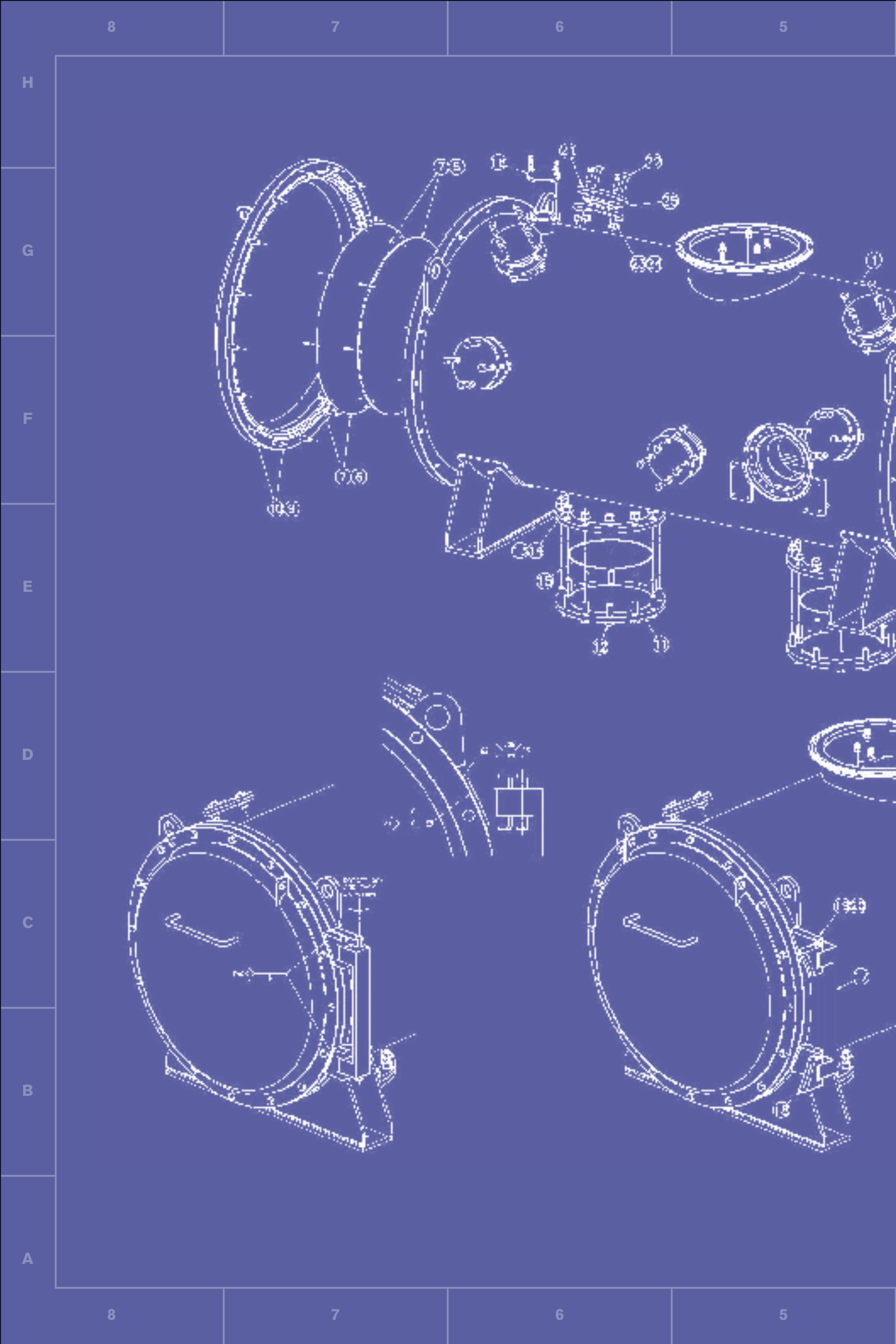

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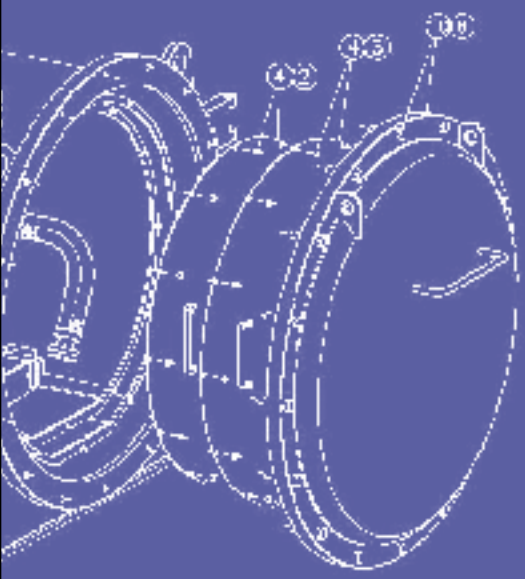
ILC

INDUSTRIALIZATION: GETTING DOWN TO BUSINESS

ILC-by-the-numbers shows the critical need for a global partnership between industry and science.

By Elizabeth Clements



The numbers add up to the future: 16,000 cavities, 2000 cryomodules, 700 klystrons, and two tunnels—these are just some of the components that will be needed in large numbers to build the International Linear Collider. Laboratories and institutions alone cannot manufacture the many components of the ILC, requiring a major role for industry in Asia, Europe, and the Americas: three different regions of the world, with three different histories of government-industry links. Scientists, engineers, and industry representatives have already established linear collider industrial forums in Europe and Japan. The recent establishment of the American forum has provided the opportunity for ILC scientists and engineers to begin the discussion with industrial representatives in the United States and Canada.

In 2002, at the request of the secretary-general of KEK, the Linear Collider Forum of Japan was formed with the purpose of promoting the linear collider. Over the past three years, several delegates from the 62-member organization have made many trips to labs in the United States and Europe to exchange information. "In the US, the labs have very good in-house facilities for making technical components," says Norihiko Ozaki,

This is the assembly drawing of a test cryostat for superconducting RF cavities. In this vessel, Fermilab will test ILC-type RF cavities at 2 degrees Kelvin.

Image: Clark Reid, Mayling Wong, and Valeri Polubotko

secretary-general of the forum. "In Japan, there is a very small in-house fabrication facility, so almost everything is produced from the very beginning by industry."

