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INDUSTRIAL PARTICIPATION IN TRISTAN PROJECT AT KEK, JAPAN

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ABSTRACT

Industry-Laboratory collaborations played a very important role in the construction of TRISTAN electron-positron colliding beam facility, and brought this construction project to a successful completion in a scheduled time. What had motivated the collaborations, what were the important elements in the successful collaborations and how the collaborations worked will be given based on the authors experience as the TRISTAN Project Director.

It is my pleasure to participate in this meeting of IISCC, and to present a talk on my experience with industry-laboratory cooperations in the construction of a major high energy accelerator facility in Japan; namely the TRISTAN electron-positron colliding beam facility project at KEK, (National Laboratory for High Energy Physics) in Tsukuba, Japan.

TRISTAN PROJECT

Let me, first, give you a very brief description of the TRISTAN facility which was commissioned in 1986 after five years of construction. It is an electron-positron colliding beam facility at the nominal collision energy of 60 GeV, the world's highest energy from the time of commissioning until 1989 when it was exceeded in energy by SLC at SLAC and LEP at CERN with successful operation of respective collider at close to 100 GeV. The main collider ring of this facility is a storage accelerator of 3 kilometers in circumference. It consists of 2.2 kilometer of four arc-quadrants where dipole-, quadrupole- and sextupole magnets are installed to guide the bunches of particles around a closed loop orbit, and four straight sections each 200 meters long connecting the arc quadrants. In order to compensate a large energy loss of electrons at high energy due to emission of intense synchrotron radiation, approximately 330 meters of radio frequency (acceleration) cavities are installed in these straight sections, providing a total of 570 MV of acceleration potential per turn supplied by 30 units of 500 MHz klystrons with 1.2 MW (CW) rating. Of these cavities, 48 meter length are of superconducting type made of Niobium metal operated at the liquid Helium temperature. These cavities are more efficient than common room temperature copper cavities and provide greater than 3 times acceleration potential per meter. An ultra high vacuum beam tube goes around the ring. A highly sophisticated computer system controls magnet

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and radio frequency power supplies and other devices to maintain a stable operating condition of the accelerator. Having two bunches of electrons and positrons counter rotating around the ring, they collide at the center of four straight sections. In order to capture the details of what happens at the moment of particle collisions, a large and sophisticated particle detector (typically measuring 10 m cube and weighing 2000 tons) are built at these collision points.

The scope of the TRISTAN project as expressed in the cost of construction was: approximately \$270 million for the civil construction of the tunnel and experimental facilities, \$300 million for accelerator technical components including an addition of superconducting cavities, and about \$100 million dollars for three major detectors. TRISTAN was the first major facility in Japan of this scope dedicated to the research of the very basic science such as high energy physics. In spite of its scope the project was carried out successfully, namely on time and within budget, with the extensive cooperation of Japan's top industries. A list of major technical components of the TRISTAN facility and the names of industrial firms involved in the development and fabrication of these components is shown Table 1.

MOTIVATIONS FOR THE INDUSTRY-LABORATORY COLLABORATION

KEK was established in 1976 as the inter-university center for high energy physics research in Japan under a direct jurisdiction of MONBUSHO, the Ministry of Education, Science and Culture of the government. The idea behind this is to build big and expensive tools of high energy physics research such as large particle accelerator facilities at this center for use by university scientists from all over Japan (and lately from all over the world). This is a departure from the traditional way the basic science research had been carried out there, i.e. at national universities. Although the laboratory's institutional nature and missions, thus the way it should have been operated, is different from those of academic universities, the organization of KEK followed that of traditional style. The resulting organizational structure based on Professor, Associate Professor and Assistant system did not induce high level engineers and highly skilled technician to join the laboratory. In addition, the ceiling imposed by the government on the staff level of the laboratory, all of whom are permanent government employees, did not allow a rapid increase of needed manpower at the beginning of the project. Also, like in most academic universities, the laboratory's machine shop capability was quite limited. In other words, the laboratory had been compelled to depend on the engineering and fabrication capabilities elsewhere for much of engineering development work for the project.

Japanese industries have a high level of engineering skills and quality fabrication capability and are very willing to engage in a frontier science project. This willingness must have been based on a number of benefits the industry may obtain in such an involvement. There, the industry can receive a transfer of forefront technology as well as intellectual stimulation which sharpens their engineer's way of thinking and enhances their engineering capability. Such involvement will provide them with demonstrable accomplishment in the advanced technology product line nationally as well as internationally. This is of great prestige or PR value; and with that there will be some profit, or at least some merit of keeping their factory running. Namely, I have had a distinct feeling that, in many cases, the industries involved in the TRISTAN project have pursued the technological advances which would promise long term growth of the company, rather than a short term profit which comes from the

manufacturing and sales of a particular equipment to the project. In addition, I have noticed that this willingness is also based on the corporate commitment and pride in their engagement in the pioneering scientific research program.

When I assumed the position of directing the project in 1981, after being accustomed with the American way of mounting a project with a strong in-house engineering support, I had a very serious concern in the lack of engineering and technical man-power in launching a new major project on the scale of TRISTAN. I was assured by my colleagues, then, that there will be a strong industrial support coming for the project. I realized very quickly that a close industry-laboratory collaboration can be established, and was able to accomplish the task quite well without having a large number of in-house engineers and technicians on the staff for the project.

