



U.S. DEPARTMENT OF  
**ENERGY**

Office of  
Science

**Annual Laboratory Planning  
Fermilab  
Fiscal Year 2011  
(July 12, 2011)**

## **1. Mission/Overview**

Fermi National Accelerator Laboratory advances the understanding of matter, energy, space and time by providing leadership and resources for researchers to conduct research at the frontiers of particle physics and related disciplines. As the only U.S. national laboratory primarily devoted to particle physics, Fermilab helps maintain U.S. global leadership in science and engineering, and achieves the high-level goal identified in the strategic plan of the Department of Energy's Office of High Energy Physics.

Fermi Research Alliance manages Fermilab for the Department of Energy. FRA is an alliance of the University of Chicago and the Universities Research Association, a consortium of 86 universities. FRA combines the depth and commitment of the University of Chicago with the broad involvement of URA universities for the benefit of Fermilab, the particle physics community and the nation.

Fermilab's 1,925 employees and 2,300 scientific users carry out a world-leading program of discovery at the three interrelated frontiers of particle physics. At the Energy Frontier, particle accelerators produce high-energy collisions that signal new phenomena. Fermilab operates the Tevatron collider, supports the U.S. community engaged in research at the Large Hadron Collider, and carries out R&D on future colliders. At the Intensity Frontier, scientists use intense beams from particle accelerators to explore neutrino interactions and ultra-rare processes in nature. Fermilab produces the world's most intense beams of neutrinos. At the Cosmic Frontier, scientists use the cosmos as a laboratory to investigate the fundamental laws of physics. Fermilab scientists investigate dark matter, dark energy, and ultra-high energy cosmic rays using underground experiments, ground-based telescopes, and Cerenkov-fluorescence detectors.

The laboratory's core skills include experimental and theoretical particle physics, astrophysics, and accelerator science; R&D and development of accelerator and detector technologies; the construction and operation of large-scale facilities; and high-performance scientific computing. The laboratory operates particle accelerators and particle detectors; test beams for detector development; test facilities for accelerator research and development; and large-scale computing facilities such as a Tier-1 computing center for the CMS experiment at the LHC, the Lattice QCD center, and the Grid Computing Center. In FY 2010, more than 100 Ph.D. degrees were received based on work done at Fermilab and about 38,000 K-12 students either participated in activities at Fermilab or were visited in their classrooms by Fermilab staff.

Fermilab's 6,800-acre site is located 42 miles west of Chicago in Batavia, Illinois. The laboratory was designated a National Environmental Research Park in 1989, and much of the site is open to the public.

## 2. Lab-at-a-Glance

### Lab-at-a-Glance

**Location:** Batavia, Illinois

**Type:** Single-program laboratory

**Contractor:** Fermi Research Alliance, LLC

**Responsible Site Office:** Fermi Site Office

**Website:** <http://www.fnal.gov/>

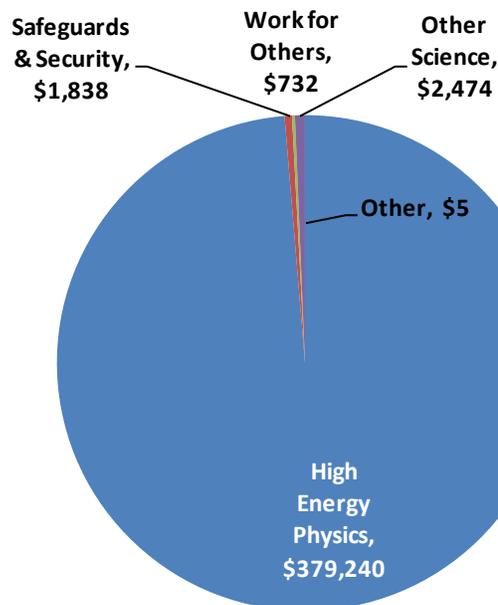
#### Physical Assets:

- 6,800 acres, 356 buildings, other structures and facilities
- 2.4 Million GSF in buildings
- Replacement Plant Value: \$1,699M
- Deferred Maintenance: \$44.7M
- Asset Condition Index:
  - Mission Critical: 0.91 (Adequate)
  - Mission Dependent: 0.98 (Excellent)
  - Asset Utilization Index: 0.99 (Excellent)