While Asia has a unique industrial partnering model, European laboratories and institutions also have a longstanding relationship with industry, particularly in the manufacturing of superconducting cavities. In 2005, about 40 industry members established the Linear Collider Forum of Europe. Like Ozaki, forum representative Michael Peiniger of ACCEL Instruments, a medium-sized company near Cologne, Germany, believes that industries should be involved from the very beginning with a large project like the ILC. "We all have to work together to get a clear picture of costing and engineering on this truly global project," he says. "Europe has had a number of superconducting projects over the last few years, and European industries have been involved since the very beginning."

The Linear Collider Forum of America (LCFOA), the newest forum on the block, hosted its first Linear Collider Industrial Forum at Fermilab in September 2005. A venue for exchanging ideas and educating attendees about the proposed project, this forum served as an important first step for forging a partnership between the ILC and industry. While industry models in Europe and Asia may be a step ahead of the Americas, the LCFOA will play a large role in bringing US and Canadian industries up to speed.

On the way to the Forum

Representatives of some 70 industries in the United States and Canada attended the first forum. During the first portion of the meeting, attendees heard from a range of speakers, including Fermilab Director Pier Oddone and Gerry Dugan, GDE Regional Americas Director for the ILC. "As the Global Design Effort is getting organized, a robust program is being developed," Dugan said. "The R&D program is growing, and we hope it will grow more. The design, construction, and operation of the ILC will require participation of a broad range of industries worldwide, and we need to fully coordinate all of the R&D efforts. The industrial forums in the three regions will provide an excellent mechanism for facilitating communication and coordination between the parties involved in the ILC program."

After an overview of the ILC and particle physics in general, the forum participants broke into working groups to discuss the technical details of the project. Bruce Shelton of Parsons Corporation, an international construction and engineering firm based in Pasadena, California, found the working group sessions to be most beneficial because industry members could offer advice on some of the hurdles that scientists and engineers are confronting in ILC design efforts.

