomodule production fits well with in-kind contribution models. The approach should scale reasonably well to any possible breakdown in production across the contributors (regions) and works well assuming a financial model where funding flows within the region or participating country. The implied sharing of the work across the laboratories (especially cavity and cryomodule testing) is a key critical component in managing the production while constraining the costs. Despite these advantages, the complexity of such a distributed production scheme should not be underestimated and care needs to be taken to avoid unnecessary cost inflation. For example, managing vendor contracts in some key cases could still benefit from a more centralised coordination of the markets. Here careful collaboration between the hub laboratories – ultimately the responsibility of the central ILC laboratory management – will be mandatory.

Other possible models

9.12 The distributed hub laboratory model provides a clear and practical approach to production of the ILC cryomodules. Nonetheless it is not the only possible model that can be considered, and at this juncture it is prudent to consider variants that could overall prove more cost-effective.

9.13 A possible more cost-effective approach to industrial contracts would be to centralise as far possible the procurement of individual components produced by industry. Such contracts could be managed by designated laboratories, and the components shipped to the production hub laboratory facilities. Such an approach is a logical consequence of dealing with the issue of laboratory collaboration on vendor contracts discussed at the end of the last section. Such a pragmatic and potentially more cost-effective approach must be balanced with preferences for in-kind contributions.

9.14 Another variant is the possibility of a centralised production plant, or one plant per region. Such a monolithic facility could be adjacent to a hub laboratory and run by industry or a consortium. Such an approach could reduce overall management overheads and might offer further cost reduction via consolidating production into a single facility. The approach offers the further benefit of best practice-sharing between the collaborating industries. In all of the possible scenarios considered, it is important to note that the role of the laboratories is critical in maintaining control of the overall costs.

9.15 Finally it should be noted that no one approach is likely to be applicable to the market, or political, situations in each of the regions, and the exact details of the production are likely to vary across the in-kind contributing regions. Again this stresses the need to maintain flexible models.

10 Project Schedule

Introduction

10.1. The overall schedule for construction and commissioning of the ILC will be determined by many factors but it will be dominated by two: the construction of the conventional facilities, buildings, tunnels, utilities etc., and the construction, testing and installation of technical components that have the longest lead time. A scenario that provides a balance between technical feasibility and cost leads to the cryogenic modules containing the superconducting RF cavities as the longest-lead items, with multiple suppliers as described in section 9. Other components or systems are assumed to be delivered by collaborators (see section 8) for installation on schedules that match that determined by the above. This leads to an overall schedule of 8 years with reasonable spending profiles amongst collaborating countries or regions. The total expended funds required in any given year never exceed 20% of the total project value estimate.

10.2. The schedule for the central region, which includes the interaction region hall and detectors, along with injectors and damping rings, has to accommodate additional desirable features. The final assembly, installation and testing of the detectors should be completed on a schedule that matches that of the overall accelerator systems. Some commissioning of the injectors and damping rings should be possible before completion of all of the linac systems.

10.3. In the following it is assumed that the processes of setting up international governance, site selection and finalising site-specific designs have been completed and that no unreasonable funding profile is required of the host or collaborators. The schedule example shown as Figure 3 begins when the first civil contracts are signed. The time estimates for various steps in construction and installation are based on experience with large-scale accelerator projects such as the LHC and consultation with large construction companies.

Civil construction

10.4. Although the final civil design will be adapted to the actual site and the construction techniques optimised for the local geology, there are many commonalities that can be assumed in studying construction schedules. In all cases the tunnels are relatively deep underground and would be constructed with tunnel boring machines, or TBMs, drill-and-blast techniques, or some optimum combination. Access from the surface would be via vertical shafts, (or horizontal tunnels in some mountainous sites), that end in caverns. These shafts and caverns (approximately four per linac and four in the central region) allow for installation and removal of the TBMs and for rock removal. These shafts are the first civil-construction activities, and after the underground construction stage, they play an important role in the installation of utilities and services and in the final installation of the technical components. Their position also determines the location of some surface facilities such as electrical sub-stations and cryogenic plants. In addition there will be several smaller-diameter shafts for special services including emergency egress.

10.5. Based on studies of similar tunneling projects worldwide using modern technologies and on experience at several accelerator laboratories with civil construction, it is estimated that it will take 1 year for shaft construction and setup followed by tunnelling at a rate of 20 to 30 m/day. The total underground construction time, from groundbreaking to beneficial occupancy, would be 3 to 3.5 years.

