Revised ILC Project Implementation Planning

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Revision C

Contents

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0. Preface

This document outlines Project Implementation Planning for the International Linear Collider (ILC) Project.

The authors of this document are scientists experienced in the organisation of large scientific projects. The list of the scientists who drew up this revision to the original PIP document, acting as a Subcommittee of the Linear Collider Board, is given below.

As was also the case for the original PIP published in conjunction with the ILC-TDR, the purpose of this document is not to pre-empt necessary discussion among governments and funding authorities; rather it attempts to put forward possible solutions to important aspects of the running and foundation of a new international laboratory, seen to be acceptable and viable by the particle physics community, for their consideration and as an aid to their discussions.

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1. Executive Summary

This document updates and in places revises the Project Implementation Planning (PIP) document published in advance of the ILC Technical Design Report. For the sake of completeness, Sections 5, 7, 8, 9 and 11 of the original PIP (Revision B) which have not been re-examined or changed are also reproduced verbatim here. Section 11 from PIP (Rev. B) now forms Section 14 of the current document.

The main rationale for revising the PIP document has been the progress made in planning for the ILC in the period since the first version appeared, in particular the interest in Japan to propose to host the ILC and the choice of a specific site, in Kitakami, where the machine would be built. Some of the generic considerations to which the PIP of necessity was limited can now therefore be revised to more specifically suit the environment likely to prevail in case Japan is the host state for the ILC project. This in particular affects the governance structure, where the current document reflects the overall perceived political environment in Japan and the place of a major international project therein. Another important reason to update the PIP has been the significant experience gained in the past few years with international projects of comparable size to the ILC, such as ITER, the European X-FEL and the European Spallation Source (ESS). This update permits the section on financial controls and the use of contingency and common fund to be expanded and clarified. The issue of an equitable division on the operating costs of the ILC laboratory is addressed here in much more detail than in the original PIP, benefitting from recent discussions in the projects referred to above. Several options are given. There are minor updates and clarifications in the sections on Host Responsibilities and Project Schedule. A new section on Intellectual Property, based on the Memorandum of Understanding of the original agreement to set up the Global Design Effort, is included as Section 7. One of the most important areas where conflicts and problems can arise is the interface between the ILC Laboratory and the accelerator, whose construction is directly under its control, and the experiments and the experimental community, which have been traditionally much more independent of the central laboratory. This area was not discussed in the original PIP. Section 8 addresses some of the important issues that arise here. The document is completed by a section on the transition from the current ILC organisation to the final ILC Laboratory by means of an "ILC pre-laboratory". This issue was not really discussed in the original PIP document and therefore this section is a new addition. Finally, as was the case for the original PIP, the purpose of this document is not to pre-empt necessary discussion among

governments and funding authorities. Rather it attempts to put forward possible solutions to important aspects of the running and foundation of a new international laboratory, seen to be acceptable and viable by the particle physics community, for their consideration.

2 Introduction and General Principles

2.1. The ILC Technical Design Report (TDR), published in June 2013, contained a Chapter on the Project Implementation Planning (PIP), which was a précis of a comprehensive document published earlier[1]. Since the publication of this document, which was produced in 2012, there has been considerable progress with implementation of the ILC at a site in Japan. Such a site has been selected in the Iwate province and efforts are now under way to adapt the TDR to the characteristics of this site. Various political developments have also occurred, with the Japanese government now having opened discussions with several countries in order to explore the possibility of establishing an international consortium to construct and operate the ILC.

2.2. In these circumstances, it was decided that it would be helpful to review and where necessary modify and update, the considerations published in the PIP document. For example, several of the projects that were studied in drafting the PIP, specifically ITER and ESS, have progressed substantially since then. In particular the ESS is now essentially agreed as a construction project and has several interesting aspects in its governance of relevance to ILC. The various problems that have been well documented in the construction of ITER also form an important source of information which needs to be assimilated in proposals for ILC governance.

2.3. In addition to these external developments, the Japanese government and the scientific community in Japan have preferred methods of operation that need to be integrated properly in a framework acceptable to participants in a major international science project. Significant experience from an internationally oriented organization based in Japan is available from the Okinawa Institute of Science and Technology Graduate University (OIST); the lessons learnt from its successful establishment and operation are in some respects very relevant for the ILC.

2.4. Although many things have changed since the PIP was first published, the basic principles that ILC governance should follow, as enunciated in section 2 of the PIP, have not. These are: openness to the world; a sound legal platform; long-term stability, short-term agility; a proper basis for a fair apportioning of intellectual property; and the maintenance of the viability of other particle physics laboratories.

[1] http://ilc-edmsdirect.desy.de/ilc-edmsdirect/file.jsp?edmsid=D00000000979545

2.5. Members of the world particle physics research community do not wish to attempt to usurp the role of the legitimate bodies for examining the inter-governmental issues from either administrative or political perspectives. The purpose of this document, as of the PIP, is to put forward possible solutions, seen to be acceptable and viable by the particle physics community, for the consideration of government and other officials who must set up the governance for the new ILC laboratory.

