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TeV-Energy Superconducting Linear Accelerator (TESLA)

Note:

This statement given by a subgroup of the steering committee „Large research facilities for basic research" of the German Science Council concentrates on the scientific and technical investigation of the project. The statement if the project should be funded or not is given by the Science Council itself by a final evaluation of all nine projects. This statement is given in a seperate report.

A. Introduction and Background

A.I Field of Research

Elementary particle physics aims at explaining the innermost building blocks of matter and the fundamental forces acting between them. During the last three decades there has been remarkable progress based on both experimental discoveries and the development of the Standard Model (SM), a theoretical framework, which has been tested and validated to high precision in a broad range of experiments world-wide. According to the SM, matter is composed of spin-1/2 constituents with two quarks and two leptons in each of three families. With the observation of the top-quark and the τ-neutrino at Fermilab (Batavia, IL, USA) all constituents predicted by the SM have now been discovered.

The SM describes our current understanding of the interactions between elementary particles in terms of three of the four fundamental forces of nature: the electromagnetic, weak and strong forces. These forces are mediated by the exchange of so-called gauge bosons: the photon, the *W*- and *Z*-bosons and the gluons. Unlike the photon and gluons, the *W*- and *Z*-bosons are massive (80-90 times heavier than the proton); in fact, their mass is responsible for the weakness of the weak force. At present, the simplest explanation for these very large masses is the interaction with a background medium, the so-called Higgs field. Its presence requires a new particle, the as-yet-unobserved Higgs boson. The quarks and leptons also acquire masses by coupling to the Higgs boson.

Due to its pivotal role, the Higgs particle has been intensely searched for at the Large Electron Positron Collider (LEP) at CERN (Geneve, Switzerland) and at the Tevatron, the proton-antiproton collider operated by Fermilab (Batavia, IL, USA), but so far without success, though hints were recently reported at LEP. If the Higgs mechanism of mass generation is correct, it is highly likely that the Higgs particle will be discovered at the Tevatron or the Large Hadron Collider (LHC) which is currently under construction at CERN. The discovery of the Higgs particle would demonstrate how weak and electromagnetic forces unify into a single weak force and would thus be a fundamental confirmation of the SM. Precise measurements of its characteristics would open the way towards the proof of a more global theory including the strong force.

However, the SM still leaves a number of facts unexplained, for instance the large number of arbitrary parameters (particle masses); the enormous difference in energy scale of the different interactions (10^2 GeV for the electroweak interaction versus 10^{19} GeV for gravity); the reason for the existence of only three families of constituents and the relations between the quark and lepton families and their properties (the charges of the electron and proton are identical within 10^{-20}). Beyond the desire to unify all four fundamental forces of nature, there are many open questions of how to relate our understanding of particles and forces to the evolution of the universe, like the origin and nature of dark matter and dark energy.

General arguments point to the need for a more fundamental theory. Supersymmetry (SUSY) is favoured as an extension of the SM in which the Higgs mechanism can be accommodated in a natural way. SUSY also provides a framework for the unification of the electromagnetic, weak and strong forces at high energies. SUSY is fundamentally related to gravity, the fourth of the fundamental forces. It predicts that all particles have a SUSY partner which has identical properties except for the mass and the spin which differs by one half. The lightest SUSY particle is likely to be stable. Since there is no direct evidence for SUSY particles so far, it is assumed that their masses must exceed the presently accessible limit of 100 GeV. In contrast to the SM, SUSY models include more than one Higgs particle, and the mass of the lightest Higgs particle is predicted to be below 200 GeV. Measuring the properties of this particle might reveal its origin in a new world of matter, the supersymmetric world, and would shed light on the other heavy particles in the Higgs spectrum, even if they lie outside the range accessible by accelerators in the near future.

A great effort is being devoted to formulate a theory that unifies gravity, the interaction responsible for the large-scale structure of the universe, with electromagnetic, weak and strong forces. Such a theory would unify the physical laws of the microcosm with the macrocosm. The rich and complex phenomena that are observed today may have emerged from a much simpler world at very high energies, as they existed in the very early phases of the universe, and all forces were united into a single force. While the world is perceived as four dimensional in space and time, there may exist hidden dimensions. For instance, one knows that gravity is a consequence of curved space-time. It is possible that hidden dimensions are intrinsically quantum mechanical, as in supersymmetry, where every particle has a SUSY partner that exists in a new dimension. Extra dimensions have also been considered in the current theoretical model of quantum gravity, the so-called super-string theory, but confined to distances of 10^{-33} cm, a scale at which gravity in three spatial dimensions becomes as strong as the other forces. Very recently it has been realized that one can introduce extra dimensions at the micrometer scale, without being in conflict with any direct observation. In such models gravity and the other forces could be unified at a new mass scale of only a few TeV, close to the scale of electro-weak unification and experimentally accessible at future accelerators. A discovery of extra dimensions of space would be a landmark in the history of science that would cause a redirection of the entire field of particle physics and cosmology.

The current status of particle physics has triggered intense world-wide discussions on how to address the open questions and in particular on which experimental facilities would be best suited to address these questions. By the summer of 2001, a world-wide consensus on the priorities of the field had emerged:

1. Full exploitation of the present accelerators.
2. Completion of the construction of LHC and start of operation in 2006/07.
3. Construction of a high luminosity linear electron-positron collider with an energy of 400 GeV or above, operating with a significant time overlap with the LHC.
4. R&D on a high luminosity neutrino-factory, on a 3–5 TeV electron-positron collider, a hadron-hadron collider with an energy well above the LHC, and possibly a high energy muon collider.

The high level of German experimental particle physics was certified by the Restricted European Committee for Future Accelerators (RECFA) in November 2000. RECFA also stressed the broadness of the experimental programs in Germany, which involve sixteen universities distributed over the whole country and five large research centers. It also pointed out that German groups at CERN are engaged with very high level responsibilities in the preparation of the LHC program. RECFA further emphasized the strength of theoretical physics in Germany covering the full range of activities in this field. The only real problem that RECFA saw in Germany were the - compared to the global job market - limited career-opportunities for young researchers who want to remain in the field. It recommended to re-examine the duration of studies, the salary levels and in general the prospects for young scientists.[1]

At the national high-energy physics laboratory DESY the carrier of the strong force, the gluon, was discovered at PETRA in the late 1970s. More recently, evidence for matter-antimatter mixing was first observed at DORIS. Today, DESY operates HERA, a world-wide unique electron-proton storage ring facility. HERA has led to a deeper understanding of the proton structure and of the theory of the strong interaction. It is, after the closing of LEP, the only operating European high energy particle collider. The Large Hadron Collider (LHC) is currently under construction in the existing tunnel of the Electron-Positron Collider LEP at CERN and is scheduled to be operating in 2006/07.

Currently Operating Colliding Beam Facilities:

Facility	**Type**	**Location**	**Energy (GeV)**
Tevatron	proton-anti-proton	Fermilab (USA)	1,000 x 1,000
HERA	proton-electron	DESY (D)	920 x 27,5
VEPP-4M	electron-positron	Novosibirsk (R)	6.0 x 6.0
PEP II	electron-positron	SLAC (USA)	9.0 x 3.1
KEK-B	electron-positron	KEK (Japan)	8.0 x 3.5
BEPC	electron-positron	Beijing (PRC)	2.2 x 2.2
CESR	electron-positron	Cornell (USA)	2.0 x 2.0
DAFNE	electron-positron	Frascati (I)	0.51 x 0.51

[1] ECFA letter to BMBF, November 6th, 2000.