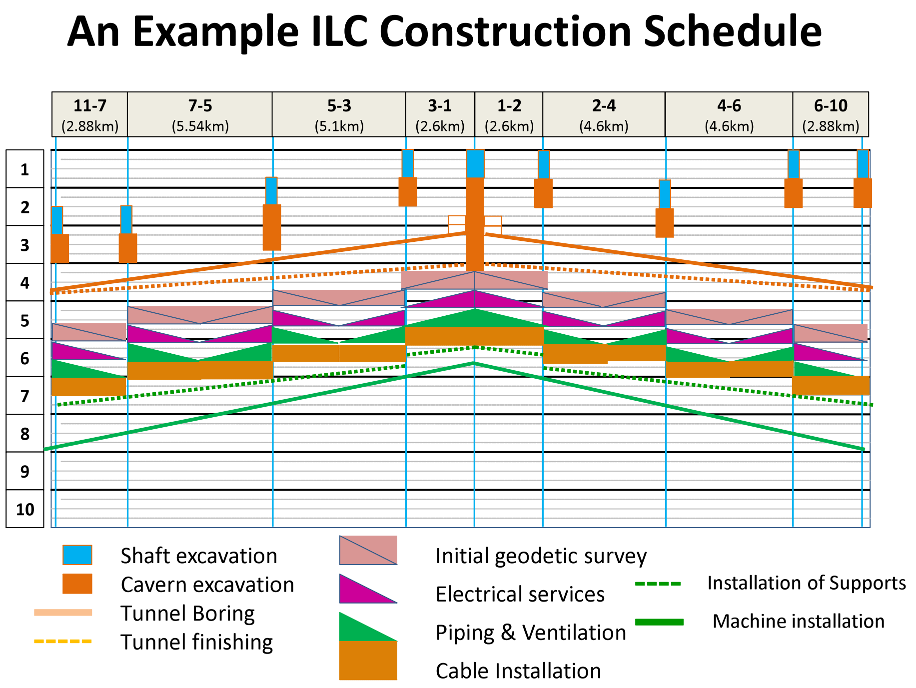

Figure 3

10.6. Figure 3 gives an example of a possible schedule that could apply to many sites. It shows these shafts and caverns with staggered start times to allow contractors to reuse heavy equipment and yet allow a smooth tunneling schedule that requires a reasonable number of TBMs operating simultaneously. The initial emphasis is on the central region, shown as +/- 2.6 km. This region has more complex multiple tunnels including the damping ring complex (not shown in Fig 3) and includes the largest excavation volume, the interaction region hall or vault. This is the region where early occupancy for installation of detectors and injector systems is highly desirable and, in principle, this example schedule would allow commissioning of the injectors and damping rings to begin 12 months before completion of the last installation for the whole accelerator.

10.7. Following the physical tunnelling, with finished floor and walls, there are several operations that are required to prepare the regions of installation for technical components. They are the initial geodetic survey to place monuments, the installation of electrical services, including those used by subsequent installation teams, piping and ventilation systems that are attached to the tunnel walls along with cable trays and the initial power and signal cable distributions. For each of these operations this schedule assumes two specialised teams per linac advancing at an average rate of 100 m per week. Allowing for transport and staging of materials and based on experience with similar underground installation in accelerator tunnels, this is a conservative assumption.

10.8. The 3.2-km-long damping ring tunnel is larger in diameter than that of the linac to allow for the future possibility of the installation of a third ring. The central-region tunnels are more complex with special purpose vaults or alcoves. It is envisaged that this region of civil construction might be optimised using different construction techniques but still starting at the same time, in parallel with the linac tunnel construction. It will be the first region available for technical component installation.

Installation

10.9. Installation of the accelerator technical components will follow the same philosophy as the civil construction, namely starting in the central region and proceeding outwards along the linac tunnels in both directions. These components or systems are likely to be supplied by collaborators as described in section 7, and delivery schedules will be a critical part of the negotiated agreements. Although there will necessarily be some level of staging and acceptance testing required on-site, it will be impractical to handle all of the technical components without carefully scheduled deliveries, which are an integrated part of the overall construction schedule.

10.10. The most complicated schedule for the longest-lead item will be the completed cryostats containing the superconducting RF cavities. It is likely that they will come from several vendors and or “hub laboratories” around the world and the schedules for manufacturing, testing, assembly, testing and staged delivery will have to match into the overall schedule as seen in Figure 3. Models for the global manufacturing and testing of these systems suggest that this would occur over a 6-year period (see section 9) and the installation in the tunnels will occur over a three-year period.

