[Tentative Translation]

Report on Measures to Secure and Develop Human Resources for the International Linear Collider

July 7, 2016

International Linear Collider (ILC) Advisory Panel

Contents

Introduction

The International Linear Collider (ILC) Advisory Panel (the "Panel") published a summary report regarding the ILC in June 2015 based on discussions from the first meeting convened in May 2014. The discussions referred to the reports from two working groups on elementary particle and nuclear physics and validation of the Technical Design Report (TDR).

As suggested in the summary report, another working group was established to verify the plan to secure and develop human resources for the construction, operation, and management of the ILC project. This working group held six meetings between November 2015 and June 2016 to discuss plans for ensuring the appropriate human resources using past large accelerator projects and the international and domestic status of such projects as a framework. This report summarizes the discussions as of July 2016.

The Panel recommends that the Ministry of Education, Culture, Sports, Science and Technology (MEXT) takes appropriate measures based on this report.

To identify human resource–related issues for realizing the ILC, the working group examined the human resources as well as the situations inside and outside of Japan with regard to large accelerator facilities. Additionally, the plan to secure and develop the human resources necessary to construct and operate the ILC was verified. The results of these discussions are described in the following sections.

1. Summary of the discussions of the Human Resource Securing and Developing Working Group

Estimated human resources required for the accelerator construction as summarized in the TDR are:

- The construction phase is expected to last 9 years. The average number of personnel required to construct the facility is 1,124 per year, while that for equipment installation is 479*. (The appendix provides a detailed breakdown of the estimated human resources.)
  * This number is averaged over 7 years beginning in the third year.

- Personnel required to construct the facility will be employed directly by the project implementing body of the ILC (including subcontracted workers). Such personnel will be responsible for designing the accelerator and its components, supervising production, assessing the performance of delivered components, and assembling/adjusting the accelerator. Personnel required for equipment installation will engage in transporting from the ground to the accelerator tunnel and installing accelerator components.

- It is assumed in the TDR that major research institutes for elementary particle and nuclear physics around the world will collaborate and provide human resources with an appropriately balanced distribution.

- The study* conducted after the submission of the TDR estimated that the preparation phase would occur in the four years prior to the construction phase and that 282 core members (25% of the annual average of 1,100 persons required to construct of the ILC) should be trained during the four-year preparation phase.
  *A detailed discussion can be found in the KEK-ILC Action Plan, which was reviewed mainly by the High Energy Accelerator Research Organization (KEK) and published in January 2016.

2. Current situation for securing and developing human resources for large accelerator projects

(1) Situation in Japan

i) Universities and Research Institutes

In Japan, human resources required to construct and operate large accelerators traditionally have become proficient by on-the-job training (OJT).

For example, many scientists/engineers were trained during the KEK-PS (Proton Synchrotron) construction in the 1970's and the TRISTAN (Transposable Ring Intersecting Storage Accelerator in Nippon) construction in the 1980's. These scientists/engineers gained valuable experience in conceptual and technical design, manufacturing, assembly, construction, and operational tests of accelerator components, coordination with relevant organizations and factories, and supervision of all procedures as an integrated system. Since then, these experienced scientists/engineers have played a crucial role in promoting accelerator science through their contributions in large accelerator projects.

However, OJT to train young scientists/engineers is decreasing as opportunities to experience constructions of large-scale accelerator are diminishing. This is partly because each project itself has become relatively longer term and larger scale resulted from advancement of accelerator science.

Consequently, there are growing concerns about the depletion of human resources to supervise an entire accelerator as an integrated system because operations and upgrades of existing facilities do not provide sufficient opportunities for young scientists/engineers to gain experience in global management of a large-scale accelerator system.

Moreover, the number of laboratories at universities specializing in accelerator science is decreasing. Although there is a career path where young researchers in relevant fields such as elementary particle and nuclear physics experiments are recruited and trained as accelerator science specialists, personnel exchanges between accelerator science and other fields with similar technical skills have yet to be fully realized.

ii) Industry

Accelerator construction requires diverse technologies such as electromagnetic field analysis, radio frequency engineering, structural and mechanical analysis, thermal insulation design, precision machining, surface treatment technology, high cleanliness welding, and precision installation and alignment. Accelerator projects are a valuable opportunity for industry to develop human resources responsible for large-scale construction since very few project are likely to employ such a variety of technologies.

Some of the accelerator components themselves are objects of research. Close communication between industry engineers and researchers should realize quality manufacturing. Hence, it is important for industry to train engineers to work directly on technology development and performance tests in conjunction with researchers from the prototype phase.

In order to fully adapt to large-scale projects like the ILC, human resources should be trained systematically with an adequate preparation period and a clear vision of the project.

To recruit and train industry engineers who can lead accelerator construction, it is important to clarify the prospects for the project, including the schedule of each construction procedure. This will enable companies to develop long-range plans for securing and retaining human resources during and after the project.

Flexible redeployment of engineers among relevant technical fields should be carried out to cope with the peak period of accelerator construction since the number of industry engineers specializing in accelerator engineering is limited.