#### Human Capital:

- 1,925 Full Time Equivalent Employees (FTEs)
- 10 Joint Faculty
- 250 Postdocs (including Facility Users)
- 540 Graduate Students
- 200 Undergraduate Students
- 2,300 Facility Users<sup>1</sup>
- 50 Visiting Scientists<sup>2</sup>

#### FY 2010 Funding by Source: (Cost Data in \$K):



**FY 2010 Total Lab Operating Costs (excluding Recovery Act):** \$384.3M

**FY 2010 Total DOE/NNSA Costs:** \$383.6M

**FY 2010 WFO (Non-DOE/Non-DHS) Costs:** \$0.7M

**FY 2010 WFO as % Total Lab Operating Costs:** 0.2%

**FY 2010 Total DHS Costs:** \$0.05M

**Recovery Act Obligated from DOE Sources in FY 2010:** \$19.1M

**Recovery Act Costed from DOE Sources in FY 2010:** \$35M

### 3. Current Laboratory Core Capabilities

As the national particle physics laboratory, Fermilab’s mission is to enable the U.S. scientific community to tackle the most fundamental physics questions of our era, and to integrate universities and other laboratories fully into national and international particle physics programs. Fermilab provides the only accelerator facilities in the United States for particle physics research. Particle physics is a central component of the physical sciences, focused on the fundamental nature of matter, energy, space and time. Discoveries in particle physics change our basic understanding of nature. The Standard Model of particle physics provides a remarkably accurate description of elementary particles and their interactions. However, experiment and observation strongly point to a deeper and more fundamental theory that breakthroughs in the coming decade will begin to reveal. To address the central questions of particle physics and thus to deliver on the missions of the DOE’s Office of High Energy Physics, Fermilab uses a range of tools and techniques at the three interrelated frontiers of particle physics:

- **The Energy Frontier**, where high-energy particle colliders are used to discover new particles and directly probe the architecture of the fundamental forces of nature.
- **The Intensity Frontier**, where intense particle beams are used to uncover properties of neutrinos and observe rare processes that will tell us about new physics beyond the Standard Model.
- **The Cosmic Frontier**, where underground experiments and ground-based telescopes are used to reveal the natures of dark matter and dark energy, and high-energy particles from space are used to probe new physics phenomena.

These three approaches ask different questions and use different techniques, but answers to challenging questions about the fundamental physics of the universe will come from combining powerful insights and discoveries at each of the three frontiers. Three core capabilities (Particle Physics, Accelerator Science, and Large Scale User Facilities / Advanced Instrumentation / Computing) support activities at Fermilab and enable Fermilab to deliver the DOE OHEP’s mission. Each core capability is comprised of a combination of experts, facilities and equipment as listed below.

World-Leading Skills	Particle Physics	Accelerator Science	Large Scale User Facilities
Theory	X	X	X
Accelerator Technologies		X	X
Advanced Instrumentation	X	X	X
Simulation	X	X	X
Data Analysis & Distributed Computing	X	X	X
Systems Integration & Operations			X
Project Management			X

#### 3.1 Particle Physics

Fermilab’s scientific program supports the U.S. scientific community with world-leading research at all three interrelated frontiers of particle physics.

Skills in support of particle physics at the three interrelated frontiers

Particle Physics: Skill	Energy Frontier	Intensity Frontier	Cosmic Frontier
Theory	QCD, Beyond Standard Model, Monte Carlo Generator	Matter dominated universe, Rare processes, Neutrino mixing	Phenomenology and analysis of Cosmic Frontier experiments
Advanced Instrumentation	Silicon Vertex detectors, 3D ASIC Design	Liquid Argon Time Projection Chamber	Cryogenic detector, Bubble chambers, CCD packing, Laser cavities
Simulation	Simulation for lepton and hadron colliders, GEANT4 detector simulation, Lattice QCD	Neutrino simulation (various kinds of detectors), Muon simulation	Large scale cosmological simulation
Data Analysis & Distributed Computing	Analysis of large Tevatron and LHC datasets, World-wide collaboration	Understanding low energy nuclear interactions and flux, World-wide collaboration	Management of data intensive cosmic surveys (SDSS, DES, LSST, etc.)

