FUNDING AGENCIES FOR LARGE COLLIDERS

REPORT 2007/08

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The purpose of this annual report is to present the status of global coordination in particle physics as seen by the Funding Agencies for Large Colliders group (or FALC), with representatives from the main funding agencies in the Americas, Europe and Asia and which meets twice yearly to discuss the status and the perspectives of the field. The Chair of the International Committee on Future accelerators (an international forum of leading particle physics researchers established in 1976) belongs to this group. This first report also summarizes FALC deliberations and actions since the inception of FALC in 2002.

Since the first identification, more than a century ago, of the basic building blocks of matter, a systematic investigation of fundamental forces and interactions and of the fundamental constituents of matter has led to the "Standard Model" of particle physics. The Standard Model has been validated with unprecedented precision by experiments at existing large infrastructures in the Americas, Asia, and Europe wherein particle beams are collided at great energies to produce the various elementary particles.

However, the most central element of the particle puzzle is still undiscovered, an elementary particle named the Higgs particle after the theoretician proposing its existence. Experimental results have given only indirect evidence for its existence. The discovery of the Higgs is so crucial that the Large Hadron Collider (LHC) at CERN, Geneva, has been devised and constructed with beam energies large enough to prove its existence or demonstrate other new physics. Such a discovery would shed light on the origin of the mass of all basic constituents of the universe.

There are good reasons to believe that the new energies reached by the LHC will open a revolutionary phase in particle physics with new interactions, new symmetries, new particles and even new dimensions of our space-time. Indeed, albeit stunningly successful, the Standard Model still has gaps and is unable to explain some compelling questions prompted by recent experimental evidence, such as why the most elusive elementary particles, neutrinos, have such tiny masses compared to the rest of fundamental particles; and, most striking, what is the composition of the universe, given that the known stable matter only accounts for a fifth of the total matter in the universe. After having realized that we are not at the center of our solar system nor of the universe we are confronted with evidence that we are not even made of the most abundant kind of matter of the universe.

Regional studies and reports commissioned in Europe, Japan, and the U.S. all place the highest priority on exploration of the Terascale at the LHC and at a future linear collider. (The Terascale denotes the energy of a charged particle accelerated by one trillion electron volts.) The exploration of the Terascale of energies will be a major challenge and will entail a complex strategy with multiple types of machines and complementary programs among regional research infrastructures. The International Linear Collider (ILC) project has been identified by a world wide consensus of the particle physics community as a very high priority for a future facility. This project is working towards the completion of a design within the next five years. Studies of the alternative, less proven, CLIC technology that could potentially reach even higher energies are also being undertaken.

Results from the LHC will demonstrate the appropriate energy range for a future linear collider and at this stage a decision could be taken on how to proceed. Coordination and co-operation in the use of available resource is mandatory to meet the tremendous challenge of the next generation of colliders and FALC aims to generate the appropriate discussion to direct in an optimal way the existing resources and identify the extra support needed to accomplish the enterprise.

Fundamental science has always been a wellspring for innovation. To document the benefits of an ILC, FALC commissioned a document exploring in detail all the benefits of the R&D related to the conception and realization of such a facility. The unification of electricity and magnetism provided the intellectual basis for the understanding, design, and operation of electrical machines and radio transmission. The elegant Einstein formulation of general relativity makes possible the incredible precision of the Global Positioning System. The strange laws of quantum mechanics are fundamental to modern electronics, nanotechnology and soon will become the standard approach for an “ab initio” comprehension of protein folding and their role in degenerative diseases and in drug design. Challenging infrastructures lead to the creation of innovative solutions, like the World Wide Web, invented at CERN to face the increasing demand to exchange information within the far-flung, world-wide communities of particle physics experiments. Very likely the next large particle physics machine will continue to inspire innovation.

The enormous effort of thousands of researchers, engineers, and technicians required for the next particle physics collider requires a crucial element to reach success; the stability of financial support extending over decades and encompassing more and more the entire research career of scientists. Through this initiative, FALC aims to establish a dialogue with the governing institutions and help generate the confidence necessary to produce such stability. This Report is organized in a brief historical introduction, a survey of current facilities, an outlook to future facilities, a description of the status of R&D programs, and is followed by the report on technological benefits of the ILC.

FUNDING AGENCIES FOR LARGE COLLIDERS

ANNUAL REPORT 2007

EXECUTIVE SUMMARY

This report describes the activities of the Funding Agencies for Large Colliders, or FALC, composed of representatives of funding agencies from Europe, the Americas, and Asia, which meets twice yearly to provide a forum for the discussion of the status, prospects, and issues regarding large international particle physics facilities. The FALC Terms of Reference can be found in the Annexes.

At its inception the prime focus of FALC was the status of the current funding for R&D towards a sub-TeV linear collider and the perceptions of the prospects for its future. Later, FALC agreed that the remit of the Group would be expanded to include those facilities in operation or under construction such as the Japan Proton Accelerator Research Complex (J-PARC), the Large Hadron Collider (LHC) in Geneva, Switzerland, and the Tevatron collider in Batavia, Illinois. Progress on the J-PARC has been steady and beam for experiments is expected to start from the latter part of Japanese FY (JFY) 2008. Construction of the LHC is complete and commissioning is preparing for first beam in summer of 2008. The Tevatron has been running extremely well and the program is expected to continue through 2009 or 2010. Details can be found in the body of this report.

FALC also promotes coordination in the R&D programs for upgrades to the LHC; for lepton colliders including the sub-TeV International Linear Collider (ILC) and shares information on possible future technologies such as those for CLIC, muon colliders and for the worldwide neutrino program. The Consultative Group on Particle Physics of the OECD and regional reports representing Europe, the U.S. and Japan all place the highest priority on exploration of the Terascale at the LHC and at a future linear collider. These "road maps" and their conclusions are discussed in this report.

The FALC considerations have been dominated by the ILC, which is the most mature technology and is working towards the completion of a technical design in the near future.

In 2007 the FALC received the ILC Reference Design Report (RDR) from the ILC Global Design Effort (GDE) team. The FALC is now considering subsequent R&D plans proposed by the GDE. The availability of first results from the LHC are expected to show if the ILC is the correct route for a future linear collider or whether a higher energy reach, as could be obtained with CLIC, is required. The need to reach international agreements on siting and construction, and the current availability of R&D funds all suggest the potential of a construction decision for the ILC near the middle of the next decade.