Because Japan's plan for future large accelerator projects is currently unclear, Japanese industry is making efforts to strengthen its international competitiveness by maintaining skilled engineers/technicians and developing advanced technologies through participation in accelerator projects outside of Japan. In addition, Japanese industry strives to maintain its pool of engineers by constantly hiring new engineers/technicians, if at all possible, to avoid a generation gap in technology handovers.

Accelerator construction requires many specific materials and components compared to other industrial products. Productivity in mass production should improve as both the manufacturing efficiency and quality control advance through greater ingenuity. For this reason, a large number of designers will not be necessary once the mass production line is established, but a considerable number of engineers is required to investigate and resolve unexpected problems in quality control, cost management, and manufacturing procedures.

(2) International situation

Similar to the case in Japan, skilled scientists/engineers are trained by OJT in Europe, the United States, and other countries, but the mobility of human resources is higher than in Japan. In these countries, human resources are actively exchanged between public and private sectors as well as different research fields.

For these reasons, skilled scientists/engineers for ongoing projects are properly trained and secured in foreign countries. However, a clear vision is necessary to ensure the availability of additional human resources if a new large-scale project is started under international collaboration.

At the European Organization for Nuclear Research (CERN), there are two types of regular employees: fixed-term staff (five-year term) and permanent staff. Less than half of the fixed-term staff are promoted to permanent core staff at the end of their terms. Furthermore, during the construction period of the Large Hadron Collider (LHC), CERN introduced a system called "Project Associates", where staff from other institutes participated in a project in cooperation with the researchers and engineers of CERN.

CERN staff dispatched from other relevant institutes are expected to return to their original institutes upon completion of their term at CERN. This requirement is stipulated in their contracts. CERN is not responsible for their next career positions. Since many of the fixed-term staff members of CERN are engineers and applied scientists in various research and technical fields, there are many opportunities with other international organizations after leaving CERN. Thus, this type of employment system does not cause specific problems.

(3) Relationship to the ILC

A significant amount of human resources must be engaged domestically and internationally when a large-scale international cooperation project like the ILC is undertaken. Therefore, the introduction of a new employment system to attract human resources internationally is essential. The ILC should refer to CERN's employment system of "Project Associates" since the system functioned extremely well during the LHC construction at CERN.

Although the estimated annual amount of human resources for the ILC construction is about 1,100 on average, it will reach 1,600 during the peak construction period. A system capable of handling the maximum number of the required laborers should be established.

Currently, human resources in Japan are managed for securing research and development of advanced accelerator components, and maintaining existing facilities and equipment. However, it is likely that the available human resources in Japan will be in short supply when the ILC is in the construction phase.

The first half of the ILC construction phase is the important term for the technological development of the accelerator as the number of elements for development decreases as the construction progresses. It should be noted that the required number and types of personnel varies according to the construction phase.

Continuously securing and developing skilled personnel is necessary to execute accelerator projects sequentially in Japan. Regardless if the ILC project is implemented, strengthening the base of human resources in accelerator science is critical.

It is traditional in Japan for a small number of accelerator experts to carry out their assigned responsibilities while simultaneously cooperating with one another for other mutual tasks. On the other hand, some foreign institutes manage entire projects by assigning highly professional engineers as managers to lead projects. A novel system integrating these two styles should be sought when an international cooperation project like the ILC is launched in Japan.

Furthermore, a system of multilayered management should be organized to monitor and control the technological development, engineering processes, and the progress of the entire system because the management needs to be very sophisticated as the project is scaled up. Therefore, securing trained core managers for each individual layer should be considered.

3. Future issues and near-term action plan

(1) Development of human resources in Japan

It is clear that the quantity and quality of the current pool of available human resources in Japan is insufficient to handle a large-scale project like the ILC. Skilled scientists/engineers should be trained and secured in a strategic manner based on an international agreement in order to share the necessary manpower.

It is necessary to train and secure experts capable of managing large-scale projects, especially if Japan takes a leading role in the ILC. It is also important to establish a risk management procedure to review and conduct the necessary actions based on risk analysis in reference to various experiences integrated in the LHC construction and operation.

The required amount of human resources increases temporarily during a large-scale project such as the ILC. However, these demands are not permanent, and potential career paths (not only domestically but also internationally) for trained and skilled scientists and engineers after the construction phase must be taken into consideration.

It is desirable to train and secure accelerator experts who thoroughly understand the entire accelerator system and can develop a flexible framework that adapts to the dynamic changes in the demand for human resources by employing highly qualified engineers in each technical area.

Existing facilities have ongoing renovations and significant upgrades of accelerator equipment. These projects provide great opportunities to train young scientists/engineers.

Additionally, when a new accelerator is constructed in Japan, the training of young scientists/engineers during the construction should be a national commitment. It is important to involve the younger generation in the management of the whole system so that they can play leading roles in future projects.