2.6. Some issues are addressed in this document that were not addressed at all, or only in passing, in the PIP. In particular, the question of running costs and the transition from the current situation to the establishment of the full ILC laboratory, are discussed in significantly greater detail.

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. The PIP suggested both general principles and outlined a specific model for ILC governance. This section updates the analysis in the PIP, including recent developments in cognate projects such as ITER, ESS and experience from internationally oriented organizations in Japan, specifically OIST.

Recommendations on Governance

3.2. **Mission.** The ILC’s mission is to provide an accelerator and the infrastructure for experiments that can explore the structure of matter and the universe with unprecedented precision. The accelerator will collide electrons and positrons to produce a centre-of-mass energy in a first stage up to 500 GeV, with provision for an upgrade to reach energies of at least 1 TeV. The ILC will be a fully international organisation, with governance and structures that achieve its aims in the most cost effective, flexible and transparent way possible.

3.3. **Legal status**. The ILC should be set up as an international treaty organisation similar to ITER, taking advantage of zero VAT and import ratings and similar privileges. The special nature of the rights and responsibilities of the host state should be set out in the treaty in a clear and unambiguous way. This should include the procedure and responsibility for decommissioning of the site at the end of the ILC’s lifetime.

There was some discussion in the original PIP of the limited-liability-company solution to governance, similar to that employed in the European XFEL and ESS. Such an option inside Europe is supported by the ERIC framework of the European Union. It was concluded for the PIP that this had no particular advantage in terms of speed or complexity compared with a treaty organization; a limited-liability company can now be ruled out as a possibility for a Japanese-based ILC since there is no such concept in Japan for publically funded organisations. An intergovernmental agreement, taking into account for example the constraints on the US government in signing treaties, therefore remains the strong recommendation for the governance of *the ILC. The host state has a special role vis à vis the other member states; this should be carefully defined in the intergovernmental agreement including the extent to which the organisation may be exempt from certain national legal requirements, taxation, import duties etc. This special role extends to responsibility for decommissioning after the ILC programme is completed; financial responsibility for this will need to be specified in the initial international treaty.*

3.4. **Management structure**. The ILC should have a Council whose function is to act as the ultimate decision-making body of the organisation, monitoring how and to what extent it is achieving its mission and ultimate goals within the financial planning envelope that it has set out. Council delegates should be of sufficient standing to be able to make most decisions on their own authority in a timely fashion and without continual reference back to their governments. In order to fulfil its function efficiently, the Council should be advised by high-level bodies on scientific policy, and on the design, construction and operation of the accelerator. The management of the ILC should be vested by Council in a Director General and a Directorate. The DG will be the Chief Executive of the ILC Organisation, with responsibility to Council for the overall running of the organisation. He or she should have significant delegated authority from the Council, allowing decisive action without continual need to refer back to Council. The DG will be appointed by Council after a full and open search process led by the Chair of Council with a search committee consisting of an appropriate subset of the Council and its main advisory bodies. Unanimity of Council on this appointment would be desirable but should not be essential.

The ILC Directorate should consist of a director of finance and administration, empowered to deal with all questions of human resources and a number of directors to be determined by the DG with delegated powers to deal with the accelerator complex, the particle physics research activity and the overall computing and information technology policy of the laboratory. The members of the Directorate should be proposed to Council by the DG for Council ratification. In the case of disagreement between a member of the Directorate, or the Directorate as a whole, and the DG, the DGs views will ultimately prevail. Regular meetings of the Directorate will monitor the day-to-day running of the ILC and prepare the agenda and papers for consideration of the Council and its advisory bodies.

The recent experience of ITER in particular emphasizes the importance of the above recommendations. It is widely accepted that a contributory factor to ITER's problems is that the DG is unable to manage effectively because insufficient authority is delegated down from Council. It is also important that the structure under the DG be optimised for the construction and subsequently the commissioning and operation of *the ILC. Under no circumstances should the management structure be devised to allow each member state or grouping of states to have one person in a Director role; balance between member states at the highest levels should be achieved by averaging over sufficient time, not by creating Directors without an important role. At the lower levels, it would be expected that a rough balance of employees would be maintained at the level of fractional contribution to the project; however, at all times, only the best person for the job in hand should be employed. Again, where necessary, balance should be achieved over time if competent persons from particular member states are not immediately available at the time of recruitment.*

3.5. **Representation and voting structure in Council**. Each Council member state should appoint 2 official delegates and a maximum of 2 advisors. One of the two delegates should normally be drawn from the particle physics community, in order to ensure that expert opinion is available to the Council from within its membership. 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. In case of serious disagreement among the member states, the President of Council may decide to postpone decision on an issue to allow consultation over a longer period.