FALC has commissioned a separate report on the technological impacts of the R&D required for large colliders, focusing on the ILC. This report has identified the key

ILC technologies that are most likely to lead to new applications, in other science areas, industry and the broader society. This report will be available in 2008.

1. HISTORY

1.1 FALC was established in 2003 as an informal body composed of funding agency representatives. The rationale for creating such a body was that the particle physics programme was increasingly confronted with the need for facilities on a global scale. This potential expansion from a national or regional level created a new need for the funding agencies to interact on a similar basis. As a first step, it was decided that an informal forum to share views and opinions on prospects and issues in each of the states would be valuable. By 2004, funding agencies from all three regions were represented (Canada, CERN, France, Germany, India, Italy, Japan, Korea, UK and US).

1.2 At its inception, the prime focus was the status of the current funding for R&D towards a sub- TeV linear collider and the perceptions of the prospects for its future. All the agencies recognised the immediate priority of successful completion of the LHC for the future of particle physics research, and a need for a proposed linear collider in an overall global strategy for future opportunities. It was observed that the initial R&D design phase could be funded through existing funding routes and structures in the participating states but that there would become a need for global governance and the establishment of an international design team as the project moved into an engineering design phase. The earliest operation of a linear collider was then envisaged to be in 2015, giving the prospect of five years concurrent running with the LHC. The Group agreed that the optimal strategy would be to pursue R&D for a sub TeV linear collider, leading to a fully costed design, on which a decision to proceed could be taken following the confirmation of the physics case by results from LHC. In parallel, R&D towards CLIC, a potentially higher energy linear collider technology, should also be pursued.

1.3 FALC recognised the need for the funding agencies and the physics community to move forward in a coherent manner following the choice of superconducting technology for the sub TeV linear collider in 2004. The Chairs of ICFA (International Committee of Future Accelerators) and its subcommittee ILCSC (International Linear Collider Steering Committee) were invited to attend future meetings of FALC. Following the establishment by the international particle physics community of a Global Design Effort (GDE) to produce initially a Reference Design, the Director of the Central Team was invited to all future meetings of FALC. The Director has given reports on the project status to each meeting of FALC, which has been impressed with the technical progress.

1.4 FALC established a Linear Collider Resource Group to provide a clear view of the funding arrangements for the linear collider, and to provide a forum to prepare for, and report, decisions on funding arrangements. Membership of the Resource Group is open more widely than that of FALC, with no formal restrictions and all interested funding agencies are encouraged to attend. The Chair of the Resource Group (a member of FALC) also attends ILCSC meetings. The FALC Resource Group established a Memorandum of Understanding between funding agencies to fund the administrative support required for the ILC GDE, administered by Fermilab, with the costs funded equally by the three regions. Provision of funding for the R&D coordinated by the GDE will be provided at the discretion of the relevant funding agencies.

1.5 By the middle of 2006, it was apparent from discussions at FALC that to make progress towards a construction decision for a linear collider it would be necessary to consider the wider picture of particle physics research, understanding the priorities and constraints in each region. It was agreed that the remit of the Group would be expanded to include promotion of global coordination of, and information exchange on, the R&D programmes for upgrades of LHC, the near term (ILC) and future (CLIC) linear colliders and the worldwide neutrino programme (such as proton driver, superbeam and neutrino factory). The Group agreed that although the acronym FALC should not be changed, it should be taken in future to represent 'Funding Agencies for Large Colliders'.

1.6 At the beginning of 2007 the ILC GDE released the Reference Design Report for the ILC. The outcome of this process was reviewed by a group jointly nominated by FALC and ILCSC. Following this Group's report, FALC congratulated the GDE on the robustness of the RDR and the achievements in the R&D phase. The ILC GDE was now aiming to reach a full engineering design in 2010. With the technically driven planning of a construction duration of seven years, this would lead to first operation around 2019. FALC noted the statement by one funding agency that based on experience of constructing large international facilities, the possible earliest start date for the beginning of construction and the potential construction phase length were unlikely to permit first operation before 2025. Taking into account the potential timescales, FALC recognised that it was too early to propose a site selection process for a linear collider, but agreed that discussions should begin to prepare a possible process.

1.7 The ILC GDE has completed the definition of the potential work programme and required resources for the engineering design phase at work package level. This plan was considered by ILCSC and the FALC Resources Group in late 2007, and it is planned that the Resources Group will have oversight of this plan as the work packages are allocated. The focus from FALC had previously been on the accelerator, rather than the possible detectors, for the ILC. Whilst this emphasis remains, the Group did receive a report on progress towards the formation of detector concepts and agreed that the focus of work for the detectors should be on the issues relevant to the accelerator engineering design programme.

1.8 FALC agreed that it was important to plan for consensus on a cooperative global programme, with synergistic and affordable futures for the major laboratory infrastructures. The current expectation is that decisions on approval of upgrades to the LHC, a linear collider, and possibly a global neutrino facility could be technically feasible on a similar timeframe. Considering that the global resources available would likely be inadequate to fund all the opportunities on such a timescale, FALC considered that coordination would be essential for the health and success of the global programme. As a first step towards this coordination, it believed that a global programme was essential and that it could be implemented with coordination by a network of laboratories until formal governmental agreements were in place.

1.9 Recognising the technological impacts of the R&D required for large colliders, FALC has commissioned a study to identify and enable the promotion of the technological applications of the R&D, focussing on the ILC. Key technologies that are most likely to lead to new applications include superconducting radiofrequency acceleration, beam control, global remote facility operations and computing. Potential applications range from short pulse radiation therapy for cancer treatment, scanning of cargo containers, monochromatic X ray sources for semiconductor circuit lithography, to new technologies to excite or break chemical bonds with applications in the pharmaceutical industry. This report will be completed in 2008.

1.10 By the end of 2007 the timescale for construction of the ILC had come into better focus. The prospect for physics results from the LHC after operations begin in 2008, the time needed for internationalization of the ILC, and the impact of recent UK and US budget reductions on the ILC R&D program collectively suggest the potential for a construction decision for the ILC near the middle of the next decade. The GDE presented a plan that responded to these developments to FALC in early 2008, which replaces the Engineering Design Report with a Technical Design Phase due for completion in 2012.