"One of the problems we discussed was how to price a lot of the civil work without selecting a site," Shelton says. "We suggested that the civil group put together a fictitious composite site for all of the candidates. From that, you would have a baseline without pinpointing a locale, but you could compare the costs. I hope that we gave them some insight into how to work around those problems and laid the groundwork for putting together an organization that the ILC members can use."

Linear Collider Forum of America

Today, six months later, the LCFOA has 14 industry members. The non-profit organization is also planning the next industry forum to be held possibly at Stanford Linear Accelerator Center this spring.

"The primary goal of the LCFOA is to integrate the capabilities of US and Canadian industries into the early stages of the ILC," says LCFOA president and retired Lockheed Martin executive Ken Olsen. "Our near-term goal is to educate the industry, and we got a great start on that at the

Industry members got an up-close view of an "ILC-like" cavity on a tour of Fermilab during the forum.

Photo: Reidar Hahn, Fermilab

first meeting in September. The ILC is a major international project, and industrialization issues must be integrated throughout all phases of the project. If we a get a real communication started now, we can avoid many pitfalls down the road."

Following the President's budget request for FY07, which would double the funding for the ILC R&D program from $30 million to $60 million, Olsen hopes new members will join the organization. "We have been on a recruiting drive," he says. "The US industry has the capability of producing at least one third of the hardware for the ILC. We want to make sure that there is adequate technology transfer and early participation so that the industries are ready to produce the components."

Technology transfer

The concept of transferring technology has existed at least since ancient times, when Archimedes was noted for applying science to practical problems. A two-way technology transfer process would need to occur between industry and the ILC science sector. "The best and most cost-effective techniques will be developed by all the international collaborators in the ILC," says Bob Kephart, the ILC Program Director at Fermilab. "We will then transfer this best technology to industry so that we can mass produce ILC components."

Rather than handing over designs, ILC scientists and engineers would like to collaborate with industry to lower costs while producing high-quality technical components. "Whether we are making one or a dozen, we will develop a design and then have a dialogue about the manufacturing process and quality assurance process, which could include design revisions," says Fermilab cryogenics engineer Tom Peterson, whose work with industry on accelerator projects includes the Large Hadron Collider now under construction at CERN. "If we tell the industry what we want, it is surprising how they can do it and ask us questions that we had not thought of when we were making the design. We revisit things in the design that are the cost drivers, and find ways to reduce the price tag."

At Jefferson Laboratory in Newport News, Virginia, physicists and engineers have become master-chefs of the recipe for building superconducting cavities. Their experience provides an opportunity for sharing their knowledge and expertise with industries in the United States who have not built cavities and cryomodules. "We would like to see our capabilities transferred to industry so that they can prepare themselves for the ILC," says Warren Funk, the former Director of the Institute for Superconducting RF Science and Technology at JLab.

Funk proposes building a prototype manufacturing facility that would teach industries how to build cavities and cryomodules. "It would be a flexible facility that would allow us to implement the best current knowledge

about how to build cryomodules and then provide a venue where industry could come and work with us," he explains. "We are going to have to engage industry to do the production at a high quality and low cost. Inviting industries into the lab and teaching them represents an idea that has some resonances in other regions too."

Hasan Padamsee, a physicist at Cornell University, suggests learning from European industrial examples about ways to reduce costs. "There have been some industrial studies done in which the industries are paid to come to the laboratory and learn about a certain process," he notes. "The industries then analyze the process, determine what the cost drivers are and then figure out how to apply better tooling to reduce the cost. They might be able to suggest a better way to do things, without radically changing the overall process. This would be a very positive contribution."

Unlike previous examples of technology transfer, the ILC will introduce new roles for industry and science. "For the ILC, we will be asking industry to invest in the infrastructure to manufacture the large quantities of components—a new issue," Peterson says. "We would like to take advantage of existing infrastructure, but because the ILC requires such massive quantities, there is the new challenge of creating the infrastructure with the help of the government."