The issue of the host state's relations with the other member states is critical for the success of any international project. There is a fine dividing line between the host state playing a leading role, acting as a backstop for particularly difficult problems and the host state being a dominant partner expected to solve all possible problems while the other member states look on. The tone to be set here begins in the Council. The host state should never be in a position to outvote all the other states. This can be effected by the proposals above. They give the host state, by virtue of its major financial contribution, the predominant influence in financial questions but always require in addition a majority of the individual member states.

An issue with ITER is the perception that the Council is often paralysed by a requirement for unanimity. While unanimity is a desirable objective, it must be accepted that the national interests of all member states will not always coincide. In such situations, Council retains the sole responsibility for the successful execution of the project and thus must make decisions by majority even if a particular decision is opposed by large and influential countries. Such decision making is present for example at CERN and has been an important factor in the success of that organisation.

3.6. **Duration of the ILC agreement**. The ILC agreement should be fixed term, a construction period of ~8 years plus at least 20 years of operation. It should be extendable by agreement of Council for an indefinite number of fixed-term periods to be decided by the Council at least 2 years in advance of the end of the current agreement . Withdrawal would be forbidden until a minimum of 10 years after the agreement comes into force and then only after two full years after notice of withdrawal.

Recently discussions of the likely science case for the ILC have implied that a period of operation considerably longer than the original 20 years envisaged is likely.

3.7. **Personnel policy.** The ILC needs to recruit the best staff available and thus needs to have attractive salary, conditions and superannuation. The staff will be a mixture of those with "permanent" contracts lasting for the lifetime of the organisation, and those on secondment or leave of absence from other laboratories and universities throughout the world. Given the gender distribution inside physics and engineering, it is particularly important that great efforts are undertaken to attract and appoint qualified female applicants for positions at every level, particularly the most senior.

The ILC laboratory, which is envisaged as a fixed-term institution, should have a mixture of staff with indefinite contracts, fixed term and persons seconded for various periods from other institutions; the optimum mixture may well evolve with time. It is however clear that a certain number of permanent staff will need to be employed by the host laboratory, to give continuity and a sense of ownership of the project. It is particularly important that the initial phase of recruitment is carried out well, with strategically placed advertisements and via search committees with experience and a strategic vision. The initial recruitment, typically for the most important posts and the concomitant administrative support, will set the tone of the whole laboratory as it begins its mission. Most international organisations have allowances to recompense employees for costs associated with moving to a foreign location, such as schooling fees, relocation allowances etc. The ILC laboratory must have such allowances set at a level that does not put it at a disadvantage compared to other similar international organisations. Appropriate pension arrangements must be put in place so that staff working at the ILC are not disadvantaged compared to others at comparable institutions.

As the project gets under way, it may well be that, despite careful and rigorous selection procedures, some staff are found unsuitable for the positions they hold. In these situations, it is essential that the DG have the necessary authority to dismiss or reassign the individuals, subject to normal best-practice employment law, without *reference to the Council. In multinational projects there is a tendency for national delegations to identify with their nationals and to exert pressure to stop them being dismissed or reassigned. This tendency must be resisted if the project is to succeed, so that Council should not involve itself in personnel matters except for the appraisal and general supervision of the DG.*

4 Funding Models & Financial Control

4.1. **Introduction:** The financial model for ILC construction can be conveniently divided into three parts: civil construction and infrastructure, the accelerator itself, and experimental facilities and support installations, including the machine-detector interface. The first will be borne almost entirely by the host state and may be managed either by the host state directly or by the ILC laboratory within a fixed, dedicated budget. The latter two categories are likely to be substantially provided by the member states via in-kind contributions. A Contingency and a Common Fund will be required and will be managed by the ILC management.

4.2. **Contingency:** The contingency of a project is required to deal with unforeseen events. If and when needed, the DG, with the approval of Council, should have the authority to call on a central contingency budget which must be agreed at the start of the project and might perhaps be 10% of the total project cost. It is important to note that the contingency discussed here is not a “full” contingency as favoured for example by the Department of Energy in the USA; rather it is more similar to the limited contingency typically applied in European projects. Examples of a legitimate call upon contingency would be the bankruptcy or closure of an industrial supplier, design changes in parts of the system required as a result of changes in other areas, discovery of missing elements in the design essential for the operation of the project, etc. Perhaps the most important use of the contingency is to allow intervention in order to deal with delays in parts of the project that are time critical and to provide the buffer and flexibility needed for the management to manage the project efficiently. This budget should be provided centrally by all project participants, perhaps as a “tax” on all value contributions. Increases in costs to produce an item to be provided in-kind should be borne by the country with responsibility for that item, except in exceptional circumstances, to be adjudicated by a committee set up by Council. 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 and project budget could lead to descoping of the project, to be decided by Council on receipt of proposals by the management. Any contingency remaining at the end of project construction can be repaid to the contracting parties in proportion to their original contribution.