A.II The Proposed Facility

II.1 Scientific Objectives and Research Prospects

TESLA (TeV-Energy Superconducting Linear Accelerator) is a superconducting electron-positron collider of initially 500 GeV total energy, extendable to 800 GeV, with an integrated X-ray laser laboratory. Except for the Stanford Linear Collider (SLC), electron-positron colliders have so far been built as storage rings, the largest being the Large Electron Positron collider (LEP) at CERN, with a 27 km circumference and a maximum energy per beam of just over 100 GeV. However, storage rings are not suitable for higher energies, because electrons radiate large amounts of electromagnetic energy when forced on a circular path. The only way to reach electron energies substantially above 100 GeV is to accelerate them in a straight line. This leads directly to the concept of a linear collider in which bunches of electrons and positrons are accelerated in opposite directions in two linear accelerators and made to collide. TESLA is planned to have an energy reach three to five times higher and a collision rate (luminosity) hundred times higher than at LEP, with a comparable length (~30km) and power consumption (~100MW).

The search for new high mass particles like the Higgs boson(s) or supersymmetric particles to establish an extension of the Standard Model is the principal motivation for extending the energy reach of present accelerators. The LHC at CERN is expected to facilitate the discovery of many of these predicted particles, but experience has shown that hadron accelerators are not best suited for precise measurements of the properties of these new particles. Particle physicists have thus reached a world-wide consensus that the next facility should be an electron-positron linear collider.[2] There is also a general consensus that only one such collider should be built world-wide, as a unique international facility.

[2] ECFA: Report of the working group on the future of accelerator-based particle physics in Europe. 21. September 2001. See also Asian Committee for Future Accelerators, 17. October 2001; Statement by the Snowmass Physics Groups, July 2001; DOE/NSF High-Energy Physics Advisory Panel. Subpanel on Long Range Planning for U.S. High-Energy Physics. Draft Report, 29. October 2001.

The complementarity of proton and lepton colliders has been demonstrated in the past and is due to the different properties of the colliding particles. It is easier to accelerate protons to very high energies than to accelerate electrons. Protons are, however, complicated objects, composed of quarks and gluons. The effective energy of the colliding quarks or gluons is usually well below the total energy of the two protons, the rate of unwanted collision processes is very high, and the detailed collision process cannot be well controlled or selected. In contrast, electrons and positrons have no internal structure. They interact at the full beam energy through weak and electromagnetic forces, which can be calculated precisely. One can therefore determine with high precision the properties of new particles, such as mass, lifetime, spin and quantum numbers.

II.1.1 Research Program

The scientific program of the TESLA Linear Collider has been worked out in a series of workshops organized jointly by ECFA and DESY. Physicists from 180 institutes world-wide have contributed to these theoretical and experimental studies. The first task at TESLA would be to establish the Higgs mechanism for generating the masses of the fundamental particles (bosons, leptons and quarks) and to test the self-consistency of the model. This requires precision measurements of the mass and couplings of the Higgs particle as well as the reconstruction of the Higgs potential through the measurement of the Higgs self-coupling. If the Higgs boson does show the expected properties, the next task would be to further refine the existing precision measurements which constrain the model at the quantum level. This could be done through detailed investigations of the properties of the top quark, and of the *W*- and *Z*-bosons, allowing extrapolations to energy scales and masses far beyond the center of mass energies reachable with the collider. A telling example of such an extrapolation is the determination of the top quark mass at LEP, even though LEP did not have sufficient energy to produce the top quark directly.

If it turns out that the observed Higgs boson does not have the expected properties or if more than one Higgs particle are observed, supersymmetric extensions beyond the SM would be investigated. Testing the properties of the (lightest) Higgs boson, unequivocally predicted to have a mass below 200 GeV in this scenario, could reveal its origin in a supersymmetric world and could shed light on the masses of the heavier Higgs bosons. The properties of supersymmetric particles can be measured with sufficient accuracy to allow extrapolations to very high energy scales. If no or no light Higgs boson would be found, one of the numerous alternative models might be realized, of which many have been investigated during the two ECFA/DESY Studies on Physics and Detectors for a Linear Electron-Positron Collider from 1996 to 2000.[3]

II.1.2 Services

As any major accelerator facility around the world, the TESLA facility would offer the following services to international scientists:

- Free access to the research program for all scientists world-wide through scientific collaboration.
- Support for the construction and operation of the particle physics detector(s) which would be conceived, planned, constructed, operated and exploited by large international collaborations.

The TESLA laboratory would take special responsibilities for a number of tasks related to user support, like safety matters, technical infrastructure (experimental halls, site- and facility management), computing infrastructure, communication services, computer assisted engineering and organizational tools, fabrication and design shops (including technical expertise and assistance), local facilities (office space, cafeteria services, shuttle service between the different sites, guest services, housing for short visits), travel and lodging expenses (depending on agreements within the TESLA collaboration), and language courses.

[3] See TESLA Technical Design Report, March 2001, Part III, pp. 89-119.

II.1.3 National/international Networks

During eight years of R&D the international TESLA collaboration, involving more than 40 institutes from 9 countries, has developed the technical basis for the proposal. The TESLA Project is expected to be embedded in the High Energy Physics Program which is coordinated on a world level. In order to realize the TESLA project in a large international collaboration the approach of a Global Accelerator Network is proposed which would effectively combine world-wide competence, ideas, manpower and financial resources:

- The project would be realized through the participation of international and national research and academic institutions.
- The partners would contribute through components or subsystems in a way that is similar to large collaborations in particle physics building jointly a major detector facility. They would also share the responsibility and cost for operation.
- The capital investments would be made under the responsibility of the participating institutions.
- The project would be part of the national programs of the participating countries.
- The accelerator would be maintained and run to a large extent remotely from the participating laboratories, using modern tools for communication and control.

II.2 Technology

The TESLA proposal is based on superconducting accelerating structures. By a focused development program, started in 1992, the international TESLA collaboration in co-operation with industry has succeeded in developing superconducting microwave cavity structures which can generate an accelerating voltage per meter five times larger than before 1990, while reducing the cost per meter of the accelerator by a factor of four. In 1997 a prototype superconducting linear accelerator was completed as part of the TESLA Test Facility (TTF) at DESY in Hamburg with the goal to gain long term operating experience.

The proposed accelerator facility is 33 km long. Its principal components are:

- a pair of linear accelerators, one for electrons, one for positrons, pointing at each other.[4] Each of the linear accelerators is constructed from about 10,000 1m-long superconducting cavities. To reach the total collision energy of 500 GeV, the accelerating field has to be 23.4 MV/m. Bunch trains of up to 1 ms duration are accelerated by pulsed radio frequency (RF) electromagnetic fields at a repetition rate of 5 Hz.;
- a laser driven polarized electron source;
- an undulator driven photon beam to generate positrons;
- two 18-km-long dog-bone shaped damping rings with very long wiggler sections;
- two 1.6-km-long beam delivery systems linking the end of the two accelerators to the interaction point, designed to focus the bunches at the collision point to 550 nm x 5 nm;
- one experimental hall equipped with a general purpose detector.