10.11. The questions of on-site staging of this equipment before installation, and/or perhaps testing, are complex as they could require considerable space and support infrastructure. This could be distributed around other collaborators’ facilities or hub laboratories, or this be on-site temporary usage or part of a final new laboratory in or near the central region. An optimum plan will be site-dependent as mentioned in section 7 on siting issues.

Interaction region and detectors

10.12. Detectors in high-energy physics are large and complex and will take a similar length of time for construction and commissioning as the accelerator complex itself. This puts a high priority on the completion of the interaction hall and its infrastructure. It is expected, as shown in Figure 3, that the availability of this hall or vault for detector assembly will not occur until 3 or 4 years before the project completion date. This suggests that, as with the LHC detectors at CERN, detector assembly will take place partly on the surface and partly in the hall.

Commissioning

10.13. It is desirable to commission the systems in the central region, both hardware and with beam, before project completion. These systems include the electron and positron injectors, the damping rings and their extraction systems. The example schedule shown above indicates that this should be feasible starting 12 to 18 months before the end of linac construction. This implies that the infrastructure in the central region, such as water and electrical distribution systems, cryogenic cooling systems and complete safety systems, is available. With radiation safety, some temporary shielding may be required if the safety systems (passive and active) in the adjoining areas, collider hall and linac tunnels are not yet complete.

10.14. The hardware commissioning of installed systems in the linac tunnels will follow right behind their installation, again going from the central region outwards to the turnaround and the start of the linacs. This is immediately followed by all systems being commissioned with beam and the start of operations, these steps having been expedited by the early start of the injection systems in the central region.

Summary

10.15. A straw man schedule has been drawn up which incorporates the desirable features (Figure 3). It has 8 years of construction and installation, and could apply to a variety of sites. The details would of course be site-dependent and the time duration assumed for installation of completed underground services and technical components will depend on the number of teams used for each operation. This schedule uses a relatively small number, 4 in central region and 4 in an efficient serial progression from the central region going outward in both directions. A larger number of teams might be faster but would be more costly with more complex logistics of underground access for people and equipment.

11 Future Technical Activities

11.1 The completion of the *Reference Design Report* in 2007 marked the start of a five-year R&D programme spanning the Technical Design Phase. This was aimed at demonstrating the requisite technical performance specifications (principally the accelerating gradient assumed for the SCRF cavities) while at the same time minimising risk through accelerator-based major system tests. The production of an accelerating gradient of 35 MV/m in the 9-cell cavities was a significant achievement marking a major advance over the state of the art when the programme started. Stable beam with very small beam spots was achieved at the ATF facility at KEK, while mitigation techniques to avoid the build-up of electron clouds were developed at CESR, operating as a dedicated test accelerator. The stable operation of a string of ILC cryomodules with beams similar to those required by ILC was demonstrated at the FLASH FEL facility at DESY. These achievements demonstrated that the technical foundations of the ILC were feasible. In addition to this technical progress, the accelerator design evolved significantly from that shown in the reference design to one with improved technical robustness and greater cost effectiveness. A low-current design with stronger focussing at the collision point maintained luminosity with smaller damping rings and fewer klystrons was adopted along with design changes in the central region, which reduced the required volume of underground construction.

11.2 The post-2012 programme will seek to build on these achievements with a primary motivation arising from the possibility of the increasing the centre-of-mass collision energy beyond the 500 GeV of the TDR. This programme would provide a flexible way to optimise the design at increased energy while minimising additional costs should LHC physics results indicate the desirability of an energy increase up to around 1 TeV. The success of the TDR programme in addressing the fundamental technical problems permits increased emphasis on cost reduction by continuing to move towards higher accelerating gradients while maintaining the cavity Q-value. Since significant unit cost decreases in conventional construction are unlikely, higher accelerating gradients that reduce the tunnel length are one of the few available possibilities to contain the costs of increasing ILC energy.

Development of alternate cavity fabrication and processing techniques for lower costs and increased gradient would include:

- new cavity shapes to reduce surface fields while maintaining or increasing the design accelerating field;
- hydroforming cavity-fabrication technology to reduce reliance on electron beam welding;
- more efficient use of raw material including reducing high-purity niobium wastage and relaxing the tantalum impurity specification;
- development of internal-surface mechanical-polishing techniques to reduce the use of electrochemical etching;
- investigation of the use of high-performance coatings to facilitate the use of low-cost cavity material such as copper or high-temperature superconductors for increased gradients.

