THE ILLINOIS ACCELERATOR RESEARCH CENTER

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Abstract

Particle accelerators are an enabling technology not only utilized in their traditional role for fundamental research, but also in such diverse fields as medicine, industrial processes, environmental mitigation, and national security. In recognition of this large impact on the US economy, the Fermi National Accelerator Laboratory (FNAL) has partnered with the Illinois Department of Commerce and Economic Opportunity (DCEO) and the Department of Energy's Office of High Energy Physics (DOE/OHEP) to build the Illinois Accelerator Research Center (IARC). Located on the Fermilab campus, this 83,000 square foot facility will house office, technical, and educational space in a state-of-the-art facility for accelerator research, development, and education. With a strong focus on industrial application of accelerator technologies, IARC will attract high-tech companies to Illinois and help train Illinois citizens in advanced technologies.

INTRODUCTION

IARC was conceived and proposed by Fermilab and DOE to the State of Illinois in 2007. The need for a US facility like IARC was recognized at the Accelerators for America's Future symposium held in Washington DC in Oct 2009. The 2010 report from this symposium contains a wealth of information on the basic justification for investment in accelerator applications as well as the opportunities for new accelerator applications for a facility like IARC [1]. Following the lead of this symposium, the 2012 Senate Water and Energy Bill encouraged DOE to pursue the development of accelerator applications more aggressively [2,3]. It requested DOE/OHEP to provide a plan to address the opportunities made evident in the Accelerators for America's Future symposium. In 2011, OHEP convened an Accelerator R&D Task Force to offer advice on the creation of such a plan. An interim report from this committee was presented at the High Energy Physics Advisory Panel (HEPAP) meeting in March 2012 [4]. The final report to the House and Senate Appropriations Subcommittees was completed in September 2012. Through this request by Congress, OHEP is now the designated steward of accelerator science and technology within the DOE Office of Science complex, with a new thrust toward applied technology.

Key to the success of IARC will be a shared understanding at the national, state, and local levels that translational technology, namely developing ideas from the laboratory into commercial practice, only happens when the proper environment is cultivated. The proper environment promotes friendly, flexible collaboration with industry and universities and provides sufficient seed resources such that non-traditional and multi-disciplinary efforts can flourish.

In 2014 Fermilab plans to increase its partnerships with industry via Work for Others (WFO) and Cooperative Research and Development Agreements (CRADA's). When the physical plant is completed for occupancy in 2015, the IARC facility will attract industrial partners to develop technology for accelerator applications, encourage development of intellectual property by laboratory and university accelerator staff, and provide a National Center for Accelerator Education. The goal is a successful IARC program that exploits and leverages resources from DOE OHEP, Small Business Innovation Research (SBIR) programs, DCEO, and other public funding with substantial private investment from industry and the venture capital community. These funds will be used to translate ideas in accelerator technology into new high tech products and industries and to create an educational program to train the skilled workforce to build and operate the accelerators of the future.

A key concept for the IARC program is that it serves as a portal to allow industrial access, not just to the IARC physical plant, but also to the facilities and technical expertise of the entire laboratory. A successful program at IARC will lower barriers for Laboratory – Industry cooperation on accelerator technology and applications and enable an entire new class of projects to be undertaken as Government-Industry partnerships.

MISSION STATEMENT

The mission of IARC is to partner with Industry, University, and Laboratory collaborators to promote the development of accelerator technology and applications, leading to new products, capabilities, and businesses. The IARC education program will support and enable the creation of the high technology workforce required for its mission.

THE VISION

The vision for IARC is the creation of a friendly, flexible environment to facilitate collaboration with industry, universities, and other national labs and to help provide sufficient seed resources such that non-traditional and multi-disciplinary efforts can flourish. The IARC environment will allow access and leverage of Fermilab's unique facilities and staff to create an innovation hub for new Accelerator based technologies and industries.