The design goal is to reach an instantaneous luminosity of 3.4 10^{34} cm^{-2} s^{-1} and to deliver an electron beam with up to 80% longitudinal polarization.

In parallel to TESLA, advanced R&D for a linear collider of similar reach is being pursued in the USA and Japan. While there is close communication and exchange of ideas among these three communities, there is so far no agreement on the choice of technology for the LINAC. ICFA (International Committee for Future Accelerators) has initiated a technical comparison of the linear collider projects currently under study. A report is expected in 2002.

II.2.1 Main strengths and weaknesses

The proponents state the following advantages of the superconducting technology for a linear collider:

[4] The first low energy section of the electron accelerator also provides the electron beam for the X-ray Free Electron Laser.

- The high beam power is the first essential requirement to obtain a high rate of electron-positron collisions. Since the power dissipation in the cavity walls will be extremely small, the power transfer efficiency from the radio frequency (RF) source to the particles will be very high, thus keeping the electrical power consumption within acceptable limits (~100 MW), even for a high average beam power.
- The second requirement is extremely small size of the electron and positron beams at the interaction point. The relatively low RF-frequency of the TESLA linear accelerator is ideally suited for conserving the ultra-small size of the beams during acceleration. When a high intensity bunch of charged particles is accelerated electromagnetic fields (so-called wakefields) are induced in the wall of the cavities which impact the beam and can spoil its quality by increasing the energy spread and the size. As these wakefield effects decrease strongly with increasing distance between the beam and the surrounding cavity walls, wakefields are much weaker in the larger cavities of accelerators working at low RF frequencies than in smaller cavities operating at higher frequencies. For the same reasons the superconducting linear accelerator of TESLA would also be suited to operate an X-ray Free-Electron Laser (X-FEL), which also requires an electron beam with large average power, high bunch charge, small energy spread, and small beam size.
- Due to the large aperture of the TESLA cavities the alignment accuracy of the cavity axis with respect to the beam would be relatively easy to achieve. Moreover the bunch separation of more than 300 nsec permits orbit control by a fast feedback system. Such a feedback system would maintain the beams in collision at the interaction point, making TESLA quite insensitive to mechanical vibrations which could otherwise lead to a serious reduction of the interaction rate.

The most expensive part of the investment cost is the 30 km long cryogenic accelerator module string with about 1/3 of the total investment cost. It would be a considerable cost advantage to achieve higher accelerating gradients in the cavities. The gradient is limited by superconductivity break down that occurs when the microwave magnetic field at the cavity surface exceeds a critical value. This value corresponds to an accelerating field of 50 MV/m for the geometry of the TESLA cavities. The average gradient obtained in the cavities which have been produced so far is well below this theoretical limit.

The proposed schemes for damping rings and the positron source have not yet been tested; they rely on extrapolation of existing facilities or detailed calculations and computer simulations.

II.2.2 Enlarging/upgrading

The capabilities of TESLA can be extended by polarizing the beam particles and by increasing the energy to 800 GeV and beyond. The proponents of TESLA plan to implement an energy upgrade beyond 500 GeV depending on the scientific results obtained both at TESLA itself and at the LHC.

From R&D results on superconducting cavities in various laboratories the applicants conclude that cavities with the required performance for the eventual operation of the linear collider at 800 GeV could be installed into the accelerator from the beginning. Thus the LINACs would be equipped to allow an upgrade to 800 GeV without any major change to the accelerating structures. To fully exploit the luminosity potential of TESLA at the highest energy additional RF components and cryogenics would have to be purchased and installed.

If in the future scientific arguments strongly demand an energy beyond 1 TeV and if at that time no other adequate technology for even higher energies would be available, an extension of the length of the TESLA collider could be considered. Through preliminary investigations the feasibility of an extension regarding the geographical conditions and the soil has been verified. TESLA can also provide a variety of other options for experiments, including e^-e^-, $e^-\gamma$ and $\gamma\gamma$ collisions at a variety of energies; collisions of electrons from the TESLA LINACs with protons circulating in the HERA ring (THERA) or fixed target experiments using the positron LINAC of TESLA for “parasitic” electron acceleration. These options would require some modifications for the accelerator systems and the construction of additional beamlines and experimental facilities.

II.3 Transfer of Research Results

R&D work on the TTF has already provided experience on the possible utilization of knowledge that would be gained through research on TESLA. Novel technologies are being developed for the accelerator and the experiments in a wide range of sectors. These include new techniques for joining metals, metal surface treatment, ultra-high vacuum technology, superconductivity at high frequencies, high-power RF generators, laser technology, precision long-distance alignment methods, computational methods in electrodynamics, and methods for distributed high-throughput, high-performance computing. In the past, detector development for particle physics has frequently created advancements in electronics, fast signal transmission, imaging, and pattern recognition technology. It is also expected that TESLA could have a significant impact on the development of detectors for the quality control of materials and on new methods of diagnosis and therapy in medicine. Already now there is a spin-off related to work done in one of the institutes participating in the TTF, namely the commercialization of software for electromagnetic field calculations.

Research with TESLA would cover particle physics and the interdisciplinary use of synchrotron radiation down to atomic space resolution and sub-picosecond time resolution. The further development of communication technology, computing, and data storage technology is vital for all of these fields and could be influenced by work related to the TESLA project. In addition, the proposed Global Accelerator Network with distributed control rooms presents a major challenge in information technology, computing, data storage and communication. The experiences could be made available to other large international projects and industry.

Applications for five patents have been issued so far and several license agreements have been requested by industry, for instance a request for fabrication of complete

TESLA modules for other accelerator projects. This exemplifies that superconducting RF accelerator technology developed for TESLA has already influenced the technology choice in other accelerator based projects, like the US Spallation Neutron Source. Furthermore, there are indications that light sources driven by superconducting LINACs are particularly promising for the future.

Further technology transfer mechanisms and better support of spin-offs are currently being established at DESY for research and development with the existing HERA, DORIS and PETRA accelerators.

A.III The Institutions Participating in the Project

The international TESLA collaboration is based at DESY Hamburg. The institutes listed in the following table are members of the TESLA collaboration and have profound knowledge in accelerator physics and technology as well as experiences in operating their own accelerator facilities:

Country	**Institute**	**Specific competence and contribution**
Armenia	Yerevan	- Beam dynamics calculations for TESLA LC - Design and production of magnet power supplies - Qualified manpower for operation of TTF LINAC
China	IHEP Beijing	- RF systems and nc LINACs - Contribution of manpower
France	Saclay	- Special knowledge in LINAC technology and sc cavity technology, cryostat test facility (together with Orsay) - Concept and performance of HOM measurements at TTF LINAC - Beam dynamics calculations for TESLA LC - Design and delivery of HOM couplers for TTF cavities - Design and delivery of tuning system for sc cavities - Design and delivery of horizontal test cryostat for TTF - Cavity R&D - Supply of 8 sc cavities from French company - Substantial contribution to the layout of beam delivery and final Focus section of LC and cost estimate of this part of LC - Various beam diagnostics equipment for TTF
	Orsay	- Complete Injector system together with Saclay including Sc capture cavity - Cavity R&D copper coating of niobium structures - cryostat test facility together with Saclay - R&D on high power input coupler
Germany	BESSY	- Layout of beam lines for X-FEL; Preparation of pump and probe experiments at TTF - Together with DESY-Zeuthen and Max-Born-Institute set up of photo injector PITZ in Zeuthen