2. STATUS OF CURRENT MAJOR PROJECTS/FACILITIES

J-PARC

2.1 The Japan Proton Accelerator Research Complex (J-PARC) is to be one of the most powerful proton accelerators worldwide. It will produce various secondary particles such as neutrons, muons, kaons and neutrinos in order to promote a wide range of research which covers nuclear-particle physics investigating microscopic-scale science to material-science and life-science searching characteristics of material structure and mechanism of life, opening new frontiers of science. The accelerator complex is being constructed at the Tokai site of the Japan Atomic Energy Agency (JAEA) as a joint project between High Energy Accelerator Research Organization (KEK) and JAEA.

2.2. The initial phase of this project includes the following five facilities: a) a mega watt (MW) class 3GeV Proton Synchrotron (PS) together with a 181-MeV Linac as an injector, b) a MW-class 50GeV PS, c) a 3 GeV Neutron/Muon Experimental Facility, d) a 50 GeV Hadron Experimental Hall, and e) a Neutrino Experimental Facility. The construction work started in JFY2001, with anticipated first beam in the latter half of JFY2008. The R&D facility for nuclear transmutation, an expansion of the Neutron/Muon/Hadron Experimental Facilities, and an upgrade of the 50GeV Hadron experimental facilities will be included in the next phase of the construction. In addition, the Linac energy is planned to be upgraded to 400 MeV immediately after the completion of the initial phase.

2.3 According to the current plan, the 3GeV beam will be injected to the 50GeV ring in May 2008. Within JFY2008, beams will be delivered to both the Materials and Life Science experimental hall (which provides muon beams and neutron beams) and

Hadron Experimental hall (which provides kaon beams). It is anticipated that the neutrino experimental facility will be completed by the end of March 2009.

2.4. The J-PARC Center, which is a new organizational body, was set up for operating J-PARC. The program advisory committee for experiments has evaluated many proposals in the field of nuclear-particle physics, material science, and the life sciences. At the government level, a review board concluded that the future plan for utilization was appropriate.

LHC

2.5 When it begins operation in 2008, the Large Hadron Collider (LHC) at CERN will be the frontier, highest energy accelerator in the world. It will very likely discover the Higgs Boson, which is postulated to give particles their mass, and Supersymmetry, if they are in the mass ranges expected today, or observe other new physics beyond the Standard Model, a result of equal or greater significance. The LHC will provide unprecedented sensitivity to physics beyond the Standard Model and many of the theoretical models describing the likely physics at these energy ranges predict the existence of a wide spectrum of new particles.

2.6 Construction of the LHC and its four detectors, ATLAS, CMS, LHCb and ALICE, began in 1995. During 2007 work began on commissioning all machine components up to the conditions required for 7 TeV beams, working on sectors in parallel wherever possible. As at December 2007 all machine sectors had completed high-pressure testing and the sequence of flushing and cooling was continuing. A pilot run is planned by the end of 2008 with an initial energy of 10TeV, ramping to maximum energy of 14TeV in 2009.

2.7 The LHC experiments are in an intense phase of installation and commissioning until the closure of the beam pipes by summer 2008 and should be fully installed and commissioned on the same timescale as the machine except for the CMS endcap, which will be installed in the first shutdown. CERN Council has approved additional resources over the period 2008 – 2011 to enable the laboratory to begin renewal of injector infrastructure essential to the full exploitation of the LHC, enhance its luminosity, and begin R&D for upgrades.

TEVATRON

2.8 The Fermilab Tevatron collides protons and antiprotons at a total energy of 2 TeV and will remain the world's highest energy particle accelerator until operation of the LHC. Throughout 2007, the Tevatron collider at Fermilab continued to set new records. The highest peak luminosity achieved in FY 2007 was 2.92×10^{32} $cm^{-2}s^{-1}$, which is 16% above the peak achieved in 2006. The integrated luminosity for FY 2007 was 1.31 fb^{-1}, which is twice the integrated luminosity achieved in FY 2006. The integrated luminosity for the current data run now exceeds 4.00 fb^{-1}.

2.9 Two large, multipurpose detectors, CDF and D-Zero, are used to study the particles produced in these collisions. The Tevatron physic program consists of studies of the top and bottom quarks, searches for supersymmetry and extra dimensions, and precision measurements of the electroweak. Recent highlights include evidence for single top quark production; observation of new baryonic states, the first observed particle formed of quarks from all three families of matter; and the world's best single measurement of the W mass, which leads to an estimate for the mass of the yet-undiscovered Higgs boson that is lighter than previously predicted. In 2007, together CDF and D-Zero experiments published 81 papers in refereed journals.

2.10 By the end of the current data run late in this decade, both experiments are expected to accumulate around $7\ fb^{-1}$. The full Tevatron dataset will permit initial exploration for the standard model Higgs boson in the entire allowed mass range.

3. FUTURE FACILITIES - Roadmaps for Particle Physics

3.1 "A 'roadmap' is an extended look at the future of a chosen field of inquiry composed from the collective knowledge and imagination of the brightest drivers of change in that field." (R. Galvin, former CEO Motorola)

3.2 Research in particle physics is motivated by the goal of attaining a fundamental understanding and knowledge of elementary constituents and interactions and to discover the universal laws of nature. Thus, particle physics is revealing fundamental questions by probing the deep structure of matter, energy, space and time. Although fundamentally driven by the quest for knowledge, the ensuing research is performed at the edge of what is feasible technologically and hence drives the development of technology in many areas.

3.3 With the beginning of CERN's Large Hadron Collider (LHC) in 2008 and global preparations for the International Linear Collider (ILC) in full swing, we expect from those next generation experiments revolutionary results and significant progress in explaining long-standing questions such as the origin of mass, the nature of dark matter & energy, the mystery of extra spatial dimensions or the puzzle of grand unification of forces. Any of these new insights will explore unknown domains and would dramatically change the way we see our Universe.

3.4 In order to portray the larger context for the existing and further developments in this field several roadmaps in different world regions have been worked out. The Consultative Group on particle physics of the OECD submitted a report to the Global Science Forum in June 2002, which was later endorsed by the OECD Committee for Scientific and Technological Policy at Ministerial Level. In addition to the global OECD report there were three more recent regional reports from Europe, US and Japan. The European Strategy Report approved in July 2006, by the CERN Council, consisting of delegates from the 20 European member states, the EPP2010 report 'Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics' initiated by the U.S. National Research Council and released in April 2006, and 'Prospects for Elementary Particle Physics' approved by the Japanese Association of High Energy Physicists (JAHEP) in October 2006. Details of the roadmaps can be found in Annex 2.