**At the Energy Frontier**, after a very successful 26 year program, Fermilab’s Tevatron collider and the CDF and DØ experiments will end data taking in September 2011. Despite a fast ramp up of the LHC collider at CERN in Geneva,

Switzerland, the Tevatron remains the leader in a number of high profile analyses. Fermilab’s accelerator, detector, computing and physics facilities support the ongoing LHC program. Fermilab is the principal U.S. contributor to the LHC accelerator and the CMS detector. Fermilab’s Remote Operations Center and LHC Physics Center make the participation of U.S. institutions in the LHC and in CMS more effective. Fermilab is a world-leading institution in the development of accelerator technologies for future lepton colliders such as the International Linear Collider and the Muon Collider.

Experiments at the Intensity Frontier provide critical and unique tools to address some of the central questions in particle physics that cannot be answered at the Energy Frontier. **Fermilab experiments at the Intensity Frontier** aim to uncover properties of neutrinos and to probe new physics from rare processes in muons, kaons, and nuclei, and they are the laboratory’s primary focus in the short and intermediate term. The discovery of neutrino oscillations was the first experimentally observed phenomenon that departed from the very successful Standard Model of particle physics. This discovery strongly suggests a connection between neutrino physics and physics on a very high mass scale and identifies a number of key questions that could open a path to new discovery. Using the NuMI neutrino beam, the most powerful in the world driven by 120 GeV protons from the Main Injector accelerator, Fermilab’s long-baseline neutrino experiments MINOS (on-going / short term), NOvA (intermediate term – under construction), and then LBNE (under development) address the masses, mixings, mass ordering, and matter-antimatter asymmetry of the three known neutrinos in the neutrino Standard Model. The 8 GeV Proton Booster Ring drives a second beam of neutrinos for short-baseline experiments MiniBooNE (on-going / short term) and MicroBooNE (intermediate term – under development) to probe questions beyond the neutrino Standard Model. The current MINERvA experiment with the NuMI beam focuses on precision measurements of cross sections for neutrinos and anti-neutrinos that are critical to extract physics of long-baseline and short-baseline experiments. The Booster Ring will also provide beams of muons for two future experiments: Mu2e, a major new experiment that searches for the conversion of muons to electrons, a critical signature for any unified theory of particle physics; and the g-2 experiment to precisely measure the muon anomalous magnetic moment. Fermilab is developing a multi-megawatt proton accelerator, *Project X*. This accelerator would provide a neutrino beam for the LBNE and beams of muons, kaons and nuclei for rare-process experiments simultaneously. It will be the most powerful and flexible facility at the Intensity Frontier anywhere in the world.

**At the Cosmic Frontier**, Fermilab is a critical partner in a number of world-leading experiments. Fermilab manages the construction and operation of the Cryogenic Dark Matter Search (CDMS) and the Chicagoland Observatory for Underground Particle Physics (COUPP) that search for particles of dark matter; the Sloan Digital Sky Survey (SDSS) and the Dark Energy Survey (DES) that probe the properties of dark energy; and the Pierre Auger Observatory that studies the source and nature of ultra-high-energy cosmic particles.

Theoretical work in particle physics and particle astrophysics are an essential part of the laboratory. Theorists guide the development of experiments and elucidate their results, emphasizing the connection between theory and experiment to advance cutting-edge science. As Fermilab addresses the defining questions in particle physics and delivers the DOE’s high energy physics mission, it pays special attention to educating future generations of scientists. Fermilab trains about 250 postdoctoral fellows and 540 graduate students each year, resulting in more than 100 Ph.D. degrees awarded each year based on research performed at laboratory facilities. Fermilab contributes to science, technology, engineering and mathematics (STEM) education with a broad program for undergraduate university students and K-12 students and teachers.

This core capability enables the laboratory to support the DOE’s Scientific Discovery and Innovation mission (SC 4, 5, 21, 22, 23, 24, 25, 26, 27, 29, 34, and 35).

### 3.2 Accelerator Science

Skills in support of accelerator science at the frontiers of particle physics

Accelerator Science: Skill	Energy Frontier	Intensity Frontier
Theory	Collider beam dynamics (beam-beam, IBS, etc.)	Instabilities, Loss mitigation
Accelerator Technologies	SC Magnets (Nb <sub>3</sub> Sn, HTS), SC RF ( $\beta=1$ ), RF power	SC RF ( $\beta < 1$ ), Particle sources, RF power
Advanced Instrumentation	Beam diagnostics and feedback	Beam diagnostics and feedback
Simulation	Integrated accelerator simulations (Synergia, Muon Collider), Energy deposition (MARS)	Integrated accelerator simulation (Synergia, Muon Collider), Energy deposition (MARS)
Data Analysis & Distributed Computing	Shot Data Analysis	

Particle accelerators are key resources for DOE’s program of scientific discovery. Fermilab’s accelerator science capabilities—operation, design, development and research—form the foundation of the present and future accelerator-

based activities at the lab and in the U.S. particle physics community. Fermilab is home to one of the largest accelerator facilities in the world, including a complex of nine accelerators, test accelerators, and infrastructure for the development of accelerator technologies. Nearly half of the lab staff are directly engaged in accelerator activities.