	DESY	- Set up of infrastructure for cavity treatment and operation of the test facility (RF, power, cooling, cryogenics, clean rooms, controls and diagnostics, vacuum systems etc) - Set up of TTF LINAC with all necessary subsystems and operation of TTF LINAC and TTF/FEL - R&D on sc cavities towards higher gradients - Undulators and diagnostics for FEL proof of principle experiment - Supply of most of sc cavities for TTF - Accelerator physics for TESLA LC and FEL - Layout of TESLA facility; time schedule and total cost estimate
Italy	INFN	- Design and supply of all 12m long module cryostats built in Italian industry; assembly of modules at DESY - Cost estimate of module cryostats for TESLA - Development and supply of cathode system for photo injectors - R&D on sc cavities especially spinning technology - Supply of 8 sc cavities built in Italian industry - Various beam diagnostics for TTF LINAC - Supply of nc magnets for TTF LINAC - Layout and cost estimate of damping rings with Italian industry
Russia	BINP Novosibirsk, branch Protvino	Group was involved in essential way in the development of VLEPP--the first elaborated LC concept—in Novosibirsk since 1971. Many problems of LC have been addressed and solved first by this group. Idea of positron generation for TESLA was invented in Novosibirsk. Design and construction of precise beam position monitor system and scheme to measure potentially dangerous HOM at TTF.
	Dubna International Laboratory	- Competent manpower for the operation of TTF LINAC
	IHEP Protvino	- Design and construction of nc magnets, various electronics, cryogenic components, beam dumps. - Competent manpower for the control system of the TTF facility, the RF system and the operation of TTF. - Study and design of TESLA beam dump systems
	INR Troitsk	- Calculations and construction of tooling for hydro forming of niobium cavities - Various beam diagnostics for TTF - Design of nc LINAC and transport lines. Competent manpower for the operation of TTF
	ITEP Moskau	- Study of production of high quality niobium by Russian industry
Switzer-land	PSI Villigen	- Know how on Beam dump system - Short-pulse technology, detectors
USA	Argonne	- Design and delivery of complicated vacuum chambers for the undulators at TTF/FEL, improved magnetic materials
	Cornell Newman Lab.	- substantial contributions to the development of high gradient sc cavities
	Fermilab	- Design and delivery of RF modulators for TTF - Design and delivery of Input couplers for TTF - Design and delivery of substantial cryogenics components for cavity test facility and test LINAC - Photo injector for TTF - Vertical test cryostats - Set up of photo injector test facility A0 at FNAL
	Jefferson Laboratory	- Extensive experience with sc cavity systems - Essential R&D on treatment of sc cavities

In addition to the institutes of the TESLA collaboration, there have been substantial contributions by CERN and KEK:

Country	Institute	Specific competence and contribution
Switzerland	CERN	- Know how on clean room technology and cavity treatment - Set up of high pressure water cleaning system at TTF - Set up and operation of electro-polishing facility for 1 to 3 cell TESLA cavities at CERN
Japan	KEK	- Know how of super-conducting cavity technology - Know how of electro-polishing technology - Electro-polishing of TESLA 9 cell cavities at company NOMURA plating

There are several institutes in the collaboration without a major accelerator facility, which however have experiences with special components needed for TESLA:

Country	Institute	Specific competence and contribution
China	Tsinghua University	- Electronics - Contribution of manpower
Finland	Helsinki Inst.of physics	- 3D code for calculation of multipactoring in RF components
Germany	Max Born Institute Berlin	- Laser systems
	HMI Berlin	- Radiation protection problems - Fast electronics
	GKSS	- R + D for mirrors and multilayers
	FZK	- SMES
Poland	Institute of Physics Warsaw	- Radiation damage of optical components - Contribution of manpower
	University Warsaw	- Material science - Contribution of manpower
	University of Mining Cracow	- Vacuum technology - Contribution of manpower
	Soltan Inst Otwock-Swierk	- RF technology - Contribution of manpower
Russia	Mephi Moscow	- RF technology - Contribution of manpower
USA	UCLA	- Theoretical studies of photo injectors

The following table shows the involvement and main contributions of German university institutes:

University	Main contributions
RWTH Aachen	- Excellent and dedicated students. - Beam diagnostics - Wakefield effects - Operation of TTF and TTF/FEL - Coherent synchrotron radiation and transition radiation
Berlin, TU	- R&D on position monitors for LC and FEL

Bonn	- Study of ELFE at DESY
Darmstadt	- Investigations of beam dynamics and diagnostics - Wakefield calculations
Dresden	- Layout of cryogenics for TESLA and cost estimate
Frankfurt	- Study of HOM in cavities; effects at very high frequencies
Hamburg	- Excellent and dedicated students - Cavity R&D towards higher gradients - Wakefield effects - RF regulation; active compensation of Lorentz force detuning - Development of superstructure
Rostock	- Cavity mode calculations
Weimar	- Survey techniques for TESLA
Wuppertal	- Substantial R&D on sc cavity technology

Many institutes participating in the TESLA collaboration have broad experiences in the planning and operation of large-scale accelerator facilities. Fermilab (Batavia, IL, USA) for instance has pioneered the field of superconducting accelerators using superconducting magnets with the first storage ring, the Tevatron. The institutes which are involved in the planning of the TESLA detector for particle physics have the necessary experience to design and construct the respective detector components.

The main activities of DESY in accelerator physics during the last decade have been the operation and upgrading of the electron-proton storage ring HERA, the operation of DORIS for synchrotron radiation, and a study of the exploration of PETRA as synchrotron light source. R&D has been focused on TESLA, including construction and operation of the TTF. DESY planned and constructed the two HERA storage rings which with a total length of 13 km represent more than one third of the length of TESLA. The planning, construction and scientific exploitation of the four large scale detectors at HERA were done within large international collaborations and scientists of DESY have been leaders in this endeavour, which included R&D on particle detectors, new detector concepts and electronics, system aspects, data acquisition systems and analysis techniques. DESY (through the John-von-Neumann Institute for Computing) is active in the development of massively parallel computing for lattice gauge theory. DESY also has a strong computing infrastructure for the acquisition, storage and analysis of the data from the HERA experiments. In the field of computing there exists a close collaboration with other major accelerator centers.

A.IV Users of the Facility

External users are expected to come from all around the world and the participating institutes would be engaged for the duration of operation of this facility. The particle physics part of the TESLA proposal is a result of the joint effort by physicists from 180 institutes world-wide, DESY scientists only represent a minority. The work on the TESLA project has been organized within the framework of world-wide linear collider workshops and the ECFA/DESY Studies, with most of the convenors and coordinators coming from external institutions. The results are well documented in the proceedings of the workshops and summarized in the TESLA Technical Design Report (TDR). The 180 international institutions which have contributed to the preparation of the TDR are also the potential particle physics users of the TESLA linear collider. The design, financing, construction, and exploitation of the experiments would also be a joint international effort, with DESY scientists being a minority, but with essential contributions by the host laboratory, as is already the case for the large HERA-experiments.