3.5 All four reports are primarily science and research roadmaps that communicate the prospects of the field. Although being science driven, the roadmaps include other perspectives from design, development and technological points of view. The three regional reports that are relatively recent are based on a broad consensus among the scientific community and embed the future particle physics landscape in a local context of each region.

3.6 The roadmap conclusions and recommendations, summarized in Table 1, provide a consensus view of the future scientific landscape and communicate the visions of the field of particle physics. All four roadmaps agree on the fundamental future directions in particle physics. These goals remained unchanged since the first roadmap was drafted in 2002. Broadly speaking, the four roadmaps place the highest priority on exploration of the Terascale at the LHC and at a future linear collider. It is remarkable that three different world regions share the same view in their report. Priority is also assigned to a worldwide neutrino physics program and accelerator R&D. All three regional reports endorsed collaborative efforts within their regions.

Scientific activity	OECD	CERN Council	EPP2010	JAHEP
High Energy Frontier				
LHC	*** (complete and fully exploit LHC)	***	*** (fully exploit LHC potential)	(make LHC experiments a success)
LHC upgrade	Not considered at time of report	*** (motivated by physics results and operation experience to be implemented by around 2015)		
ILC	***	** (fundamental)	*** (strong bid to host ILC)	(highest priority)
Flavor Physics				Pursue goals in single master plan
Quarks		* (effort should be led by national labs)	* (level of support sensitive to overall budget picture)	(promote KEKB upgrade)
Neutrinos		** (promote R&D, physics program tbd 2012)	** (pursue a staged and internationally coordinated	(Make T2K at J-PARC to success)

			program)	
Fixed Target		maintain capability for fixed target program		(Kaon experiment at J-PARC)
Non-Accelerator Physics		Seek to work with ApPEC	** (expand program, together with DoE/NASA/NSF)	
Future accelerator R&D	*** (R&D program into novel accel. Technologies)	*** (CLIC, strong field magnets)	Promote R&D towards ILC	Common R&D ILC/KEKB upgrade
Cooperations		ApPEC, NuPECC Strengthen EU-relationships	Priorities at HEP/Astroparticle interface determined through DoE/NASA/NSF	Stronger partnerships with Asian countries
Organizational Issues	allow significant time for inter-governmental consultations	Need for updating strategy		

Table 1: Overview of the various Roadmaps. The priority within each Roadmap is indicated with * being the highest.**

4. STATUS OF R&D PROGRAMMES

a) Upgrades to LHC

4.1 Construction of the Large Hadron Collider (LHC) at CERN will be completed in 2008. The four large LHC experiments will then provide access to *Physics at the Terascale*. Their major physics goals include experimental investigations of the mechanism of electroweak symmetry breaking, a detailed study of phase transitions in quark-gluon matter, CP violation in the b-system and scenarios to understand the reason for the large hierarchy gap between the Planck scale to the mass scales of known particles and interactions. Such novel concepts will go beyond the Standard Model and most likely unravel very new physics with yet unknown consequences. Supersymmetry is one of the most attractive solutions for the hierarchy problem proposed so far, but other scenarios like extra spatial dimensions may also be accessible to the LHC experiments.

4.2 Despite this unrivalled scientific outlook the LHC community has started to consider upgrades to the machine and the experiments in order to push the discovery limits of this unique machine even further. Two basic scenarios are being studied: The SLHC would increase the luminosity by about a factor of 10 providing integrated luminosities of 1000 fb^{-1} which in turn would make very small cross-sections in the sub-fb region accessible. The DLHC is a far more ambitious scenario with a complete set of new high-field bending magnets doubling the collision energy in the pp-system to 28 TeV compared to 14 TeV now.

4.3 The SLHC scenario would increase the reach in mass scale by typically 20-30%. Squarks, as a reference case for supersymmetry, would be accessible up to a mass of 3 TeV compared to 2.5 TeV from the current LHC machine. Limits on the scale of extra spatial dimensions would be pushed from 9 TeV to 12 TeV. The luminosity of the SLHC would be as high 10^{35} $cm^{-2}s^{-1}$ with a most likely bunch spacing of 50 ns which would give rise to pile-up rates as high as 300-400 for each bunch crossing. Experiments will have to cope with increased backgrounds, larger particle fluxes and higher rates on all levels of the data processing chain. Detector concepts for the SLHC are currently being studied in coordinated efforts by all four LHC experiments. An envisaged timescale for first operation of the SLHC is 2015.

4.4 The DLHC scenario would be far more costly than the SLHC because new extremely high field magnets reaching 18 T around the 27 km LHC tunnel would have to be developed. New superconductors like Nb_3Sn are currently studied but the necessary R&D to reach an engineering design will certainly require around ten years and the actual production time would most likely match that of the current LHC magnets.

4.5 The CERN Council Strategy Group has placed the luminosity upgrade scenario (SLHC) high on its priority list. It explicitly states that a luminosity upgrade of the LHC, motivated by physics results and LHC operation experience should be enabled by focussed R&D.

b) Future Linear Collider Studies

4.6 A world-wide consensus emerged during the past decade that the next large HEP facility for the post-LHC era should be an electron-positron linear collider with a colliding beam energy of 500 GeV upgradeable in energy up to at least 1 TeV. Two linear collider studies are presently underway:
(i) ILC (0.5-1 TeV) based on Super-Conducting RF technology with accelerating gradients of 30 to 35 MV/m following the technology developments by the TESLA collaboration.
(ii) CLIC (0.5-5 TeV) based on normal-conducting RF technology with accelerating gradients of nominally 100 MV/m and considered as the only possible technology to extend Linear Colliders into the Multi-TeV colliding beam energy range.

4.7 The ILC technology has been demonstrated to be feasible and construction could begin within 4 years. The results from LHC will determine the appropriate energy range for a future linear collider. The CLIC technology is not yet proven and is at a much earlier stage in R&D, however it has the potential to reach the multi TeV scale. A decision on how to proceed will be taken when LHC results are available. ILC and CLIC study teams are collaborating on number of common issues, mainly beam dynamics, civil engineering & conventional facilities, beam delivery systems and detectors.

4.8 In Europe detector R&D is supported by the EU through the EUROTEV design study, the EUDET detector study and the future EUCARD accelerator R&D activity. Linear collider detectors must meet very stringent performance requirements in order to realize the linear collider's full discovery potential. FALC has been working to ensure that the linear collider detector R&D is compatible with the potential collider technologies and ensuring that the machine / detector interfaces are properly addressed.