When the IARC physical plant is complete in 2015, the laboratory envisions attracting industrial partners to develop technology for industrial accelerator applications; encouraging the development of advanced innovative accelerator science and technology as well as intellectual

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property by laboratory and university staff; and creating a National Center for Accelerator Education.

The key components of the IARC mission and vision are:

- Partnerships with industry, university, and laboratory collaborators to promote the development of accelerator technology, projects, and applications.
- Creation and support of entirely new U.S. based high tech industry sectors based on accelerator technology that enables new products and capabilities.
- Partnerships with universities to create a national educational center for accelerator science and technology.

IARC'S VALUE TO INDUSTRY

IARC will offer value to U.S. industrial companies and entrepreneurs by:

- Helping to overcome the technical barriers that currently impede development of ideas into new accelerator based applications and businesses.
- Serving as a portal organization to provide industry with better access to the extensive expertise in accelerator science and technology available from the Fermilab staff as well as the staff at nearby Argonne National Laboratory.
- Providing access to the specialized and unique accelerator infrastructure at Fermilab.
- Enabling and encouraging collaborations to propose and demonstrate the use of accelerator technology for new applications or markets.
- Serving as a Center for Accelerator Education allowing industrial staff to acquire needed technical skills to pursue businesses based on accelerator technology

CAPABILITIES AVAILABLE TO INDUSTRY THROUGH IARC

IARC will provide unique infrastructure for the development of new accelerator based products and businesses. However, key to its success is the powerful core capabilities available at the entire laboratory. The Accelerator Sector at Fermilab is made up of nearly 700 Scientists, Engineers, and Technical staff. Staff members have extensive experience spanning decades of design, construction, and operation of some of the most technically challenging accelerator components, accelerator systems, and facilities in the world. A brief summary of some specific areas of expertise and excellence that currently exist at the laboratory are listed in Table 1.

Table 1: Fermilab Core Capabilities Available to IARC Partners

Core capabilities	Areas of Expertise
Accelerator Science	Beam dynamics and theory Simulation and Modeling Phase-space manipulation Energy Deposition
Accelerator Operation	Operation and commissioning of large, complex accelerator systems
Accelerator Technology **(design, fabrication, test)**	Linear and circular particle accelerators Superconducting RF cavities Superconducting magnets Cryomodules Conventional, and pulsed magnets Magnet field mapping Beam Cooling systems Design of high power targets High and low-level RF systems Cryogenic Refrigeration systems
Accelerator Engineering	Accelerator design & fabrication Accelerator integration & commissioning Accelerator system cost estimates Design of accelerator RF systems Radio Frequency system modeling Low and High power electrical systems Water cooling systems Energy deposition and activation Cryogenic Engineering
Particle Detectors	Advanced Detector development Beam test of detectors Custom ASIC development
Controls Engineering	Control systems modeling and design Control & Interlock systems Data acquisition systems VHDL, PLD, PLC, DSP programming
Computing	Management, analysis of large data sets High speed parallel (GRID) computing High speed networks Data Storage and Cloud computing

The Fermilab accelerator sector staff and that of nearby Argonne National Laboratory represent the largest collection of Accelerator capability in North America. Similarly, the challenging experimental particle physics program at Fermilab has created world class capabilities in particle detector development and in advanced computing.

FACILITIES AVAILABLE TO INDUSTRY THROUGH IARC

IARC, located in the heart of the Industrial and Technical area of the Fermilab campus, will consist of 36,000 square feet of heavy assembly, technical, and office space in an existing Heavy Assembly Building (HAB) plus 47,000 square feet of new technical, office, and educational space in the State of Illinois funded addition. These two buildings make up the IARC complex.

The OTE building will provide office space for scientists, engineers, and administrative staff from Fermilab and IARC industrial, university, and laboratory partners. The OTE building provides meeting rooms, a

lecture hall, and technical lab space. The layout of OTE and the nearby Heavy Assembly Building (HAB) is shown in Figure 1, which also indicates IARC's location in relation to the buildings that make up the Fermilab "Industrial Complex".