4.3. **Common Fund***:* All projects have recognised the necessity to pay for some items via a central fund. For particle physics experiments, examples include large magnets, infrastructure in the experimental hall, etc. There may be some items of limited technological interest that will find no member state wishing to bid to provide them as in-kind contributions; these could be paid from the Common Fund. Other possible uses of the Common Fund include purchase of specialist management or engineering advice, for example seismic engineers, or personnel costs where such expertise is not readily available from partner states. The salary and employment costs of the top management should also be paid from the Common Fund, in order to guarantee independence from particular member states, including the host state.

4.4. The funding model for the host state is different, to reflect the substantial economic contribution a project of this size and duration makes to the local economy. The host pays a significantly larger share of the project than would otherwise be expected. In particular the host must expect to pay for all costs associated with land acquisition and provision of services and with all civil construction costs for the accelerator and the central campus, the latter being not covered, except for the minimum services required to operate the accelerator, in the TDR costing. Assuming that the host state will also wish to have a share not smaller than other major contributing states in the provision of the technologically advanced items such as the superconducting RF, a host state contribution of approximately 50% seems likely. This number will clearly be set as a result of the intergovernmental negotiations necessary to approve the ILC project.

Operational costs

4.5. The operational costs of a facility can be defined in several ways: a) the cost of services such as electricity, cooling water, etc. that are directly used to produce the accelerated beams; b) these services plus the associated installations such as computing, salaries of persons directly involved in luminosity production, and that fraction of the central administration necessary to service them; c) the total costs of running the laboratory, including all salaries of those directly employed at the ILC; d) all of these plus the cost of replacements for the hardware of the accelerator and peripheral services. The provision of spares for specialised equipment is best left to those who produced it, so that spares for the accelerator components should be provided by those states involved in the accelerator construction. This should be subtracted from their share of the other running costs. The remaining items discussed above, i.e. option c), should, following recent practice in cognate projects such as XFEL, ESS etc., constitute the operational cost under discussion in this section. In addition to these costs relating to the operation of the laboratory, there are costs relating to the operation of the detectors. Historically, these have usually been paid by countries in proportion to the number of PhD physicists taking part in the experiment. They are small in comparison to the running costs of the accelerator, so that they can either be rolled up in the overall operational costs or paid separately in the traditional way.

4.6. The ICFA guidelines with regard to running costs have recently been modified to permit operating costs to be shared among those nations with a stake in the project. 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 unless this is really justified by the economic analysis.

4.7. Nevertheless, it has been the case that almost always the running costs of previous major particle physics projects have been borne by the host state. However, in the current round of major projects, the XFEL agreement is that each country pays its share according to the investment share, e.g. Germany 60%, Russia 25% etc. It is foreseen that eventually the division of running costs would reflect the relative usage of the facility. The running costs of ITER over 20 years are estimated to be approximately equal to the construction costs. The ITER agreement[2] shows that in fact the other partners pay a larger fraction of the running costs than they did for the construction and that the host state therefore pays a smaller fraction – 34% compared to 45%. For the ESS, the exact distribution of operational costs has yet to be decided, but there is agreement that the host states will, collectively, pay 20% of the total. This means that their contribution will fall from 50% of the construction costs to 20% in operational mode. Even so, it is highly unlikely that users from the three Scandinavian host nations will use 20% of the available beam-line time, so that this still represents a net contribution from the host states.

4.8. The modification of the ICFA guidelines clearly reflects the realisation inside the particle physics community that rules that were appropriate when there were many front-line facilities, with several in each region, are no longer appropriate under current conditions. There is considerable variation in practice among the most recent major projects, but a trend that can be seen is towards countries paying operational costs in proportion to their usage of the facility. It must be recognised however that facilities such as ESS and XFEL, where there are many beam-lines and a large number of users, are very different to monolithic facilities such as ITER. The ILC sits somewhere in between; it has users, the experimenters who build and operate the two foreseen experiments, but these are relatively stable in number and committed to operate their experiments for many years.

[2] http://www.eurosfaire.prd.fr/7pc/doc/1274371364_iter_sec_2010_571.pdf

4.9. Taking all these factors into account, three possibilities to apportion the operational costs to the contributing governments have been identified:

a. in proportion to the capital contributions of the partners;
b. in proportion to the capital contributions of the partners *excluding* the civil construction, land purchase costs, provision of laboratory buildings and road access that fall to the lot of the host state to provide;
c. in proportion to the number of PhD experimenters employed by each country and taking part in the activities of the laboratory.

4.10. In addition to the three options outlined above, there are hybrid possibilities in which the initial cost is attributed according to one scheme which is gradually transformed to another over a number of years. Such a hybrid would be particularly important during the commissioning stage of the laboratory which has very different challenges to that of stable operation. Given the simplicity of scheme a) and given that it will pertain until commissioning begins, it is recommended that operational costs from the start of accelerator commissioning are apportioned according to scheme a), transforming over 3 years to either scheme b) or c).