International Linear Collider (ILC)

4.9 Internationally collaborative accelerator R&D on alternative technologies led ICFA in 2004 to choose superconducting technology as the accelerating technology for the linear collider. ICFA established the ILCSC as a steering committee for this new initiative. Based on a technical design parameter of 500 GeV centre of mass energy, current plans are for 2 x 11 km linear accelerators, accelerating the electrons and positrons to a central interaction region with a 14 mrad crossing angle, giving a potential site length of 31 km with damping rings and sources on the central campus.

4.10 Following the acceptance by the worldwide particle physics community of the superconducting technology choice, a Global Design Effort was put in place, coordinated by a small central team, to take forward the required physics performance specifications and reach a Reference Design Report (RDR). These specifications required an energy of 200 – 500 GeV, upgradeable to 1 TeV, with a potential luminosity of $500fb^{-1}$ in 4 years. The energy stability and precision had to be below 1%, with electron polarisation of at least 80%. The interaction region should allow for two experiments, with a detector change over within one week. The RDR produced in spring 2007 is consistent with the scope and provides a definition of the detailed design of the accelerator and reached a first estimate of potential costs as 6.62 Billion ILC Value Units (1 Value Unit equalled 1 $US at 2007 prices) for site specific and machine costs. Labour requirements were estimated at 13,000 person-years. The GDE administrative support is managed through Fermilab and funded equally by the funding agencies from the three regions.

4.11 The global R&D programme is focussed on the critical research and development required to ensure a feasible proposal when LHC results justify construction. Three project managers, one in each region, have been appointed to steer the next phase of technical design, scheduled for completion in 2012. This phase will be carried out in two stages, Technical Design Phase I and II. R&D will concentrate on three areas: the main linac, conventional facilities and accelerator systems. For the main linac the priorities will be to complete studies on the optimum feasible superconducting accelerating gradient, with the current baseline being 31.5MV/m; reaping the maximum benefit from the studies for the European XFEL;

and designing a cost effective RF power and distribution system. Conventional facilities work will focus on developing the most effective design of underground space and utilities. System performance specifications and cost/performance trade offs will be defined for the accelerator systems, integrating ILC and CLIC efforts where appropriate. In each area the R&D programme will seek synergies with other programmes. Phase I will focus on reducing technical risk and carrying out value engineering on the largest cost drivers. Phase II will complete preparations for undertaking the final engineering design and industrialisation and develop a plan for implementing construction.

4.12 The target performance goals are very challenging. An impressive worldwide effort on ILC detector R&D is underway in Asia, Europe and the USA. Internationally coordinated R&D reviews under the aegis of the World Wide Study group have been convened in the past year for the tracking (Beijing), calorimetry (DESY) and vertex detection (Fermilab).

4.13 The ILCSC has recently appointed a research director for the ILC, who will report on a regular basis to the ILCSC. He will be responsible for the experimental programme of the ILC, which currently has three proposed detector concepts. His tasks include the guidance of the global R&D detector activities and implementing procedures for validation of contrasting and complementary detector designs that are capable of meeting the design goals. To help complete these tasks an International Detector Advisory Group (IDAG) will be formed. Recently, the ILCSC has issued a call for letters of intent (LoIs) to produce reference designs for the two ILC detectors. The LoIs will be the basis for the validation of concepts by the ILC research director and IDAG with possible recommendation for further steps. The LoIs are validated on a timescale which tries to ensure consistency with the R&D for the accelerator Technical Design Phase. This call puts new emphasis on the need for detailed detector simulation and optimization studies.

CLIC

4.14 The objective of the CLIC study is to develop a technology for a Linear Collider in the multi-TeV colliding beam energy range for the post LHC era. The current aim is to address the feasibility of the CLIC concept and technology in order to arrive at a firm conclusion by 2010 on its possible use for a Linear Collider. At this time, the initial results from LHC should provide key inputs for the requirements of future Physics Facilities at the High Energy Frontier.

4.15 The work programme for CLIC after 2010 will be defined following results of the CLIC feasibility study and the international context at the time. During the period 2008 to 2010, it mainly consists of:

- Demonstration of the feasibility of the CLIC technology by addressing the main technological issues mainly in the CLIC Test Facility (CTF3).
- Design and optimization of a Linear Collider based on the CLIC technology and estimation of its cost.
- CLIC physics studies and detector development.

A report documenting the results of this study is expected to be published in 2010, and evaluated by ICFA.

4.16 An ambitious R&D program has been launched to address the feasibility of the CLIC concept and technology. It mainly consists of building and commissioning a scaled version of the novel CLIC scheme of RF power production, the CLIC Test Facility, CTF3, as well as developing and testing accelerating structures for the CLIC main linac with RF power provided by CTF3. This Test Facility is vital to verify the performance of CLIC as predicted by theoretical studies. The CTF3 project consists of a chain of challenging accelerators and an experimental area where key issues of the Two Beam Acceleration method are tested. It is being built in stages by a collaboration of Institutes and Funding Agencies from CERN member and non-member states, joining the efforts of 24 institutes from 13 countries.

c) Neutrino facilities

4.17 There are a number of important issues in neutrino physics following the discoveries of neutrino oscillation by the SuperKamiokande (SK) experiment and determination of mixing parameters by SK, SNO, KamLand and other experiments. The big issues include whether neutrinos are Majorana or Dirac particles, their absolute mass, the value of mixing parameter θ_{13}, and if neutrinos are responsible for the matter-antimatter asymmetry of the universe.

4.18 Two future types of accelerator based facilities are beta beams and a neutrino factory. Neutrinos from J-PARC to SuperKamiokande (T2K, 295km), and Fermilab NUMI beam to NOυA (820 km), and their upgrade programs are the initial superbeam projects currently being constructed. Other potential experiments being considered are a CERN to Frejus experiment (130 km), and very long baseline beams of ~1000 km (Fermi to DUSEL).

4.19 Neutrino factories provide neutrino beams from decays of accumulated muons in a storage ring. The key technology issue is that the muons must be cooled down and then accelerated before their decay into neutrinos, with R&D underway to determine the optimum technology. Demonstration of muon ionizing cooling is expected by the MICE experiment which is an international collaboration based in the UK. After cooling the rapid acceleration of the muons is achieved by a fixed field alternating gradient synchrotron and recirculating linear accelerator. The optimization of a neutrino facility could be performed after results are obtained from the long baseline neutrino beams from Fermilab and J-PARC currently under construction.