Infrastructure

The existing industry specializing in accelerator technology has never before produced 16,000 superconducting cavities: scientists estimate worldwide industrial production to date at less than ten percent of what the ILC will require. "The change with the ILC is the scope," says Ed Bonnema, VP Operations of Meyer Tool and Manufacturing, a woman-owned small business in Illinois that manufactures cryomodules and pressure vessels. "The numbers for the ILC, in comparison to any other project, are tremendously huge. Our cottage industry of a bunch of small companies isn't going to be sufficient without new models of cooperation between industry partners and labs around the world."

The infrastructure challenge raises questions about industrializing the ILC, many of which will not be answered until the project matures. "One of the big hurdles to overcome will be getting enough critical mass with the companies that have the expertise to ramp this project into production," Bonnema says. "We might have a lot of smaller companies get together and work with the labs. It is really too early to see what will shake out as the best model."

Most firms specializing in accelerator technology have fewer than 50 employees; risking an investment in the infrastructure for a major proposal such as the ILC is not realistic for them. The industrial model suggested by Bonnema could play a crucial role in providing assistance for industry to acquire the necessary infrastructure. "The ILC will definitely be a hard sell if you tell industries that in order to get a seat at the table, they are going to have to invest millions of dollars," he says.

At Stanford Linear Accelerator Center, Ray Larsen, an electrical engineering manager with many years of experience working with industry, recognizes the need to be aware of the infrastructure hurdle, especially as the GDE develops its global industrialization plan. "The cost of unique infrastructure has to be built into the industrialization model of the ILC," he says. "In the prior days, when we were working on warm-technology development for the Next Linear Collider, SLAC's manufacturing models included the cost of greatly expanding the capacity of klystron factories by at least two vendors for the major construction phase and a steady re-supply and repair business for later phases. The ILC is supposed to be a global science partnership, and industry must be involved in the early

"We want to involve industry in the project, but we need to do it right." **Barry Barish, GDE Director**

development stages by providing design-for-manufacture prototypes at an early stage, performing studies for industrialization, and forming their own partnerships for bidding on work packages. There is no doubt that we will see some global business partnerships participating as well."

In the United States, companies may apply to the Small Business Innovation Research (SBIR) program and the Cooperative Research and Development Agreement (CRADA) for grants and funding for the ILC, but the infrastructure requirement is just one of the challenges. "We want to involve industry in the project, but we need to do it right," Barish says. "In the US, competitive bidding and intellectual property rights have the potential to create hurdles in ILC industrialization. These are subtle issues that will need to be carefully addressed as we move forward. The earlier we get industry involved the better."

Why now?

Although the ILC timeline might seem long, both industry members and scientists believe that a partnership cannot be formed early enough. "The forums are intended to inform appropriate industries about the project, and then make the connections to have a good communication back and forth," says Fermilab's Kephart. "We will look for feedback from industry partners that will reduce the price either through mass production or design changes. We want to form good working relationships, but we also want the industries to bid competitively."

With the publication of the Baseline Configuration Document, a report that outlines a design for the ILC, scientists and engineers around the world are now writing a Reference Design Report. To be completed by the end of 2006, this detailed document will contain costing estimates–a key motivation for involving industries at such an early stage of the project.

"The biggest concern for building the ILC is getting the cost right," says Tony Favale, president of Advanced Energy Systems in Medford, NY. "If industries don't get involved to do costing estimates, it will be difficult for the costing to be accurate. We have to come up with real numbers, and involving industry in those cost studies is crucial."

Because the industrialization of the ILC will be as international as the project itself, industries around the world must start now to collaborate with scientists and engineers to establish one set of codes and standards for the components for the machine. "A part from Japan must be able to work with a part from Canada," Olsen says. "It is very important for the three forums to collaborate and develop one set of technical specifications. Ideally, you should be able to pull a cavity out of the box and have no idea where it came from."

R&D contracts and industrial studies will be the next step for ILC industrialization. "We hope to double our R&D efforts in FY07," declares Fermilab's Shekhar Mishra. "We would like to get industry involved early in the R&D effort. The labs can build some of the cavities now, but they would also give contracts to small industries so that they can learn the techniques. We could then transfer the technology to them, and in the future, if they have enough infrastructure, they can do it themselves."

Around the world, industries and scientists alike agree that the ILC cannot happen without a global industrialization effort. "Industrialization is like the gluon that holds the quarks together in a proton," says Ozaki. "We hold everything together."