4.11. An important consideration is the long-term predictability and stability of the laboratory budget over an extended period. The advantage of schemes a) and b) is that they automatically give this stability. If scheme c) is used, either initially or, as recommended above, only after routine running is achieved, it is possible to achieve some stability and predictability by the following process. The operational cost calculations for a given year should be based on the count of physicists from the previous year, together with an estimate of the total running costs for the year in question. Assuming that the annual operational costs are slowly varying per year, this should give one year's notice of the approximate level required from each funding authority. An alternative, given the rather slow variation in the number of physicists per country, would be to fix the running costs for periods of say five years. This might however lead to "game playing" as the five-year re-evaluation approaches, so that an annual re-calculation seems preferable.

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, led by the Director-General of the ILC laboratory, 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 through the Director-General.

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, the host will need to foster an 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. The Kitakami site is relatively remote, without many of the amenities expected by a highly educated and sophisticated workforce and without obvious opportunity for spouse employment. The host government will need to address this issue head-on by encouraging related industry and leisure facilities to locate to the neighbourhood of the ILC laboratory. The availability of housing types suitable for an international community with a wide range of cultures will also be important.

6.3. The ILC laboratory must have a strong department whose task it is to facilitate the arrival of families at the ILC site, to introduce them to available facilities and help with matters such as finding suitable housing, dealing with landlords, registering with local authorities, obtaining driving licences where necessary and all the other aspects of living in Japan which will be unfamiliar to non-Japanese.

6.4. To recruit and maintain staff, high-quality bilingual kindergarten and primary education is essential. The laboratory should found a Child Development Center on campus. Experience from the Okinawa Institute for Science & Technology (OIST) Graduate University shows that such a facility is one of the main reasons that staff and faculty decided to join and is a strong factor in staff retention.

6.5. It is essential that the local community fully supports the new ILC laboratory. This should be achieved by making the laboratory open to the local inhabitants, sponsoring and staging cultural events in the laboratory, making facilities, e.g. sporting facilities, provided for laboratory staff open to the general public at certain times, hosting regular tours and open days and working hard to make the laboratory an integral part of the community.

6.6. 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. A sizable fraction of the long-term visitors will have families and will require access to schools, including an international baccalaureate school at all educational stages, flexible enough to accommodate both multiple short-term and long-term stays.

6.7. Short-term visitors have a different set of requirements to those of residents. 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 should be of a hotel or on-site hostel type; it will be essential, given the isolated nature of the site, that the laboratory provide housing facilities for short-term visitors on the laboratory site.

6.8. 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 to all collaborating countries and unfettered web access to scientific web sites from the host are minimum requirements.

6.9. 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 a maximum of 210 MW for the 500 GeV machine and up to a maximum of 300 MW for the 1 TeV upgrade. The laboratory staff is estimated[3] to reach around 1750, some of whom could be industrially based, 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.

6.10. 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 heavy as 50 tonnes. Within the ILC site, access and transport roads and conventional utility distribution will be installed as part of the construction process and eventual

[3] Based on experience at a laboratory of similar scope, Fermi National Laboratory (2014)

laboratory operation. However, required upgrades to improve existing roadways for access to the ILC site from existing highway systems should also be considered if existing roadways are not capable of supporting loads of this nature. In particular, the road network from the nearest large port must be capable of transporting the largest loads required for the accelerator and detector to the ILC site. Building rail access to the ILC site should also be considered, preferably with direct access to the main line to Tokyo.

6.11. 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.

6.12. 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.

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.

8.3. 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.

8.4. 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*. Member states should be strongly urged to make bids for all WBS packages for which they 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*.

8.5. 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?

8.6. 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?

8.7. 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.

8.8. 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).

8.9. 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.

8.10. 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.

8.11. 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.

8.12. 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.

8.13. 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

8.14. 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).

8.15. 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.

8.16. 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.

8.17. 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.

8.18. 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

8.19. 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".