4.20 Development of multi-purpose underground detectors is also important. For experiments at neutrino factories, charge identification is necessary and the magnetic detectors might be needed. For neutrino superbeams or an upgrade of current long baseline neutrino beams, either large volume water Cerenkov detectors, high density scintillator detectors like NOυA, or liquid argon detectors can all offer good solutions.

4.21 These types of facilities have not been discussed in detail at FALC. However, it is envisaged that as the remit of FALC has now broadened future discussions will include the prospects for these facilities.

ANNEX 1

TERMS OF REFERENCE

1. To consider the wider picture of particle physics research, to understand the priorities and constraints in each region and to provide information and guidance to governments for planning and coordinating large particle physics facilities.

2. To improve the possibilities for international co-operation by understanding the planning processes in the funding agencies.

3. To provide a forum to prepare for, and report, decisions about funding arrangements for future particle physics facilities.

4. To provide a forum to promote knowledge of the applications of the technologies to be developed for large colliders, both in other scientific areas and in industry.

5. Recognising ICFA as the scientific reference point, to receive reports from ICFA (and its subsidiary bodies as appropriate), on the status of programmes for future particle physics facilities.

6. To exchange information on R&D projects being carried out for future particle physics facilities requiring international cooperation.

7. To encourage global cooperation in the R&D programmes for existing projects (such as the LHC and J-PARC), promote coordination for projects in the R&D and design phase (such as the ILC) and share information on possible future technologies and projects (such as CLIC and a neutrino factory).

8. To promote for the ILC specifically, the coordination of resources and the conduct of an R&D programme for the engineering design phase, and to work towards an appropriate organisational structure for the engineering design phase.

9. To produce a public annual report, including a scientific report from ICFA and information on the global picture of R&D for future particle physics facilities.

These Terms of Reference will be reviewed no later than 2010.

Membership:

Representatives of funding agencies (up to 5-7 per region), or their nominees. The Chairman should be elected from amongst the members, for a period of 3 years.

In attendance: Chairs of ICFA and ILCSC

Chair of the FALC Resources Group

The Public notes of the meetings can be found at http://www.linearcollider.org/cms/?pid=1000305.

ANNEX 2

DETAILS ON THE INDIVIDUAL ROADMAPS

The OECD Report

A3.1 The Consultative Group on particle physics of the OECD Global Science Forum was established in 2000 with the objective to exchange views on future directions in particle physics. Participating OECD governments nominated delegates as members. In the interest of openness and transparency of the roadmap process and also to ensure that the Group's finding were based on the best information, representatives from non-OECD countries and from main scientific communities were invited to participate and take part in all discussions at the four meetings that took place at the leading particle physics laboratories in the world.

The Consultative Group submitted its report[1] to the Global Science Forum in June 2002. In January 2004 the Meeting of the OECD Committee for Scientific and Technological Policy at Ministerial Level welcomed the report.

A3.2 The remit of the Consultative Group was to

- Exchange views on future directions of particle physics, particularly regarding to large accelerator-based facilities;
- examine the rationale behind program priorities and strategies;
- look at common or generic issues and approaches;
- identify and discuss relevant organization and managerial issues

A3.3 Based on the input from the communities the Consultative Group constructed a roadmap in particle physics extending to beyond 2020 as an indicative framework. The principal conclusions from the Report are

1. Regarding the roadmap in particle physics
    - concur with the world-wide consensus of the scientific community that a high-energy electron-positron linear collider (LC) is the next facility on the roadmap
    - there should be a significant period of concurrent running of LHC and LC, requiring LC to start 2015
    - the cost of the LC is broadly comparable to LHC and can be accommodated if the historical pattern of expenditure on particle physics is maintained, taking into account the additional resources that the host country will need to provide.

2. Regarding international R&D Cooperation
    - There are long-standing ties between HEP-labs as a sound basis for targeted and effective R&D
    - diverse accelerator R&D program should be maintained

3. Regarding Organisational and managerial issues

[1] The report is available at http://www.oecd.org/dataoecd/2/32/1944269.pdf

- Allow sufficient time for inter-governmental consultations well before any financial, manpower, timeline or other commitments are made

A3.4 The roadmap contains finally four interdependent strands:

- Exploit current frontier facilities until the contribution from these machines is surpassed by the results from LHC or LC;
- Completing and then fully exploiting LHC
- Preparing for the approval of a linear collider, to run concurrently with the LHC
- Supporting an appropriate R&D programme into novel accelerator designs

A3.5 In the meeting 'Science, Technology and Innovation for the 21 Century' of the OECD Committee for Scientific and Technological Policy at Ministerial Level held on 29-30 January 2004 the following communiqué[2] was issued:

Ministers acknowledged the importance of ensuring access to large-scale research infrastructure and the importance of the long-term vitality of high-energy physics. They noted the worldwide consensus of the scientific community, which has chosen an electron-positron linear collider as the next accelerator-based facility to complement and expand on the discoveries that are likely to emerge from the Large Hadron Collider currently being built at CERN. They agreed that the planning and implementation of such a large, multi-year project should be carried out on a global basis, and should involve consultations among not just scientists, but also representatives of science funding agencies from interested countries. Accordingly, Ministers endorsed the statement prepared by the OECD Global Science Forum Consultative Group on High-Energy Physics (Annex 4).

European Strategy for Particle Physics

A3.6 On the initiative of the CERN Council in 2005 an ad-hoc scientific advisory body, the Strategy Group, had been installed with the mandate to draft a strategy document addressing the main lines of Particle Physics in Europe, accelerator-based and non-accelerator-based, including R&D for novel accelerator and detector technologies. The Strategy Group was composed of scientists nominated by the CERN Member States' delegations, the directors of the major particle physics laboratories in Europe, as well as of members from ECFA and the CERN Scientific Policy Committee. During the strategy finding process an open symposium to collect the views of the community was held. The strategy document[3] was finally unanimously approved by the CERN Council during a special session in Lisbon in July 2006.

A3.7 The Strategy Report is structured in four sections covering general issues, scientific activities, organizational aspects and finally complementary issues.