Groups from German universities working at the DESY facilities are generally supported by DESY which provides the local infrastructure, housing for short visits, computing facilities as well as travel and per-diem expenses. Scientists from abroad are provided with office space. The access for potential users to the linear collider facility is planned to be similar to the access of presently running accelerators at major national and international laboratories. Written proposals would be first refereed by an international Programme Advisory Committee (PAC). Its recommendations would then be discussed in the Scientific Council which advises the TESLA Directorate, and the final decision would be taken by the TESLA Directorate. The PAC would also monitor the progress and performance of the experiments. New members of a collaboration would be admitted, after a presentation of their case, by the existing collaboration and the TESLA Directorate. A formal memorandum of understanding, which spells out benefits, responsibilities and duties of the individual collaborating institutes would be prepared for signature by all parties.

Because of the increasing emphasis on remote operation of both the accelerator and the experiments, DESY also plans to make the data available by remote access to all institutes of the TESLA collaboration around the world.

IV. 1 Scientific Education

The training of the future generation of scientists would be similar to the present program at DESY and other accelerator laboratories. Key elements in the training of young scientists are workshops, triggered by and related to a special project, such as the ECFA/DESY workshops on particle physics with linear colliders. Several institutes of Hamburg University (Experimental Physics, Theoretical Physics) are located on the DESY campus while the Laser Institute is presently moving to the campus. Advanced courses as well as general and special seminars take place at the DESY site.

The following educational activities take place at DESY, many with a close connection to TESLA:

- Summer student program: Each summer about 80 students at the graduate level from Germany and abroad attend lectures on the scientific program of DESY (accelerators, research with synchrotron radiation and particle physics) every morning. For the remaining time, they work in the research groups.
- A special program for graduate students: A “Graduiertenkolleg” is already established at DESY, focussing on the high energy physics program and experimentation at TESLA.
- Diploma and PhD-theses related to the work at DESY: In 2001, approximately 90 diploma and 390 PhD-students from all over the world have chosen a research topic in accelerator or particle physics related to DESY. They normally spent a significant fraction of their research time (>1 year for PhD-students) at DESY.
- Presentation of research: The DESY research groups organize special seminars and discussion groups for students, where they learn to present their work and report on topical results from their field of research. German and foreign Diploma- and PhD-students are encouraged to take the opportunity to report their results at the yearly spring meeting of the Deutsche Physikalische Gesellschaft (DPG).

From the second year onwards, PhD-students are given a chance to present their results at international conferences and workshops.

- Fellowship program: In 2001, approximately 40 post-doctoral fellows worked in one of the research groups at DESY for a period of 2 or 3 years.
- workshop-program
- Awards: Sponsored by the “Association of the Friends of DESY” a yearly award is given to the best PhD thesis that is based on the use of DESY's facilities. Every second year the “Bjoern H. Wiik Prize” is awarded for outstanding contributions to the advancement of research programs or technical development projects at DESY.

Scientist who were educated at DESY continue to work at Universities, in particular particle physics and accelerator research or find jobs in different branches of industry, like information technology, technical instrumentation (medicine, measurement techniques etc.), electronics and telecommunication, high level management in industry or consulting.

IV. 2 Public Relations

Since 1996 DESY has made a substantial effort to inform the general public about the TESLA project with a special emphasis to the region affected by the construction of TESLA. The main methods of communication are press releases, the world wide web, exhibitions (e.g. at DESY within the EXPO 2000 in Hannover), public presentations, organized visits to DESY, and detailed information of interest groups (e.g. neighbors of the planned tunnel). In 2001 DESY established a hotline for TESLA neighbors. It is planned to continue and intensify these activities with special attention to establishing a direct contact to the TESLA neighbors, decision-makers, and other stakeholders. Special TESLA teaching material on the topics X-ray lasers and particle physics was developed for schools and teachers. Information is distributed to local, national and international media though direct contacts, press releases, press conferences at special events (e.g. the TESLA colloquium in March 2001) as well as individual visits of journalists. It is intended to appoint for each member-country of the TESLA Collaboration a TESLA correspondent who would be in charge of arranging and coordinating press contacts in the country.

A. V Project Management, Location, Costs and Schedule

V.1 Project Management

Strategic decisions and personnel appointments would be made by the TESLA Collaboration Board which would be constituted from representatives of the participating institutes. This board would also appoint the project manager who would come from one of the participating institutes.

As a large-scale international project with contributions from many countries and institutions, TESLA would have a well defined project organization and supporting organizational methods and tools. Resources and responsibilities, also with respect to documentation, change management, and quality control, would be defined by the TESLA collaboration. The project management would be structured on the basis of the systems and subsystems of TESLA. The full lifecycle of several decades duration would have to be supported with consistent data. This includes design, construction and installation, commissioning, and operation of the facility. Methods and tools for information management are regarded as the technical basis for project planning and quality assurance at TESLA.

An Engineering Data Management (EDM) system, currently evaluated in a pilot project at the TTF, would accommodate information like 3-D mechanical CAD models, parts lists, and many types of less structured documents. During construction and operation, an information record for each individual component would be created. This information is stored in an Asset Management (AM) system for the individual objects and in a Facility Management (FM) system for the larger assemblies and for the buildings with their technical infrastructure as a whole. For both systems pilot projects have been set up at DESY. The operation phase requires access to all documents mentioned above for efficient support of troubleshooting and maintenance. The documents contain a complete history of each object describing operational performance, faults, and replacements, including detailed operation and maintenance procedures with associated workflow support.

Assuming that the project would be realized in the framework of a Global Accelerator Network, the budget responsibility for the subsystems and components would lie with those institutes and countries which are in charge of them. The overall project and budget responsibility would rest with the project management. DESY plans to offer financial services and support for the budget responsibility to the project and proposes to administer the project's finances on the basis of a commercial system, which would offer flexible tools, especially with respect to budget control and reporting. This would also enable a Resource Review Board of the funding agencies to closely monitor the resources and expenditures.

At present, the TESLA Collaboration Board serves as the advisory board for the development and operation of the TTF. It meets regularly to discuss matters of common concern. It appoints the project leader for the TTF. For the planning and realization of the TESLA Project itself several advisory committees (accelerator, science etc.) would be set up by the management of the TESLA collaboration as soon as its organizational and legal structures have been defined. In addition, the ECFA together with DESY has appointed an international advisory committee which has also organized a series of ECFA/DESY workshops on physics and detectors for particle physics.

It is proposed to set up the TESLA project as an independent legal entity in the form of a German GmbH (Limited Liability Company), which would be headed by the Project Management (identical with the Geschäftsführung or Directorate of the GmbH). This management would have the ultimate responsibility for the operation of the facility. The management of the TESLA GmbH would establish contracts for services, for instance from DESY, which plans to make its infrastructure and administration available for services to the project. The members of the project management would be appointed by the Council, which in turn would be elected by the Shareholders, i.e. the participating Governments or institutions.

V.2 Location

In 1998 the Federal States Hamburg and Schleswig-Holstein passed a law to submit the planning basis for the construction of TESLA. The layout of the facility has been presented in 1999 at a meeting held by the assigned approval authority (Oberbergamt Clausthal-Zellerfeld). The meeting was attended by all parties concerned (both public and private) and the next steps towards a formal planning procedure were agreed upon. Meanwhile, there is acceptance of the project by the local population and strong support from local authorities.