11.3 Since the GDE Technical Design Phase (TDP) concentrated primarily on cavity performance, there is significant remaining scope for cost reduction strategies in the cryomodule. Cryomodule value engineering studies will include:

- Cold-mass design and assembly improvements. This includes:
    - elimination of the 5 K thermal shield;
    - development of a demountable superconducting connection between cavities to allow a single high-power coupler to feed two cavities;
    - development of flange disassembly and reassembly procedures.
- Practical reviews of cryomodule component integration, primarily from analysis of the European XFEL construction experience and including:
    - review and availability evaluation of cold electromechanical (tuner and coupler) mover systems;
    - redesign of the cryomodule instrumentation and magnet systems;
    - reduction in the number of cryomodule vacuum-vessel flanges and a corresponding relaxation in flange-alignment tolerances.

11.4 Much of the system-test infrastructure is being commissioned in the TDP and full system characterisation, especially, will not be started until after the TDP. While the primary objectives of linac system testing are expected to be achieved during the TDP, the potential of the multi-cryomodule high-current test linacs to demonstrate new cost-saving designs will only subsequently be realised. The highest post-2012 priority for these installations will be to validate the cryomodule technology in a value engineering cycle, together with regional industrial partners. This activity will be highly leveraged so that important cost reductions can be achieved by modest investments in various aspects of the design.

11.5 Although operating in a different beam parameter regime, the European XFEL will represent the world’s largest 1.3-GHz SCRF installation when it begins operation in 2015. The XFEL will be a vital demonstrator for the ILC and many lessons will be learned during commissioning and early operation.

11.6 Although technology transfer to global industry has been successful for the high-gradient cavity programme, cryomodule production has not yet matured to this point. In neither case has any development been attempted that recognises that high-volume production is likely to be based on a much more automated and parallel approach than hitherto observed. Although initial studies are planned for the TDP, such an approach cannot be completely developed or implemented until project approval is obtained. One goal of the post-2012 programme would be to investigate these issues by building appropriate industrially related infrastructure at KEK. Next-generation processing and welding techniques will be developed in an environment of partnership between the national labs participating in the post-2012 programme and likely industrial vendors. Such a step will not only reduce the production costs but will also minimise the time needed to initiate full-scale production.

11.7 In addition to the technology and engineering R&D described above, it will be desirable to further develop designs that are optimised for a few specific candidate sites. In the TDR there are technical options still being considered that appear to be more or less optimal for different types of sites, in mountains or on plains. Further detailed technical and civil studies are required to understand better the impact of specific site characteristics; these will be invaluable in the development of a final proposal.

9.16

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Appendix A

Section 3.7 discussed the models for the legal status of an ILC Laboratory. Another model not considered in as much detail by the authors of this section was a multinational laboratory model established by Memoranda of Understanding (MoU) among the laboratory partners. For completeness, more details of this model are included in this appendix.

Multinational Laboratory model

A.1 A basic principle of the governance for global projects is that they should be established on the basis of a balanced partnership among the project management organisation, which would be located at a central Host Laboratory, and participating research laboratories, which are distributed across the world. Each of the research laboratories, or the groups of research laboratories under regional representative bodies, that wishes to participate in the project (a Multinational Laboratory), will set up its own branch within the Multinational Lab, as shown in Figure 4. These participating research laboratories are called Member Laboratories. Formation of this Multinational Lab may be realised as a relatively seamless expansion of the present management bodies for the R&D and design efforts for ILC, namely, the GDE and the RD.

Legal status

A.2 The Multinational Lab for the ILC would be formed on an existing legal platform, which would provide the basis for Agreements (or MoUs) to be signed by the Host Laboratory, Member Labs, and national and/or regional organisations. As found appropriate and desirable, these Agreements could be endorsed via government-level agreements among the home nations of the Host Laboratory and Member Labs. Precise definitions of eligible laboratories and national and/or regional organisations participating in this round of MoUs would be one of the important issues to be addressed if this model were to be adopted.

Management structure

A.3 The council of this Multinational Lab would comprise representatives from Member Lab branches. We note here that the academic members (scientists) would be required to take responsibility for operation of the Multinational Lab.