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[2] The full communiqué is available at http://www.oecd.org/document/15/0,2340,en_2649_34487_25998799_1_1_1_1,00.html

[3] The CERN Council Strategy Document is available at http://council-strategygroup.web.cern.ch/council-strategygroup/

On general issues the CERN Council Strategy Report states in the beginning:

- Europe should maintain and strengthen its central position in particle physics.
- A well-coordinated strategy for particle physics in Europe is paramount. This strategy will be defined and updated by the CERN Council

The strategy of the CERN Council contains the following scientific elements:

- Highest priority is to fully exploit the LHC physics potential; resources for completion have to be secured such that machine and experiments can operate optimally at their design value. Motivated by physics results R&D for machine and detectors for a LHC upgrade has to be vigorously pursued now.
- Vital to strengthen the advanced accelerator R&D programme: develop CLIC technology and high performance magnets for future accelerators.
- It is fundamental (=absolute necessary for the progress of the field) to complement LHC results with measurements at a linear collider. There should be a strong well-coordinated European activity towards construction decision, to be ready for new assessment by Council around 2010.
- Studies of scientific case and R&D for future neutrino facilities are required to define optimal neutrino programme around 2012.
- There is a range of very important non-accelerator experiments at overlap between particle and astroparticle physics. Council will seek to work with ApPEC to develop coordinated strategy.
- Flavour physics and precision measurements at lower energies complement our understanding; these should be led by national or regional collaborations, and the participation of European labs should be promoted.
- There is a variety of important research lines at interface between particle and nuclear physics. Council will seek to work with NuPECC in areas of mutual interest.
- Forthcoming LHC results will open new opportunities for theoretical developments, and create new needs for theoretical calculations, which should be widely supported.

A3.8 On the organisational issues the report remarks the following:

- There is a need for an on-going process to define and update European strategy for particle physics. CERN Council shall assume this responsibility based on a dedicated scientific body that shall be established for this purpose.
- The Council will prepare a framework for Europe to engage with the other regions to optimize particle physics output through the best shared use of resources.
- There is a need to strengthen the relationship to the EU for communicating issues related to the strategy.
- The Council will establish how the non-member states should be involved in defining the strategy.

A3.9 The report closes with statements on complementary issues:

- Establish a network of closely cooperating professional communication officers for a European particle physics communication and education strategy.
- Create a technology transfer forum
- Consolidate and reinforce European industry connection.

The EPP2010 report

A3.10 In April 2006 the EPP2010 report 'Revealing the Hidden Nature of Space and Time: Charting the Course for Elementary Particle Physics' was released[4]. This report assesses the field of particle physics and makes recommendations for the future of US particle physics. The report was initiated by the engagement of a broad survey of Physics that the National Research Council's Board on Physics and Astronomy is carrying out every ten years. For the study a committee with members drawn both from inside and outside the field of particle physics was formed to provide an in-depth assessment with a 15-year plan and recommendations for the future US particle physics. Town meetings and other events were conducted to ensure broad community involvement in the process of formulating the plan.

A3.11 The results of the committee's analysis led to the chief recommendation of the EPP2010 report:

The US should remain globally competitive in particle physics by playing a leading role in the worldwide effort to aggressively study Terascale Physics.

To implement this main recommendation the following objectives should be achieved in priority order:

1. Fully exploit the opportunities afforded by the construction of the LHC
2. Plan and initiate a comprehensive programme to become the world-leading center for R&D of science and technology for the linear collider; mount a compelling bid to build the ILC on U.S. soil
3. Expand the programme in particle astrophysics and pursue an internationally coordinated, staged programme in neutrino physics.

A3.12 In accordance with the objectives the following action items are recommended:

- Highest priority is to continue as active partner in realizing physics potential of LHC.
- The U.S. should launch a major programme of R&D, design, industrialization, management and financing studies for ILC
- The U.S. should announce its strong intention to become the host country for ILC.
- Scientific priorities at the interface of particle physics, astrophysics, and cosmology should be determined through a mechanism jointly involving NSF, DOE, and NASA.
- Recommendation to determine properties of neutrino through a well coordinated, staged programme of experiments developed with international planning and cooperation.
- U.S. participation in large-scale, high precision experiments should continue but the level of support that can be sustained will have to be very sensitive to overall budget picture.

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[4] The EPP2010 report is available at http://www7.nationalacademies.org/bpa/EPP2010.html

The JAHEP Roadmap Report

A3.13 The Japanese Association of High Energy Physicists (JAHEP) unanimously approved its roadmap report 'Prospects for Elementary Particle Physics'[5] at the general JAHEP meeting on October 25, 2006.

The key elements of the JAHEP strategy report are:

- Physics at the high energy frontier is of prime importance. Highest priority is given to ILC. Before the ILC experiment commences, flavour physics is promoted that is complementary to physics at the energy frontier. The above two goals should be pursued in a single master plan.
- To realize the ILC, industrialization of accelerator technologies has to be facilitated and accelerator R&D boosted. Unify existing accelerator R&D for both, energy frontier and flavour physics.
- Make neutrino and kaon experiments at J-PARC successful and promote upgrade to B factory
- Expand internationalization and form stronger partnerships with Asian countries and other countries in the world.

A3.14 With the following short-term action plans:

- Physics at the energy frontier
    - Make the LHC experiments a success
    - Promote R&D aimed towards ILC construction, in particular establish technologies for mass production and industrialization and strengthen R&D organization
- Flavor Physics
    - Complete the construction of J-PARC
    - Promote experiments incl. T2K and rare Kaon decays
    - Upgrade KEKB and utilize accelerator for ILC R&D
- Common issue/synergies
    - ILC and KEKB have large commonality. Share human and material resources
    - Unify forces to pursue master plan

[5] The JAHEP report is available at http://www.jahep.org/hec/doc/jahep_tenbou_eng_final.pdf

ANNEX 3

STATEMENT PREPARED BY THE OED GLOBAL SCIENCE FORUM CONSULTATIVE GROUP ON HIGH-ENERGY PHYSICS

The January 2004 OECD Ministerial Statement on International Co-operation on Large Accelerator-based Projects in High-Energy Physics

Ministers expressed their appreciation for the work of the OECD Global Science Forum Consultative Group on High-Energy Physics. They welcomed the report from the Group and commended the clarity and world-wide consensus they found amongst the high-energy physics community in developing the Roadmap for future large accelerator-based facilities.

In particular, the Ministers note several important points that were articulated in the report:

• A roadmap that identifies four interdependent priorities for global high energy physics (HEP)facilities

i) the exploitation of current frontier facilities until contribution of these machines is surpassed,

ii) completion and full exploitation of the Large Hadron Collider at CERN,

iii) preparing for the development of a next-generation electron-positron collider, and

iv) the continued support for appropriate R&D into novel accelerator designs.

• The need to have large, next-generation facilities funded, designed, built, and operated as global scale collaborations with contribution from all countries that wish to participate.