Fermilab's world-leading accelerator R&D efforts focus on the areas of superconducting radio-frequency (SCRF), superconducting-magnet, ionization-cooling, high-intensity proton accelerator and advanced beam manipulation technologies. Fermilab's unique capabilities in superconducting magnet development are currently focused on upgrades to the LHC and the development of high-field solenoids for the Muon Collider. Fermilab provides U.S. leadership in the development of high-gradient SCRF technology for a future multi-megawatt proton source, *Project X*, and for the ILC, and Fermilab develops integrated design concepts and technologies for *Project X* in support of world-leading neutrino and rare-process experiments. Fermilab leads U.S. technology development for ionization cooling required for muon-storage-ring based facilities, supplies integrated design concepts for the Muon Collider and a neutrino factory, and advances fundamental understanding of beams and their manipulation in dedicated test facilities. In addition, Fermilab pursues comprehensive integrated theoretical concepts and simulations of complete future facilities at both the Energy and Intensity Frontiers of particle physics. These activities, while focused on particle physics, can be applied widely across other fields of science, serving the broader goals of the DOE's Office of Science.

Advanced accelerator R&D activities, currently centered at the A0 PhotoInjector, will move to the new AARD (Advanced Accelerator R&D) Users' Facility that is being created in conjunction with the new SCRF test facility. These activities include novel beam manipulation techniques, high-performance electron source and diagnostics development, and advanced beam cooling tests, conducted in collaboration with other laboratories and universities.

Activities in accelerator and beam physics include advanced beam studies at the laboratory's operating accelerators in support of optimizing accelerator performance; energy deposition simulations, including the upgrade, maintenance and distribution of the MARS code, a resource to the worldwide community; theory of beam instabilities in current and future accelerator facilities; development of new techniques for compensation of beam-beam effects; experimental studies of ground motion effects in accelerators and electron cloud effects in high-intensity proton beams; as well as theory and experimentation on new collimation and cooling methods.

Fermilab, together with BNL, LBNL, and the SLAC, provides joint leadership of the national Muon Accelerator Program. MAP manages the development of future facilities including a neutrino factory at the Intensity Frontier and the Muon Collider at the Energy Frontier. Fermilab is developing design concepts and major subsystem technology simulations and demonstrations for these muon-based facilities. This work also features strong cooperation with companies funded by the DOE's Small Business Innovation Research (SBIR) program.

Fermilab leads the ComPASS (Community Petascale for Accelerator Science and Simulation) collaboration which develops a comprehensive computational infrastructure for accelerator modeling and optimization and advances accelerator computational capabilities from the terascale to the exascale to support DOE priorities for the next decade and beyond. This project is funded by the DOE's Offices of HEP, NP, BES and ASCR.

Fermilab carries out a comprehensive program for training of the next generation of accelerator scientists and engineers. The program includes hosting the U.S. Particle Accelerator School, a national consortium, which holds two sessions a year for undergraduate and graduate students; the Lee Teng Internship in accelerator science and technology for undergraduate students; a Joint University-Fermilab Accelerator Ph.D. program; the Bardeen Fellowship in accelerator engineering for M.S. and Ph.D. students; and the Peoples Fellowship in accelerator science for post-graduates. The new Illinois Accelerator Research Center, to be constructed in 2011 and 2012 with funds from a State of Illinois grant, will significantly enhance the accelerator science education program at Fermilab.

This core capability enables the laboratory to support the DOE's Scientific Discovery and Innovation mission (SC 4, 5, 24, 25, 26, and 35).