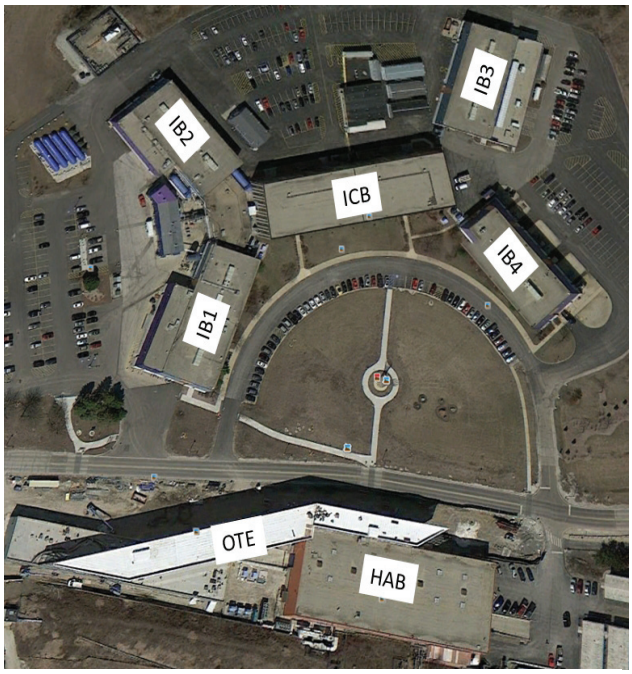

Figure 1: The IARC OTE & HAB Buildings shown in the Technical Division Complex.

The Industrial Complex houses the bulk of the Fermilab Technical Division (TD). TD staff located in the Industrial Complex includes experts in conventional and superconducting magnets, experts in warm and superconducting RF technology, and a powerful superconducting materials technology group. It is planned to move the Accelerator Physics Center (APC) to the OTE building with the goal of integrating FNAL staff with industrial and university partners encouraging exchange of information and true partnerships. APC has a long history of working with industrial partners on diverse topics. Members of the APC staff have strong Accelerator Physics, Beam simulation, and energy deposition capabilities.

The industrial complex includes extensive technical infrastructure for the development of accelerator components. Additional technical infrastructure at other locations on the Fermilab campus will also be available to IARC partners. Several test accelerators and beams will also be made available to IARC partners.

The IARC OTE Building can be seen in Figure 2. The IARC HAB, seen in Figure 3, was formerly used as the assembly building for the Collider Detector at Fermilab (CDF). CDF was a large 5000 ton experimental detector used at the Fermilab Tevatron collider. This building has a large assembly area equipped with 50 ton and 10 ton overhead crane coverage, and also has a deep pit that is ideal for testing or operating pilot scale accelerators or any similar equipment that will require radiation shielding. Extensive test and operation infrastructure already exists in this facility, including cryogenic refrigeration, low conductivity cooling water, and 1.5 MW of installed electrical power feeds. The HAB also has additional office space, meeting areas, and a technical shop with equipment for general machining.

Figure 2: Illinois Accelerator Research Center (Office Technical and Education addition) under construction at Fermilab.

Figure 3: Photo of the interior of the IARC Heavy Assembly Building.

A successful program at IARC will lower barriers for Laboratory – Industry cooperation on accelerator technology and applications and enable an entire new class of projects to be undertaken as Government-Industry partnerships. In this spirit we have compiled a list of the extensive technical infrastructure and test capabilities available at Fermilab via the IARC program. Table 2 lists fabrication and test capabilities at Fermilab, while Table 3 lists Fermilab test accelerator and beam test facilities.