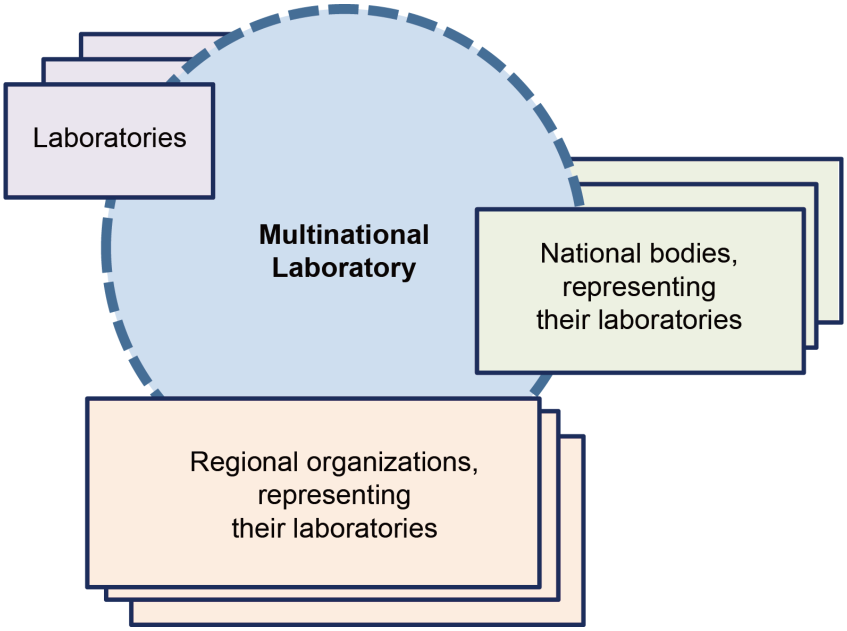

Figure 4 A supporting conceptual model for a Multinational Laboratory

Representation on and voting structure of governing body

A.4 In order to assure that experimental physicists across the world gain access to the projects, various forms of participation should be established: member, associate member, observer, non-member, etc.

A.5 Financial matters will be determined through voting rights weighted according to relative levels of contribution. Scientific matters will be determined through technical/scientific discussion among members participating on an equal footing.

A.6 The organisational chart and the reporting scheme, as shown in Figure 5, would be similar in many respects to those of CERN.

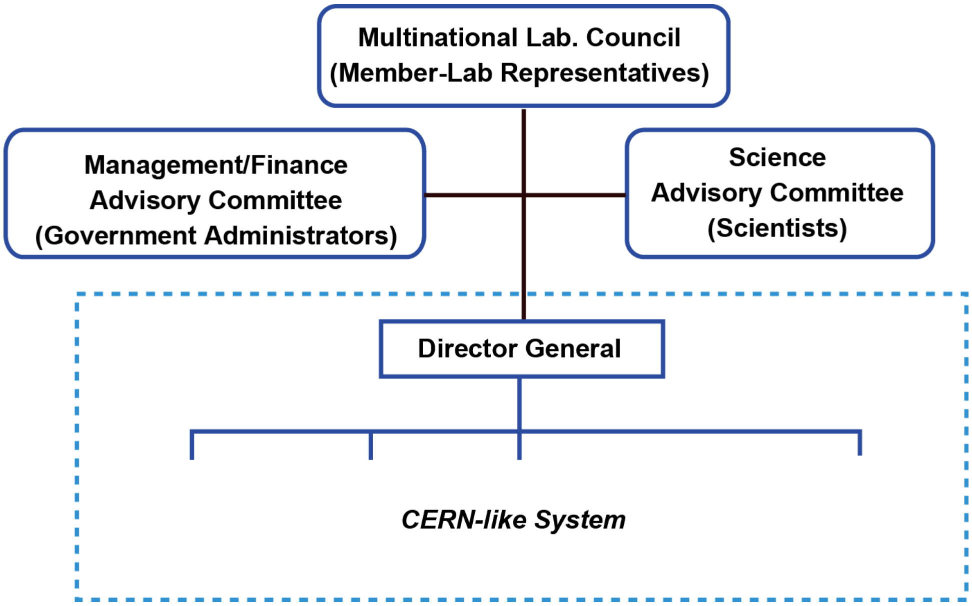

Figure 5 Possible organisation chart and reporting scheme

Human Resources

A.7 The Member Labs would contribute, on a shared basis, human resources (scientists, engineers, technical staff and administrative staff) and financial resources (common fund with specified overheads and in-kind contributions). The composition and amounts of these contributions of human and financial resources would depend on the project stage in progress (construction, commissioning, operation) and on the type of Member Lab (host or otherwise).

A.8 Many of the on-site personnel would be mobilised primarily as seconded personnel from Member Labs. The Member Labs would need to decide on appropriate working conditions (salaries, insurance, pension and retirement plans, etc.) for the employees who work at their branches in accordance with their own regulations and international standards. However, some on-site personnel may have to be directly hired.