The facility is planned to extend from the DESY site about 32 km in the NNW-direction. This direction is chosen to allow for an eventual later option of colliding high-energy electrons from the TESLA LINACs with protons circulating in HERA. Therefore the tunnel direction runs tangentially to the straight section West of the HERA accelerator.

The site is judged to be well suited for tunnelling and the construction of halls for service buildings and experiments: The variations in height above sea level are only about 10 m, which allows for a moderate depth of the tunnel below ground (following the curvature of the earth) and cost effective construction of the halls. The soil is mainly sand, which allows the use of tunnel-boring machines in the same way as for HERA. This construction has the smallest impact on the existing surface buildings, infrastructure and on the natural environment. The land above the tunnel is not densely populated, which has made it easier to find proper locations for the surface halls needed for cryogenic plants and RF power supplies. Most of the environmental impact studies including studies on radiation safety that are required for the formal approval procedure have been performed or are ongoing. Detailed civil engineering work is continuing. The preparation of the formal procedures is well advanced and all necessary investigations for the final plan-approval procedure will be completed by 2002. In the applicant’s point of view there are no disadvantageous factors for the proposed site.

For the realization of TESLA no other site in Europe has been considered, but sites in Japan and in the USA have been proposed. In the TESLA Conceptual Design Report, published in 1997, Fermilab (Batavia, IL, USA) was discussed as a possible site for the project.

The international implications of the site selection are supposed to become less important if large accelerators are built within the framework of the Global Accelerator Network which was proposed by DESY. The feasibility of this concept was attested by two studies performed by the International Committee for Future Accelerators (ICFA) and will be developed further in the next months by a sub-panel of the OECD Global Science Forum including government representatives.

V.3 Costs

V.3.1 Costs for Development

The following table shows the expenditures since 1992 for the preparation of the TESLA project, especially for the construction of the TTF. 45,6 Mio € have been financed from the DESY Hamburg budget (90% Bundesministerium für Bildung und Forschung, 10% Hamburg). The amount of person-years contributed by DESY is estimated to be 550. The foreign partners of the TESLA collaboration have contributed components amounting to a value of about 12,9 Mio €, in addition to about 400 FTE.[5]

Components	**Total Staff (FTE)**	**Capital Cost (million €)**	**Staff Cost (million €)**	**Total Cost incl. Staff (million €)**
R&D, construction of TTF	950	58,5	47,5	106

V.3.2 Cost Estimates for TESLA Construction

The cost estimate was established by a planning group consisting of senior scientists from the collaboration and persons responsible for each of the major subsystems of the project. The costs given include all components necessary for the baseline

[5] FTE= full time equivalent one man per year.

design of the 500 GeV TESLA collider. Not included are the costs of the high energy physics detector (estimated to be in the range of 160 Mio € to 280 Mio €) and the incremental costs for the X-FEL (241 Mio €). It is stated that all costs have been derived from studies made by industry and are based on the assumption that a single manufacturer would supply the total number of a given component. A production schedule of three years of peak production plus one year for start-up of each component is assumed. The civil construction costs as well as the assumed salary costs are site specific. No contingency has been specifically allocated because full scale prototypes of all key components have already been industrially manufactured and tested.

Components	**Total Staff (FTE)**	**Capital Cost (million €)**	**Staff Cost[6] (million €)**	**Total Cost incl. Staff (million €)**
Main LINAC modules	821	1.131	41,1	1.172,1
Main LINAC RF system	1.274	587	63,7	650,7
Injection systems	848	97	42,4	139,4
Damping rings	602	215	30,1	245,1
Collider beam delivery systems	718	101	35,9	136,9
Civil engineering	65	546	3,3	549,3
Machine Infrastructure	1.168	336	58,4	394,4
Auxiliary systems	775	124	38,7	162,7
Construction Total	6.271	3.137	313,6	3.450,6

Development and construction Total	7.221	3.195,5	361,1	3.556,5

V.3.3 Cost Estimates for TESLA Operation

The operating costs include the electrical power, water, and cryogens, and regular replacement and refurbishing of components like klystrons and power supplies. A

[6] The staff costs at DESY of 50.000 € for 2000 (average of all qualifications) has been used for this estimation.

number of spares for critical components will be included in the initial production, and thus their cost is not included here. The general maintenance costs are assumed to amount to 2% of the original investment, an estimate that is consistent with current experience at HERA.

It has been estimated by a ICFA working group on the Global Accelerator Network that a staff of up to 300 experts would be needed for the operation of TESLA on the site of the linear collider. This would amount to about 15 Mio € per year.

Operation	**Capital Cost (1.000 €)**	**Staff Cost (1.000 €)**	**Total Cost incl. Staff (1.000 €)**
Staff		15.000	
Electricity	39.000		
regular replacement or refurbishing	14.000		
maintenance	67.000		
Operation Total/a	120.000	15.000	135.000

Since the operation of the TESLA facility is planned as a Global Accelerator Network the institutions would remain responsible for the components they have contributed to the project and they would supply the required manpower for the operation of their components. Assuming that DESY as host laboratory would take main responsibility for a substantial fraction of the investment costs of the project and that DESY would have responsibility for civil construction, infrastructure and auxiliary systems as well as a fraction of the accelerating modules for the linear accelerators, the present manpower at DESY should be sufficient for operation of the linear collider. In order to free resources for the preparation, building and exploitation of TESLA, the HERA program at DESY would be terminated, so that the present size and composition of the staff i.e. physicists, engineers, technicians and craftsmen should be adequate for this task.

From the beginning, it was envisaged that TESLA should be realized as an international collaboration with substantial foreign contributions. For the TTF substantial contributions have been given by some of the international partners, namely institutions in the USA, France and Italy. Further commitments from foreign partners can only be expected after the host country has declared its intention to shoulder the largest fraction of the financial burden. The idea of the Global Accelerator Network is to have the international contributions predominantly in hardware for accelerator components and subsystems and in the delegation of personnel. Bilateral agreements between the project management and the respective partners on these contributions would be needed which should include design, construction and also the maintenance and operation phase.

The physics program and operating costs have been developed under the assumption that TESLA would operate 5000 hours per year for at least 15 years. No additional manpower for upgrades and expansions are included.

V.4 Schedule

The construction of TESLA (including the X-FEL) is planned to extend over eight years beginning in 2004. This estimation is based on industrial studies and the experience gained during the construction of HERA and TTF.

Date	Construction
2004-2009	- civil construction work - infrastructure installation - machine installation (installation speed ~15m/day)
2010-2011	- machine installation (installation speed ~30m/day) - X-FEL installations - e^- LINAC installed - all e^- beam lines installed - RF & Cryogenic Tests
2012	- infrastructure installed - machine installed - X-FEL & HEP experiments installed - e^+ LINAC installed - RF & Cryogenic Tests

The schedule is based on the assumption that orders for all major subsystems can be placed at the time of ground breaking for the civil construction. Commissioning of technical systems would proceed after their installation and while installation of other parts of the facility is still going on. The accelerator facility consists of about 2.5 km subsections which can be operated independent of the other sections: Individual cryogenic plants and the corresponding sections of the accelerator would be commissioned as soon as they have been installed. Commissioning of the accelerators with beam would start after the completion of the installation. The commissioning of the accelerator for X-FEL can start 6.5 years after start of civil construction. A detailed schedule of installation and commissioning remains to be worked out. The commissioning time from first beams to a substantial fraction of the design luminosity has been estimated on the basis of previous experience to be about two years.