Table 2: Fabrications and Test Capabilities at Fermilab

Facility	Capability	Specifications
Technical Division IB1	Superconducting RF cavity test facility.	3 vertical test Dewars 3.6 m in depth 0.86 m in diameter 1.4 K min temperature
	Conventional magnet test and mapping facility	3 horizontal test stands Pulsed power supply 750V, 25 kA, 2 HZ Complete magnet mapping capability
	Superconducting Magnet Test and Mapping facility.	Vertical Dewar 3.85 m deep 0.6 m diameter 1.8 K capability; Horizontal

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Facility	Capability	Specifications
		SC magnet test stands 2 or 4 K SC magnet Power supply (30 KA, 30 V); Interlocks and DAQ
	Cryogenic System	Helium refrigerator: 1,500 watts at 4.5K or 300 l/hour liquefaction
Technical Division IB2	Conventional magnet fabrications and repair.	25 ft long curing and de-bonding ovens 7 ft dia, 250 F, vacuum furnace; Lamination stacking and winding of large conventional magnet coils
Technical Division IB3	Superconducting magnet development and fabrication	SC cable machine; SC cable winding line 7 meter curing presses Nb3Sn reaction ovens Analytical equipment: Scanning electron microscope with Energy Dispersive Spectroscopy, Laser confocal and contact surface profilometry, FT-IR/TGA, Stress/Strain equipment, Residual resistivity ratio testing
Technical Division IB4	Quality Control Cavity Processing Lab	Large CMM machines State of the art cavity tumbling machine Electro-polish tool for SRF cavities; Class 10 clean room High purity, high pressure water rinse, Small and large 1000 C vacuum furnaces
Technical Division ICB	High Bay Assembly Area	Large high bay area with two 30 Ton overhead cranes and extensive Cryomodule assembly infrastructure
Technical Division MP9	Large Clean Rooms Clean SRF assembly Large Vacuum Oven	Large class 10- class 100 clean room; Fixtures for the clean string assembly of SRF cryomodules, Titanium welding infrastructure Large 1000 C high vacuum oven.
Technical Division MDB	Dressed Cavity Test Facility	Test of dressed SRF cavities at 2 K with pulsed or CW RF. 3 stands in 4 Shielded reconfigurable enclosures 1800 W @ 4K of cryogenic refrigerators Large vacuum pump provides 100 W at 2 K.
ANL-Fermilab Cavity Processing Facility	Surface processing and clean assembly of SRF cavities	Class 10 clean room for assembly; 2 EP/BCP tools for chemical surface processing of SRF cavities; 2 high pressure rinse systems; Ultra-clean water system; Trained Fermilab and ANL staff Facility located at Argonne Nat Lab.
Accelerator Division CMTF	CryoModule Test Facility	Test of SRF cryomodules at cryogenic operating temperatures and with RF Power. The facility is equipped with two large cryogenic refrigerators and can easily be adapted for other cryogenic testing activities.
Technical Division Solenoid Test Facility IB1 & CHL	Testing of large cryogenic magnets powered and at operating temperature	Proximate to the Tevatron Central Helium Liquefier. This facility and its large test Dewar is capable of testing very large magnets at 4 Kelvin.

Table 3: Fermilab Test Accelerator and Beam Test Facilities

Facility	Description
NML Pulsed SRF Facility	Currently this facility consists of a 40 MeV photo-injector and a facility to allow cold test of single 1300 Mhz cryomodule. Proposed as the basis of a world class Advanced Accelerator R&D (AARD) program. (see ASTA below)
Advanced Super-conducting Test Accelerator (ASTA)	ASTA is envisioned to contain 3 to 6 ILC/PX 1300 MHz cryomodules each containing eight cavities. Beam lines and test areas will support a user facility for a world class advanced accelerator research program. ASTA will provide intense electron beams from 50 to 800 MeV/c energies. A small storage ring IOTA with the capability of storing either electrons or protons is also planned to explore new techniques to store intense beams. See: http://apc.fnal.gov/programs2/ASTA_TEMP/index.shtml
Fermilab Test Beam Facility (FTBF) At MDB	A high energy beam facility devoted to Detector R&D. The facility consists of two versatile beamlines (MTest and MCenter) in which users can test equipment or detectors. Details can be found at http://www-ppd.fnal.gov/FTBF/.
MuCool Test Area (MTA)	Used for R&D on ionization cooling components for the Muon Accelerator Program (MAP). The facility includes an experimental hall with radiation shielding, a 600 W cryogenic plant , access to 400-MeV high-intensity H- beam from the Fermilab Linac, 201 & 805 MHz RF power, a large-bore solenoid magnet, liquid helium and nitrogen, vacuum and hydrogen safety systems, Details can be found at http://mice.iit.edu/mta/.