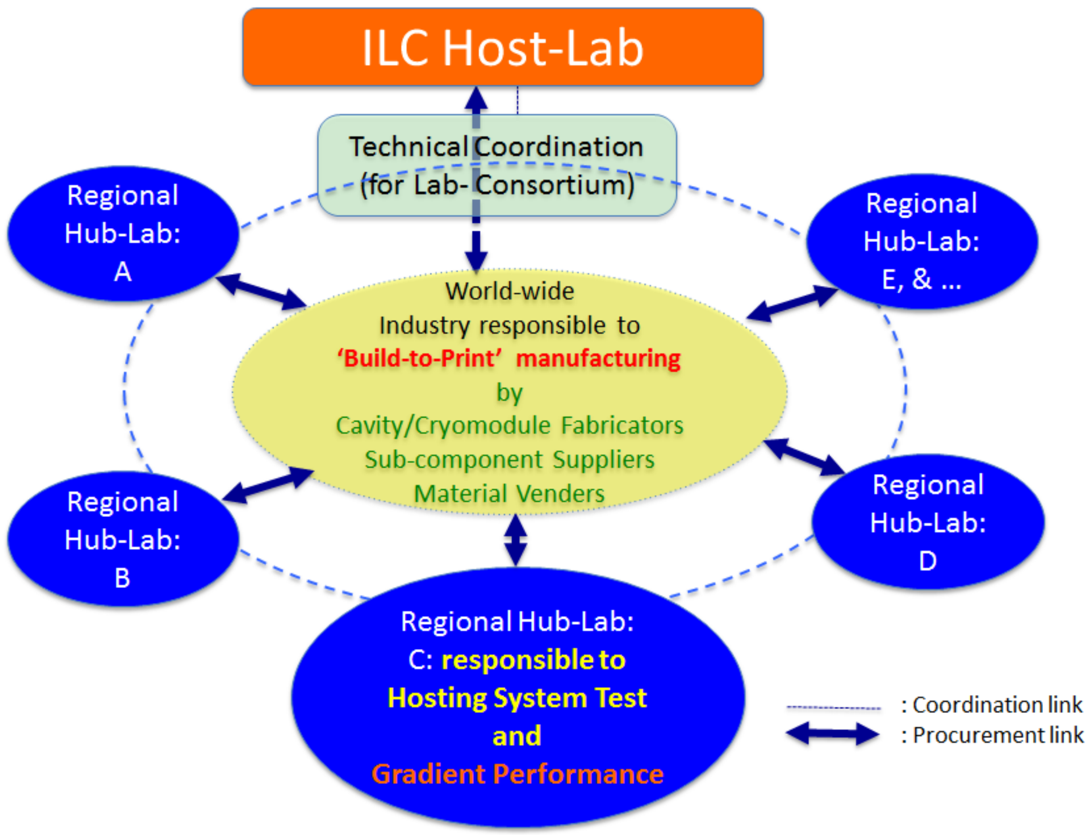

Figure 2 Globally distributed cryomodule mass-production based on the hub laboratory concept

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 Issues related to Project Schedule

10.1 The site-specific considerations for the project schedule are now being worked out. The local topography in the Kitakami site tends to favour horizontal access to the experimental area and the tunnel. However, the construction of specific large items, mostly for the experiments, make vertical shafts attractive in optimizing the schedule. The optimum balance between horizontal and vertical access is currently being explored.

10.2 Although the schedule for construction of the machine has not changed substantially from that set out in the PIP, considerable work has been done on mapping out the preparatory work required before ground can be broken. This includes further geological investigation, fixing the complete footprint of the machine the exact position of the interaction point, a land survey to determine ownership of any land affected by construction and preparations for purchase of land that is essential for the operation of the machine. Although by Japanese law an environmental survey is not required for the complete footprint of the ILC, it is intended that such a survey should be carried out as it is deemed essential to ensure that local and regional support for the project can be maximised. The cost of these measures is considerable and the time required to carry them out is substantial, so that the work with the longest lead times must begin now if delays to the current schedule for the project are to be avoided. At the moment the resources to carry out the necessary preparatory work are not available; providing a budget for the essential preparatory work is essential in advance of a final decision by the Japanese government on proposing to host the ILC.

10.3 The construction/commissioning schedule must be realistic without being unduly conservative. Any schedule that takes twice as long as necessary is realistic but unaffordable; a schedule that takes half as long as possible is both unrealistic and useless. Experience from several recent major projects, in which an unrealistic schedule was adhered to when it was obvious to all that it was impossible shows the dangers of management being unwilling or unable to admit to Council that the schedule was slipping. In a situation where dates known internally to be impossible are nevertheless presented, no useful planning to cope with the actual position can be done. Furthermore, this situation is deeply demoralizing to the project teams, who feel that they have failed even though the failure may be at a much higher, political, level.

10.4 Holding to a schedule that is crafted to be success oriented but feasible continually challenges management and staff. The careful monitoring of milestones and the ability to accelerate parts of the schedule when trouble is encountered is essential and is the reason for the use of contingency under management control as discussed in Section 4. Recognising the onset of a problem is the first duty of the project management; this is however useless unless they are empowered to address it with appropriate resources.

11 Intellectual Property

11.1 The question on intellectual property was not addressed in the original PIP. This section is a very high-level outline of a policy on Intellectual Property that has been adapted from that used for the original MoU under which the Global Design Effort of the ILC functioned. It corresponds to the typical practice of experimental particle physics collaborations in its generous interpretation of collaboration that none-the-less safeguards valuable intellectual property developed outside or only partially dependent on the ILC project. It is expected that at the time of the foundation of the final ILC Laboratory, a more detailed policy on Intellectual Property will be part of the founding instrument. The term “Party” in the following refers to the contracting governments, or their laboratories or universities, or individuals employed within their institutions, as appropriate under their national laws and contractual arrangements.

11.2 Intellectual property as defined in this section shall mean all intellectual property, including know-how, in forms such as drawings, designs, documents, inventions, software programs, reports, processes and protocols, and protected by means such as secrecy, patents, copyrights and trademarks.

11.3 Each Party shall remain the owner of any intellectual property developed prior to their involvement in the ILC project or outside its scope.

11.4 Unless otherwise agreed in writing, each Party will be the owner of those results generated in its own facilities. Under these conditions the said Party will be the holder of all the rights including but not limited to intellectual property rights, titles and benefits relating to such results.