Furthermore, an accelerator facility network to enhance the exchange of human resources should be considered. Such a network should be designed to intensively provide human resources for a new accelerator under construction in such a way that many scientists/engineers can gain valuable experience. As an example, the cross appointment at two institutes should be utilized as well as existing employment schemes, such as joint affiliation, in order for talented personnel to take responsibility in the project as a member of the organization promoting the new accelerator project.

It is also important to consider sending young scientists/engineers to foreign accelerator institutes when they execute new construction or upgrades using the aforementioned network. This should help cultivate talent with practical experience.

Moreover, intensive communication should be promoted among scientists/engineers in different fields whose expertise is required to construct the accelerator system. This will widen the sources of human resources and help establish a management organization where various expert scientists/engineers with accelerator experience work together. It should also be noted that retiring experts with experience promoting large-scale accelerator projects can contribute to the future project by transferring their expertise and technology to younger engineers through collaborative work.

To train scientists/engineers involved exclusively in each project such as the ILC, the target recruitment plan will be settled when the concrete schedule of the project is determined. However, realizable human resource development issues should be addressed promptly as this will help consolidate the foundation of human resources and continuously promote future accelerator projects in Japan.

(2) Human resources from abroad

It is assumed that there will be close negotiations with partner institutes abroad in order to share the human resources required for the ILC project. It is important to accommodate the human resources provided by these institutes. To develop feasible resource sharing plans, the availability of such human resources and assignment duration should be taken into account.

Furthermore, if many non-Japanese scientists/engineers are to be involved, consideration in cooperation with local communities should be given to establish a comprehensive supportive environment for housing, daily life with family members, and coordination of salary and working conditions, especially considering the disparity in such conditions between Japan and their home countries.

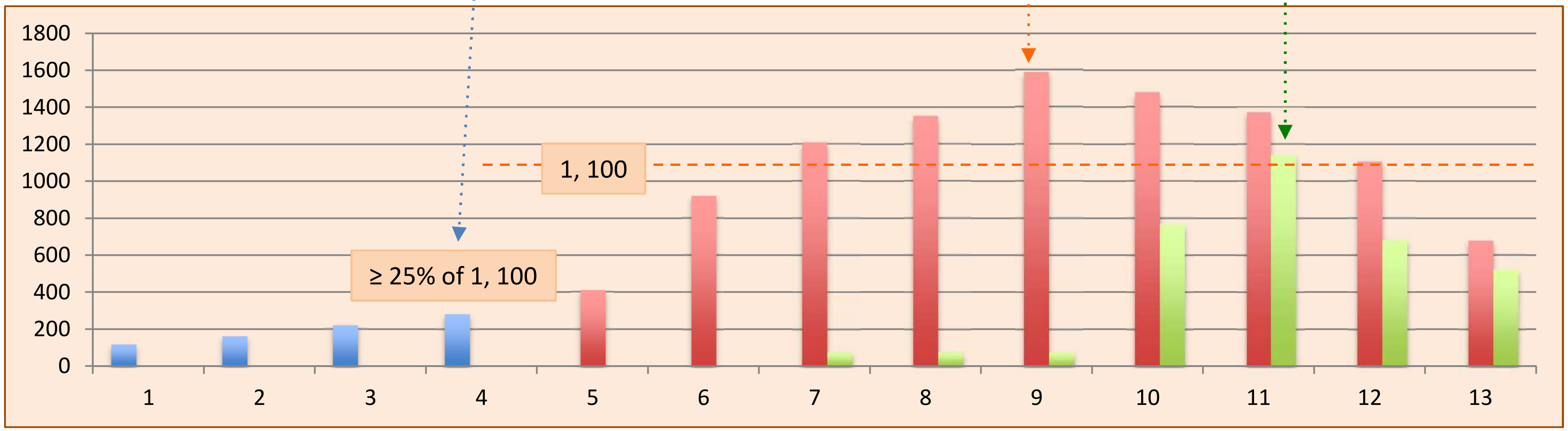
[Appendix]

Overview of Human Resources during the ILC Construction

Preparation stage (4 years) ~ Construction stage (9 years)

unit: person

Stage	Preparation				Construction									Total
Year	1	2	3	4	1	2	3	4	5	6	7	8	9	
	KEK Study after TDR was issued													
Prep.	118	161	222	282										
					TDR Study by ILC Global Design Effort (GDE)						Ann. average: ~ 1,100 persons			
Constr.					410	922	1,208	1,350	1,589	1,480	1,374	1,106	679	10,118
Install.							80	80	80	768	1,140	683	522	3,353
Total					410	922	1,288	1,430	1,669	2,248	2,514	1,789	1,201	13,471



- This data is taken from "Human resources securement and development in the Technical Design Report of the International Linear Collider " presented by Prof. A. Yamamoto (KEK) at the 1st Human Resource Securing and Developing Working Group, on November 18, 2015.
- The number of persons described above is based on and updated from the work estimate in the Reference Design Report (RDR) with an assumption of 1,700 yearly working hours.
- Work categories of project human resources are: research, engineering, administration, and sub-contractors. Installation work in the accelerator tunnel is mainly to be outsourced.