B. Statement and Recommendations

B. I Field of Research

Particle Physics stands at the threshold of a new era of discovery. The foundations of the so-called Standard Model (SM) that has withstood experimental challenges over the past decades are about to be explored and experiments are expected to produce revelations of a more fundamental theory. Specifically the following questions are being asked:

- What is the origin of particle masses?
- What is the nature of the unknown dark matter?
- Is there an ultimate unification of forces at extremely high energies?
- Is there a supersymmetric structure of particle interactions?

Progress in experimental and theoretical particle physics will continue to strongly depend on large scale facilities. There is a world-wide consensus in the particle physics community that the open questions can only be answered by extending the energy reach of accelerator facilities. For this reason a high-energy, high-luminosity positron-electron linear collider with an energy of 400 GeV or above has been identified as the top priority of the field. Based on the experience at the Stanford Linear Collider (SLC) and recent breakthroughs at DESY and elsewhere, there is confidence that such a machine is technically feasible. Failure to realize a large linear collider would seriously impact the progress in particle physics, in particular, it would not allow for a timely and in-depth exploration of the new phenomena that are expected from the Large Hadron Collider (LHC) at CERN. This would be a serious loss to the field. Since there is a world-wide need and effort for constructing a linear collider the most advanced project should be realized as soon as possible. Germany has a strong tradition in particle physics. German research groups have made leading contributions to experiments at most of the major accelerators in Europe and the USA, as well as to important non-accelerator particle physics experiments. Collaborations between German universities and the large research centers is close, with common faculty appointments and university institutes located on-site. In recent years, experimental and theoretical physicists from Germany have been intensely engaged in the preparation of the scientific program of a high-energy electron-positron collider.

B.II Scientific Program

The scientific program of TESLA is well defined. Its physics program is broader and more compelling than that of any other type of new project in particle physics currently under consideration. TESLA will provide the capability to address and answer fundamental questions in particle physics and cosmology.

The TESLA research program will be complementary to the program at the LHC proton collider currently under construction at CERN. The LHC will start operation first and experiments will perform a broad search for physics beyond the SM at the energy frontier. With the great simplicity characteristic for electron-positron interactions TESLA is best prepared to provide the definitive explanations of any phenomena observed at LHC. Specifically, at a linear collider, the spin and the quantum numbers of new particles can be unambiguously determined and precisely measured, production rates and branching ratios can be compared to theoretical predictions.

In its baseline configuration TESLA will be able to reach a total energy of 500 GeV which is 2.5 times higher than at LEP (CERN). At the same time the luminosity of TESLA, a measure of the beam intensity determining the event rate, is expected to be about 10.000 times higher than that achieved at 100 GeV by SLC, the presently only existing linear collider. Both, energy and luminosity are prerequisites for the expected discoveries. From the onset of operation at energies of 500 GeV or even below the experiment will be able to produce results of important scientific interest and significance concerning the properties of the Higgs particle. In addition, detailed studies of the top quark and searches for new particles of comparable mass can be performed. As the luminosity increases, more precise measurements and broader exploration of physics beyond the SM will become possible. The polarization of the electron beam will greatly enhance the ability to distinguish the properties of potential new particles; it will, for instance, significantly contribute to a definite confirmation or exclusion of the Higgs mechanism.

In a second phase of operation, the collider energy can be extended to about 800 GeV without lengthening the accelerator provided that cavities with a higher accelerating gradient (35 MV/m) are available. This entails some reduction of the luminosity which, however, can be even overcompensated with additional klystrons, power supplies and cryogenic equipment. These upgrades will allow measurements of higher precision and can be exploited to probe new physics opening a wider potential for the discovery of new phenomena like the higher mass supersymmetric or other particles.

The present baseline of TESLA includes only one experiment that will be installed in the positron-electron interaction region. In the longer term future, the development of other experiments using the electron or photon beams might further extend this very broad and unique research program. With rather modest modification it will be possible to arrange for electron-electron collisions should the need be demonstrated. In the longer term future, it may be desirable to build a second large experiment. Its implementation will depend on the outcome of the first generation of experiments, the physics potential as well as the technical feasibility, its impact on the primary TESLA program, and the cost of delivering the desired beams.

The TESLA linear collider is a unique facility on the national level. Considering the size of the project and the general effort to globalize facilities for high-energy physics, the sub-panel is convinced that a duplication of this very complex and costly facility anywhere in the world will not and should not occur. In fact, the particle physics community is prepared to work with one high-energy positron-electron collider in global cooperation (see B. IV).

B.III Technology

The TESLA collaboration is at the forefront of R&D in high-gradient superconducting RF cavities. As a result of a well-organized and targeted R&D, the collaboration has achieved and demonstrated the feasibility of the nominal gradient of 23 MV/m in a real accelerator environment (TTF). Detailed studies of subsystems have been performed resulting in a complete and credible definition of the whole facility.

Although studied theoretically and by simulations in great detail, certain systems (final focusing, positron production, very long damping rings) that are most critical for achieving the luminosity goal cannot be tested experimentally. Long-term testing of the RF superconducting cavities at full accelerating field needs to be performed to prove robustness. However, supported by the results of extended experimental R&D and those obtained by the TTF, the technical feasibility of TESLA can be presumed.

There are alternative technologies under development in Japan and the USA using normal-conducting RF cavities. So far, no clear advantages of these technologies have been demonstrated and the level of advancement of these approaches is not as complete as the level obtained with TESLA. However, the international support for the superconducting technology is not unanimous, and ICFA (International Committee for Future Accelerators) has initiated a technical comparison and evaluation of the linear collider projects currently under study. The report will be issued in the fall of 2002. With the declared intent to build just one machine of this kind world-wide, the international high energy physics community is prepared to develop a joint plan for further R&D, for full scale tests of critical components, and for construction. DESY’s technical expertise and proven leadership is recognized and thus TESLA is in a very strong position to expand the collaboration worldwide.

A general purpose detector for TESLA will have to deal with a large dynamic range in particle energy, final states of high complexity, and high rates of accelerator generated background at small radii. The TESLA collaboration has developed a prototype design that integrates the various functions coherently and acquires very detailed information for each event, thereby maximizing the sensitivity for discovery and precision measurements. While the technology choices and readout solutions are to a large extent based on LEP (CERN) and SLC (SLAC) experiences as well as on R&D programs for LHC experiments, there are many areas where the specific implementations for a TESLA detector will need to be explored by dedicated R&D

and test programs. A detector for TESLA based on the current design is expected to have unprecedented performance and should allow full exploitation of the broad physics program that is envisaged.

Promising technological development has been actively performed by TESLA which opens realistic prospects for higher accelerating gradients (35 MV/m) as required for operation at 800 GeV. Given these good prospects, the effort should be strongly encouraged to have these 35 MV/m cavities available at the time of the installation opening a reasonable path to 800 GeV. The full upgrade in performance (luminosity) at 800 GeV can be obtained by adding to the RF power and cryogenics plants. This upgrade appears logical and straight-forward; it can be done with minimum interference with operation.