• The need for strong international R&D collaboration and studies of the organisational, legal, financial, and administrative issues required to realize the next major accelerator facility on the Consultative Group's Roadmap, a next generation electron-positron collider with a significant period of concurrent running with the LHC.

• The need to continue to educate, attract and train young people in the fields of high-energy physics, astrophysics and cosmology in the face of the increasingly competitive environment where all areas of science, industry and commerce are seeking to capture the imagination of the most creative minds.

Ministers agreed that, given the complexity and long lead times for decision making of major international projects, it is important that consultations continue within the scientific communities and, when it becomes appropriate, within interested governmental communities in order to maximise the advantages offered by global collaboration.

SUMMARY

TECHNOLOGICAL BENEFITS OF THE ILC

Humankind has always been driven by the desire to understand the world we live in. The tools invented by scientists to gain this understanding in turn yield applications that benefit all of society and play a major role in the global economy.

Particle physics has been the source of many innovations not originally part of the quest for understanding the Universe. Many of these – medical diagnostics and therapy, or the World-Wide Web are striking examples – have changed the way we live and do business. Particle physicists continue their quest, and the tools of the future should be the source of yet more technological breakthroughs. One of these tools is the proposed particle accelerator, the International Linear Collider or ILC.

Using unprecedented technology, the 31-kilometre -long ILC will hurl electrons and their anti-particles, positrons, toward each other at nearly the speed of light to collide 14,000 times every second at energies of 500 billion electron-volts. With the ILC, discoveries are within reach that could stretch our imagination with new forms of matter, new forces of nature, new dimensions of space and time and bring into focus Albert Einstein's vision of an ultimate unified theory.

Fundamental research is not done with the aim to make computers even faster, chips even smaller or medicine even better. We cannot be sure where the research into the nature's most fundamental constituents will take us, and likewise cannot be sure what beneficial innovations will emerge. However, the track record makes us confident that technological advances will occur, in one form or another.

Challenging technologies are required for the International Linear Collider. Superconducting radio frequency (SCRF) cavities will be used to accelerate particles to high energies. Unprecedented detector technologies will record the particles from the collisions. The whole ILC project is a challenge in terms of super-efficient particle acceleration, squeezing beam sizes to the nanometre scale and tracking particles to unprecedented precision. ILC scientists around the world are studying ways to meet these challenges and industry is getting ready to produce high-tech components, some of which will find their way into everyday life.

Medicine
Positron emission tomography (PET), a product of physics research into antimatter, has become an essential medical diagnostics tool, allowing previously unattainable views of chemical processes within live organs. Proton therapy has become the treatment of choice, delivering a concentrated, targeted dose of protons or ions precisely to the site of a tumor. Those treatments, however, currently need heavy and costly equipment. The ILC's new superconducting RF accelerating technologies make it possible to downsize the equipment and reduce its power consumption. Radiation therapy could become more focused and thus less damaging to healthy tissue by synchronising to the patient's breathing cycle. The superconducting technology could be adapted to produce monochromatic X-rays for medical diagnoses and treatment,

enabling radically new probes of biological processes and tissue protein structure, and help develop new medicines.

Tools for the future

The tiny particle beams of the ILC need constant monitoring and fast, precise corrections. Tools developed for this purpose, based on research in Japan, will help build new electron microscopes and design very highly integrated electron circuit fabrication methods, which will be a major boost to many industrial processes and products at the nanometre scale. PCs could become more compact and lightweight thanks to improved technologies for electron beam lithography. Techniques originally used to give the accelerator's cavities their exquisite polish could lead to cheaper, better understood technologies for the metals industry. The expertise gained in producing 16,000 superconducting cavities and all the parts that drive them is likely to enhance superconducting applications in general. The electron sources developed for the ILC could revolutionise the magnetic disk industry. Even customs officers' daily work may benefit from particle physics: with the help of detector technologies developed for particle collisions, cargo containers could be scrutinised very efficiently.

ILC Technology and other sciences

Superconducting technology should advance work on Energy Recovery Linacs (ERLs), permitting substantial savings in size and cost. The ERLs will significantly expand the capabilities for studies in nuclear science, materials science, chemistry, structural biology and the environment. The first Free Electron Lasers (FELs) now being built in the US, Japan and Germany are based directly upon linear collider research. Light sources have brought important advances within many sciences over the past few decades leading to many applications. For example, researchers at the Advanced Light Source in the US solved the structure of the avian flu virus and analyzed its specificity to human receptors. The ILC technology can also be applied to the acceleration of protons and nuclei. Proton accelerators for intense spallation neutron sources provide a wide range of studies on biological properties. Numerous applications can be found in material science, with direct implication on everyday life: medical implants, corrosion control, lighter airplanes and many more.

Environment

Superconducting technology could help to dispose of nuclear waste more efficiently by carefully shining beams of gamma rays onto the material, turning it into harmless stable nuclei. ILC radiofrequency power systems could enable remote chemical analyses of environmental hazards. Monitoring technologies for precise beam control could be used as a new early warning system for seismic activity.

Computing

The data transfer rates from particle physics experiments like those at the Large Hadron Collider (LHC), particle physics' current big adventure, are enormous, comparable to those for all the world's telecommunications put together. The latest computer and communications technologies and the advanced Grid data flow management software developed by particle physicists is essential to cope with the demands, but these now extend more broadly. The MammoGrid database developed in European laboratories distributes mammogram information among participating doctors and hospitals. A repository with 30,000 mammograms is now accessible, helping save lives.

People and skills

Over the past four decades, particle physics experiments have become increasingly international. Large collaborations with scientists from around the globe gather to share their expertise and their data. A key benefit from these collaborations is the development of close cooperative working relationships and mutual trust, which may influence the relationships among nations in the long run when the scientists return to important government positions in their home countries.

A much more immediate effect, however, is the diffusion of highly qualified and innovative scientists and engineers into the industrial and commercial sectors of society, bringing new ideas and talent to a broad range of problems. This ‘technology transfer of people’ has tremendous impact on society generally.

Particle physics has always played an important role in capturing the interest of young people and encouraging them to seek careers in science and technology. The workforce of the future, equipped with the creativity and perseverance to tackle and solve unique and challenging problems, is developing new acceleration techniques and detector prototypes right now. The ILC plays an important role as a magnet to attract the new generation of scientists and engineers that society needs.

Industrial forums are busy in America, Asia and Europe to prepare the local industry for the vast and demanding tasks that the ILC will bring.