11.5 Subject to such pre-existing conditions as may exist, each Party making a contribution to the ILC project will grant a non-exclusive, non-transferable, un-assignable, royalty free and irrevocable license to the other Parties to use the intellectual property in any such contribution for their internal purposes within the context of their contribution to the ILC project. The term “use” shall include any integration, modification, enhancement and redistribution, including by any third Party participating in the execution of the scientific programme of the other Parties within the ILC project.

11.6 Prior to making its contribution, the contributing Party shall ensure that it is entitled to license the intellectual property in its contribution to the other Parties in accordance with the provisions of section 11.5. The contributing Party provides no representations or warranties, including but not limited to a freedom to operate in respect of such intellectual property, and the using Party or Parties shall hold the contributing Party free and harmless from liability resulting from their use. The contributing Party shall have no obligations with respect to any practice of the using Party's intellectual property nor shall it have an obligation to participate in any legal actions regarding such intellectual property.

11.7 The obligations defined herein shall apply whether or not the intellectual property is pre-existing or developed in the execution of the contribution, and whether or not it was developed in a team or individually.

12 Interface between ILC Laboratory & the Experiments

12.1 The particle physics community has much experience of running experiments in global-scale collaborations. Today most of the experiments at large colliders are performed by such groups. Detector construction and physics research at the ILC will follow the same style. Two detectors designed for the ILC, ILD and SiD, are being advanced by two international teams. The groups can develop to experimental collaborations once the ILC accelerator is approved and detector proposals are called for.

12.2 The ILC laboratory will operate the mechanism to evaluate submitted proposals and to oversee the progress of approved experiments. It is a common practice of the existing accelerator labs to organize relevant committees for this purpose, such as a Program Advisory Committee or resource review committee. A similar scheme will also be deployed by the ILC Lab; its details can be worked out in the Pre-ILC lab discussions. Participation in the collaborations will be open to the entire world community, as for existing collaborations, such as those for LHC. Physicists from countries that do not participate in the construction of the accelerator may join experiments.

12.3 ILC detector collaborations will be self-organising and governing, following current practice. The ILC lab will facilitate smooth formation and operation of the collaborations so that the most productive scientific programmes can be conducted at the ILC. The financial support of the collaboration should be sought, in principle, by the participating members of the collaboration from individual funding agencies. It is not expected that the ILC Lab will make direct contributions to the detector components unless, after consideration in the Pre-ILC Lab discussions, it is found to be most effective for in special cases. The ILC Lab will, however, supply infrastructure that is common to both detectors and also staff to help with assembly and integration work. The lab needs to be kept informed of the funding of the collaborations and will facilitate discussions with funding agencies.

12.4 After approval by the ILC Lab., collaborations will first construct their detectors, components of which will be provided in-kind by the participating institutions of each collaboration and will be transported and assembled on site. Transport will start a few years after approval when the assembly hall is completed. After several years of assembly works, the completed detectors are installed in the experimental hall for the final integration. Plans for the entire procedure are currently under study by the two design groups.

12.5 Research programmes start after commissioning of the ILC accelerator and the detectors. The ILC lab will propose a scheme to decide the precise running program after consultation with the scientific community.

12.6 The laboratory is expected to provide necessary infrastructure for the approved collaborations during each phase of the program; construction, commissioning and running.

12.7 Close communication and cooperation between the accelerator team and the collaborations is of vital importance for the ILC. To this end, the ILC lab will establish adequate links between them at a variety of different levels, from the agreement of the accelerator operating schedule and mode to the work of IR integration and/or operation. This is particularly crucial in view of the high precision of the IR components and the planned running using “push-pull” operation, in which the two detectors must be swapped into the beam-line with the minimum disruption and time delay.

12.8 The required infrastructure includes a wide range of items as itemised below. Many of them can be common to the accelerator teams:

- the experimental hall and the assembly hall with necessary supplies of electric power, water, liquid He, and cranes for assembly and installation;
- access to these halls;
- well organized safety measures against all kinds of mishaps and natural disasters;
- office space for visitors both for short and long visits, some also near the hall depending on the distance between the main campus and the site;
- Meeting rooms suitable for discussions and lectures, with one meeting room sufficiently large to accommodate the largest likely audience for common ILC laboratory events;
- IT services for communication;
- housing for short-term visitors and for long-term visitors, including those with families
- Cafeteria and similar facilities

12.9 The ILC Lab is also expected to provide various kinds of services:

- assistance for transportation from the landing port to the site;
- technical support for hall-works, such as transport, crane operation or welding;

- interface with the local safety authorities about e.g., high pressure gas, inflammable gas, radiation and so on;
- various services to visiting staff like arranging accommodation, safety education, help for driving licenses and so on in order to make their life easier
- post office and banking facilities on campus
- language courses at various levels in Japanese

This is not an exhaustive list and will be expanded after investigation and discussions during the Pre-ILC Lab period.