B.IV Project Management, Location, Costs, Schedule

The international particle physics community has realized that the only way to implement a high-energy linear collider will be to unite and form a world-wide collaboration and to convince a government to host this project and thus carry a dominant fraction of the total costs. The TESLA collaboration is to be congratulated for their impressive effort and initiative for world-wide co-operation. It has developed the experimental design in a series of workshops that were initiated by DESY and ECFA. These workshops were attended by scientists from 115 institutions of 25 countries and have lead to the preparation of the physics and detector section of the Technical Design Report (TDR). Being part of the international high-energy physics network the TESLA project is expected to further attract an unprecedented level of international collaboration.

All institutions participating in the TESLA collaboration pursue similar scientific goals and have therefore joined forces with DESY to develop the TESLA project, as they see the various aspects of TESLA, such as superconducting accelerators, particle physics and the development and scientific application of the X-FEL as key elements of their own scientific future.

DESY is one of the two major accelerator laboratories in Europe. For the last forty years its main task has been the development, design, construction and operation of accelerators for national and international user groups, and the scientific use of the accelerators for particle physics and research with synchrotron radiation. DESY has always been exceptionally successful in putting together international teams and communities. Its large user community is national and international. The TESLA team at DESY stands out by a very high degree of competence and true commitment to the project. It can be stated that DESY has simply done the best possible job in leading the TESLA collaboration's preparation of the TDR that gives a sound basis for the decision to build TESLA.

DESY has pursued an open and active communication with the population along the proposed track of the accelerator, which can be considered exemplary. As a result of DESY's efforts the TESLA project is well-accepted and supported in the region Hamburg/Schleswig-Holstein. If TESLA would be built in Hamburg, DESY would become a world center of accelerator based science. Building TESLA at any other place in Europe seems neither realistic nor sensible, considering the unique expertise of DESY and the effort successfully invested in winning the support of the local population. Nevertheless, the location for the project is expected to be determined by a firm governmental decision to carry a very large fraction of the cost. An early decision in favor of major financial support will be critical secure this very large international project for Germany.

The geological conditions at the proposed location in Hamburg/Schleswig-Holstein generally seem suitable for the collider-project.

Currently, DESY's budget amounts to about 160 Mio € p.a. (including the synchrotron laboratory HASYLAB). Operation of TESLA would require some 130 Mio € per year. Hence, even if HERA will be shut down when experiments with TESLA commence, additional staff will be needed, if HASYLAB or the new TESLA X-FEL is to be operated by DESY in parallel. This could mean a shift in proportions between the Centers of the Helmholtz association (HGF) and larger emphasis on basic research and maintenance of international research infrastructure within HGF.

A very serious and solid cost evaluation has been done with strong involvement of potential industrial suppliers. In this respect, DESY has done the maximum possible at this stage of the project. However, a residual risk remains due to the fact that most of the components will be produced by highly specialized industry which introduces the usual uncertainty at this stage of project preparation.

Concerning the costs of the project, it has also to be pointed out that the dedicated R&D by TESLA has lead to a strong decrease in the unit costs (cost per MeV) of the cavities, respectively, cryogenics modules. The costs for the proposed detector is estimated to be in the range from 160 Mio € to 280 Mio €. The higher figure (covering the costs of a finely segmented Si-W calorimeter) is considered as a reasonable upper limit for the anticipated costs.

The envisaged schedule looks reasonable but the residual risk stated above is also relevant for the schedule.

B.V Users of the Facility

For several decades, the research program at DESY – as at all major particle physics laboratories – has been proposal driven, i.e. groups of scientists from many different countries and institutions have proposed and successfully carried out experiments at its facilities.

At TESLA there will be one or two large experiments that will be designed to optimally exploit the particle physics opportunities. To execute such large experiments, scientists from many universities and research laboratories will form collaborations to jointly design, build and operate large detectors over many years. The linear collider can either be built as a facility solely devoted to particle physics or part of its LINAC can also be used to drive an X-ray free electron laser (FEL). Though its scientific purpose will be high energy physics, the collider will also attract scientists from various fields of engineering as well as information technology and informatics.

Probably the most valued contribution by DESY and other members of the TESLA collaboration has been and continues to be the education of young scientists, engineers, and technicians in a high technology environment that fosters innovation. Scientists who obtain their education at a research center like DESY, have excellent career opportunities in various branches. Beyond that, DESY has developed a high school physics course on TESLA and the X-FEL. DESY's offer of practical courses at its own labs for high school students is usually well booked.

For years, the laboratory has been open to the general public for tours and special exhibits. There is also a superb set of brochures to explain the laboratory's research and technology program to the general public.

DESY's achievements in all aspects of education, training and public information are outstanding.

B.VI Transfer of Research Results

Particle physics is recognized for its scientific and intellectual achievements. The knowledge gained in particle physics has lead to a deeper understanding of the fundamental forces of nature, the constituents of matter and their interactions which is highly relevant for our understanding of the early evolution of the universe. Like other fields of fundamental research particle physics is considered to be a significant part of our culture.

Over the years, the development of large particle accelerators and detector facilities like TESLA has had significant impact on technological innovation. For example, the application of small accelerators for medical treatment, development of diagnostic devices and pattern recognition software for medicine and other fields, as well as advances in information technology and the commercialization of the software have been widely recognized as spin-offs from this field. Future experiments at TESLA can be expected to greatly advance progress in Data Grid technology. In addition, the large scale applications of superconductivity and the use of synchrotron radiation sources have already lead and will further lead to advances in many fields of science.

At TESLA, the transfer of knowledge and the support for the commercial development of high technology is well underway. These include, but are not limited to, new techniques for metal surface treatment, ultra-high vacuum, highly efficient klystrons, precision alignment techniques, and high performance computing and networking. Enhanced efforts fostering technology transfer, licensing of technology, and joint developments with industry are strongly encouraged.

Recently, advances in superconducting RF technology by TESLA have influenced the technology choices at other accelerator projects, for instance for the proton LINAC of the Spallation Neutron Source in the USA.

C. Conclusion

The proposed linear collider will provide the capability to address and answer fundamental questions of particle physics and Cosmology. Substantial contributions to our understanding of the formation of the universe and explanations of the nature of the still unknown dark matter can be expected. A timely overlap of operation of TESLA and the Large Hadron Collider (LHC) is useful since it is expected that TESLA will be able to precisely investigate the properties of phenomena to be traced by the LHC.

Among particle physicists there is a world-wide consensus that a positron-electron linear collider has been identified as the top priority of the field. However, this project is so complex and costly that only one linear collider should be built in the world with the support of an extensive international collaboration. The TESLA-collaboration headed by DESY is to be congratulated for their impressive effort and initiative for world-wide co-operation.

The TESLA collaboration is at the forefront of R&D in high-gradient superconducting RF cavities. As a result of a well-organized and targeted R&D, the collaboration has achieved and demonstrated the feasibility of the TESLA technology in a real accelerator environment (TTF). Detailed studies of subsystems have been performed resulting in a complete and credible definition of the whole facility.

Over the last forty years, DESY has gained substantial experiences in the development, design, construction and operation of accelerators for national and international user groups. The TESLA team at DESY is characterized by a very high degree of competence and true commitment to the project. DESY has simply done the best possible job in taking the leadership in the TESLA collaboration's preparation of the Technical Design Report (TDR) that represents a sound basis for the decision to build TESLA.