MY WORKING EXPERIENCES

In the course of the project, I have learnt that the laboratory-industrial cooperation does not work well without a strong technological capability at the laboratory. Namely, a cognizant scientist in the project must know exactly what he wants and have knowledge of technologies to be used in the development of the product. The knowledge must be sufficient to convince the industry engineers that they can depend on the laboratory's scientific and technological leadership. This is also a way to open a real communications channel with them. Industry engineers then, can develop the fabrication technology and technical know-how for the product development which is suitable to their manufacturing facilities and carry out the tasks effectively.

One of many successful examples was the fabrication of superconducting solenoids for three detectors at TRISTAN, namely, AMY, TOPAZ and VENUS. Owing to the fact that the TRISTAN project as it was originally envisioned had included a construction of a superconducting magnet ring to accelerate and store protons in a multi-hundred GeV energy, there had been an extensive R&D effort on superconducting magnet technology at KEK. With this basic training in hands, KEK had among its staff members a number of scientists who became expert in this superconducting technology. These people became cores of successful development of very advanced superconducting solenoids for these detectors in collaboration with industrial engineers. Another example is in the development of such standard accelerator components as magnet, radio-frequency acceleration cavities, vacuum and control system. Here again, from the experiences in building proton and electron linear accelerators and 12 GeV Proton Synchrotron at KEK built prior to the TRISTAN project, we had a good accumulation of technology within KEK. Thus the collaboration went quite well, developing the world frontier devices. On the other hand, we have experienced some difficulties in the area of a high power radio-frequency sources, klystron, where we could not provide our expertise at the beginning.

HOW THE INDUSTRY-LABORATORY COLLABORATIONS WERE STARTED

In most cases, this type of cooperation begins with technical discussions between scientists on the project and engineers from one or more industries. These discussions sometimes led to pre-contract industrial studies at no cost to the project. There usually are two ways these discussions can get started.

- i) Through sales representatives of industries who visit the laboratory frequently and who are knowledgeable on the project as well as their industrial capabilities
- ii) Through a request by a cognizant scientist of the project to specific industry that is known to have special technology and know-how needed to solve certain technical problems.

These discussions help the project scientists in formulating technical and engineering ideas to accomplish his mission, and help write more comprehensive specifications.

The job is, then, put on a competitive bid to qualified manufacturers without prejudice on the pre-contract studies. In this case, the qualification is judged only on the basis of the capital size (or financial resources) of the firm relative to the scope of the task. Any task which is estimated to cost more than a few hundred thousand dollars (depending upon the foreign exchange rate) has to be opened for international bidding.

The most important part of the collaboration comes right after the contract is awarded. Namely, this is the time when a full fledged technical discussion will take place to establish a clear and detailed understanding of the tasks ahead. This also is the time when the industry engineers and the project scientists get to know each other well, forging a close partnership needed to accomplish the task.

Thereafter, a close association based on timely plant visits by the project scientists for inspection and guidance and laboratory visits by industry engineers for consultations keep the task rolling on the correct road. In the process, we sometimes encountered changes in the design or changes in the approach. In these cases, a clear understanding of what is to be accomplished for the task established at the beginning helped produce an amicable solution on how the additional cost are to be shared without placing a blame to one side or the other.

CONCLUSION

As a whole, the industry-laboratory collaboration worked very well in the case of the TRISTAN project. The accelerator and detector facility was successfully built in time and within budget thanks to the corporate commitment to the project. The availability of industrial engineering and fabrication capability to us played an important role in construction of this most advanced facility. In many cases, the most advanced technology available in major industries in the area of materials, machining and material treatment, electronics and computer software were made available to the project. Also, from the laboratory's point of view, the industrial help has made it possible to accomplish the task of building a major accelerator and detectors without an enormous bulge in the engineering and technical staff level which would have been necessary if we were to carry out the task of the construction without the help of the industry.

At the same time, I trust that the industries involved have gained something from this association. I hope that the next speaker, Dr. Takao Suzuki will have something to say about it.

Table 1: List of Major Technical Components for TRISTAN Colliding Beam Accelerator and Detectors and Name of Companies which were Involved in the Development and Fabrication

TRISTAN MAIN RING:

Dipole Magnets	HITACHI LTD.
Quadrupole Magnets	HITACHI LTD.
Magnet Instal'n & Align't	HITACHI LTD
RF Cavities, Room Temp.	MITSUBISHI Heavy Ind.
RF Cavities, Superconducting	MITSUBISHI Heavy Ind.
500MHz, 1MW RF Krystrons	TOSHIBA
	VOLVO of West Germany
Vacuum System	ISHIKAWAJIMA-HARIMA Heavy Ind.
Control Computer System	HITACHI LTD.

DETECTORS:

Superconducting Solenoid	
AMY: 3.0 T, Thick Coil	HITACHI LTD
TOPAZ: 1.0 T, Thin Coil	FURUKAWA Electric Works
VENUS: 0.75T, Thin Coil	MITSUBISHI Electric Inc.

Magnetic Flux Return and Detector Structure

AMY: 700 tons	MITSUI Ship Building Co.
TOPAZ: 2000 tons	ISHIKAWAJIMA-HARIMA Heavy Ind.
VENUS: 2000 tons	KAWASAKI Heavy Ind.

Particle Track Detector

AMY: Cyl. Drift Ch.	KEK Shop & Research Group
TOPAZ: Time Proj. Ch.	TOSHIBA
VENUS: Cyl. Drift Ch.	KAWASAKI Heavy Ind & Research Group

EM Calorimeter

AMY: Pb-Drift Tube	The US University Laboratory
TOPAZ: Pb-Glass Blocks	OHARA Glass Work & IHI
VENUS: Pb-Glass Blocks	NIKON and MITSUBISHI Heavy Ind.

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