Facility	Description
Project X Injector Experiment (PXIE)	PXIE is the integrated systems test for the Project X frontend. It is expected to accelerate a 1-mA CW beam up to 30 MeV with 1 mA average current. See: http://www-bdnew.fnal.gov/pxie/

SCHEDULE AND TIME LINE

The near term plans for IARC focus on construction of the IARC facilities and development of the business plan. This will be followed by launching the Accelerator Applications Program and then the Education Program.

The shell of the State funded OTE Building is finished and the building is scheduled to be complete in December of 2013. Building layouts that will optimize the different functions of IARC are being finalized so that outfitting of the OTE can begin in January of 2014. This will allow for beneficial occupancy of the OTE building in September of 2014.

Preparation of the HAB has 3 concurrent projects currently: Removal of old experimental equipment from the building, Life Safety Upgrades, and refurbishment. The main schedule driving element is decommissioning of the Tevatron CDF detector including heavy steel work and removal of over 2500 T of experimental equipment from the deep pit of HAB. Assuming adequate funding in FY14, it is envisioned that HAB Deconstruct and Decommission (D&D) will complete by the end of 2014. The HAB Life Safety Upgrades are scheduled to be complete in October of 2014.

Completion of OTE, HAB D&D, and HAB life safety projects will allow Industrial Partners to begin to utilize portions of the IARC facility in early 2015. The HAB Refurbishment project will modernize the 2nd and 3rd floors of HAB as the space is reconfigured into office, meeting, and technical spaces. A new HVAC system and controls, new insulated exterior, new windows and other modifications will allow the building to meet required energy and ADA standards.

In parallel with the construction of the IARC physical plant, the business plan and IARC program will be further developed by the IARC Staff, Fermilab Directorate, Fermilab DOE Site Office, and DOE Office of High Energy Physics leading to the launch of the formal IARC Accelerator Applications and Education programs.

THE PARTNERSHIP MANAGEMENT CHALLENGE

IARC is expected to drive significant changes in the way Fermilab interacts with industry. This Partnership Management Challenge has three major components:

- Forming new relationships
- Negotiating agreements
- Protecting Intellectual Property

Historically, Fermilab's communication program has focused on announcing scientific discoveries and promoting the Laboratory's technology transfer success stories to DOE, elected officials, industry, and the general public. As IARC develops, Fermilab will need a more comprehensive program to advertise licensing opportunities; coordinate events to attract new industrial partners; enlist the support and participation of industry groups and/or venture capital firms; and many other activities that require advanced marketing and sales techniques.

On a daily basis, IARC team members may be collaborating with other Fermilab scientists and engineers; industry or university partners; Department of Energy program managers or contracting officers; other research facilities, both U.S. and foreign; elected officials; or even the public. Each of these stakeholder groups has a different culture, a different language, and different expectations for partnering with the Lab. One of the top priorities for IARC and the Office of Partnerships and Technology Transfer (OPTT) is to establish simple and efficient processes for initiating, developing, negotiating, and administering a variety of partnership agreements that will meet the needs of these different stakeholder groups.

Ultimately, a key outcome of the IARC Program is to promote the commercialization of new technologies in support of U.S. competitiveness. In order to promote commercialization, these new technologies must be protected, which represents a major culture shift for Fermilab researchers. Intellectual property management is a very specialized field of knowledge covering the protection and licensing of intellectual property, such as copyrights, trademarks, patents, mask works, industrial design rights, tangible research products, and trade secrets. IARC Program management and OPTT are working together to develop an intellectual property management program that will provide the tools and training to help IARC team members work effectively in this new culture.

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