12.10 In addition to the many physicists and engineers who will visit from the collaborating institutions, there will be physicists, engineers and or technicians belonging to the ILC lab who work mostly on servicing tasks. It would be very beneficial for the experimental collaborations to have a number of experimental physicists and phenomenology theorists resident at the ILC-Lab. These physicists can provide a kernel to assist the collaborations to produce physics. The Lab should consider a mechanism to employ and/or invite such physicists, some for extended periods, similar to the Associateship scheme at CERN.

13 Transitional arrangements

13.1 The governance structure outlined in the PIP and in Section 2 above is a long-term structure aimed at producing the stability essential to construct a project such as the ILC. It is necessary to consider how to make the transition between such a desirable organisational structure and the current situation, in which a very small expert team with correspondingly small resources is making necessary preparations for approval of the project. This transition has already begun with the establishment at KEK on January 1st 2014 of the ILC Preparation Office, headed by the Director General of KEK, whose purpose is to facilitate the transition to an ILC "pre-lab". Further details of the steps necessary to achieve the final governance structure are discussed in this section.

13.2 The "ILC pre-lab" would be the precursor body for the ILC organisation to be established in due course. The ILC pre-lab represents a qualitative advance on the structures existing during the TDP. The goal is to persuade the participating laboratories and other organisations to commit resources and staff in a more specific manner, with the very explicit goal of realising the ILC. For this purpose, the present LCB would be re-formulated as the council for the ILC pre-lab. Likewise, the management structure, currently the LCC, within the ILC pre-lab would be expanded by the addition of an advisory board explicitly comprising representatives of the participating laboratories and other organisations.

13.3 The ILC pre-lab would continue to operate within the pre-construction budget; i.e., without any guarantee of proceeding with actual project construction. The latter could only be obtained after formal project approval was granted by the relevant government bodies. Therefore, on the social and political fronts, the most significant mission of the ILC pre-lab would be to facilitate and service negotiations with various groupings of government agencies.

13.4 The ILC pre-lab would play the role of "originator" of the required technical information, including: scientific merits of the project, technical feasibility and status of the project, reliable cost estimates and proof of the existence of an adequate expert population in the academic and industrial sectors for successful project execution. The ILC pre-lab would have to produce these technical data, which would be suitably updated periodically, and to assist in creating the materials required for interactions with government agencies and media.

13.5 The main mission of the ILC pre-lab on the engineering front, while undertaking all of the above tasks, would be to complete an engineering design report (EDR), derived from the TDR of 2013. The EDR would represent the "technical drawings" for actual construction of the ILC and would also be expected to serve as critical material to be evaluated in certain countries in the context of formal project approval.

13.6 Another important role of the ILC pre-lab would be to oversee progress in the area of experimental facilities, both technical and organisational. On the technical front, the world high-energy physics community would need to continue critical detector R&D, which would be interfaced with development of detailed engineering design of detector facilities. On the organisational front, a consensus would need to be formed as to how to conduct a peer review process that could result in amicable agreement regarding formal collaborations to conduct experiments at the ILC. An evolutionary scenario which connects ongoing efforts by the SiD and ILD groups with those by numerous horizontal collaborations and common groups, into specific proposals for experimentation at the ILC will need to be developed. The ILC pre-lab would play a leading role in formulating the procedures to be followed in this complex process. The ILC pre-lab would also have to develop a model as to how it could best interact with community members on theoretical physics.

13.7 The ILC pre-lab 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 laboratories, universities or other national and/or regional organisations. As found appropriate and desirable, these Agreements could be endorsed via government-level agreements among the nations of the host laboratory and member organisations. The identification of the organisations that should be partners in the ILC pre-lab is an important and delicate task that should begin as soon as possible. The duration of the pre-ILC lab should be until the signing of the international agreement setting up the ILC project, or until it becomes clear that such an agreement is not possible for the foreseeable future.

13.8 The site of the ILC pre-lab is an important question. In the short term, given the current resources dedicated to the ILC, and the position of KEK as the only organization which can receive funding for particle physics from MEXT, it is inevitable that the pre-lab will be sited on the KEK site. However, experience from ITER implies that it can damage the building of an international laboratory if it is too dependent on or closely integrated with an already existing institution. The independence to build its own structures and develop its own ethos is vital for a new institution with a challenging task. As soon as practicable therefore, and well before the coming into operation of the final ILC organisation by international agreement, the pre-lab should relocate to the Kitakami site, with the help and support of the local authorities. It will be symbolically important for the DG of the pre-lab to move his or her office to Kitakami as soon as reconcilable with efficiency. However, the travel time between Tsukuba and the ILC site is sufficiently long that, for the period in which frequent travel to KEK is unavoidable, the ILC HQ could be based on an interim basis in Sendai. A move to the final ILC laboratory site would then be a second phase.

14 Future Technical Activities

14.1 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.

14.2 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.

14.3 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.

14.4 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.

14.5 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.

14.6 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.

14.7 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.