### 3.3 Large Scale User Facilities, Advanced Instrumentation, and Computing

#### *Large Scale User Facilities*

For more than four decades, Fermilab has conceived, planned, designed, constructed, managed and operated large-scale user facilities and hosted international scientific collaborations for particle physics and particle astrophysics. Research at these facilities has led to many discoveries, including the top quark, the bottom quark, the tau neutrino, and the matter-antimatter transition in the  $B_s$  system, and numerous precision measurements. Current user facilities include

the Tevatron, the world’s highest energy proton-antiproton collider, and the CDF and DØ experiments at the Tevatron; NuMI and Booster, which create the world’s highest-power neutrino beams, and the MINOS, MINERvA, and MiniBooNE neutrino experiments. NOvA, a second-generation long-baseline neutrino experiment, and the Dark Energy Survey, a third-generation dark energy experiment, are currently under construction. Fermilab has established design concepts and begun technology development for the next generation of world-leading particle physics facilities including longer baseline (>1000 km) neutrino beams and LBNE experiment; Mu2e and g-2 experiments to study rare processes with muons; *Project X*, a multi-megawatt proton facility for Intensity Frontier physics; and the ILC. Efforts are underway to establish design concepts for a multi-TeV Muon Collider and a neutrino factory.

Skills in support of large-scale user facilities at the frontiers of particle physics

Large Scale User Facilities: Skill	Energy Frontier	Intensity Frontier	Cosmic Frontier
<b>Theory</b>	Lattice QCD national facility	Lattice QCD national facility	Cosmological computing
<b>Accelerator Technologies</b>	NML Accelerator test facility, MuCOOL test area, Muon Collider, ILC	NML Accelerator test facility, NuMI, LBNE, Mu2e, muon g-2, SeaQuest, <i>Project X</i> , Neutrino Factory	
<b>Advanced Instrumentation</b>	Silicon detector facility center	Liquid Argon R&D facility, Extruded scintillator facility	Liquid Argon R&D facility, Silicon detector facility center (DES CCD packaging)
<b>Data Analysis &amp; Distributed Computing</b>	LHC physics center, Open Science Grid, CMS Tier-1 center, Advanced network, Massive data storage	Open Science Grid	Survey data archive
<b>Systems Integration &amp; Operations; Project Management</b>	Tevatron complex, CDF/DØ detectors, LHC remote operation center, Test beam	NuMI & BNB (neutrino beams), Neutrino and muon detectors, Soudan underground laboratory, Test beam and small experiments	Test beam, Soudan underground laboratory, Silicon detector facility center, Pierre Auger

### Advanced Instrumentation

Fermilab develops cutting-edge particle detector technologies and applies them to the construction of detectors for a variety of scientific disciplines. In the area of semiconductor-based detectors, Fermilab employed dedicated-readout integrated circuits and pioneered the construction of very low-mass silicon detectors for the Tevatron and LHC collider experiments. Fermilab currently pursues three-dimensional vertical integrated silicon technology and silicon-based multi-pixel photon detectors. In the area of cryogenic detectors, Fermilab uses an ultra-cold bolometric detector for dark matter searches and is developing liquid argon technology for neutrino and dark-matter detectors. The laboratory made additional innovative contributions to the development of scintillators and their applications, now used in a wide array of particle physics experiments. Fermilab’s test beam facility, operated simultaneously with the collider and neutrino program, is used by the international particle physics community for the development of detector technologies. The laboratory advances the instrumentation of its test beams through the development of picosecond time-of-flight systems and versatile, integrated data acquisition systems.

### Computing

Fermilab’s computing leadership and resources enable the particle physics community to deliver scientific results at the Energy, Intensity and Cosmic Frontiers. Fermilab has internationally recognized experts in programming languages, high-performance computing and networking, distributed computing infrastructure, petascale scientific data management, physics simulations and scientific visualization. Fermilab supports large-scale computing, data management, and data analysis facilities for CDF and DØ experiments; the CMS experiment and the LHC Physics Center; the Sloan Digital Sky Survey; the Dark Energy Survey; neutrino and rare-process experiments; and computational cosmology. Fermilab hosts the CMS Tier-1 center, the U.S. Lattice QCD computing project, the campus grid FermiGrid, leads the ComPASS collaboration for accelerator modeling and simulation, and is a leader in the Open Science Grid.

- *CMS Tier-1 Center*: The scientific challenges of particle physics require data storage, networks and processing power on an extreme scale. The CMS experiment uses a distributed computing model, in which seven national Tier-1 centers and more than 40 university- and laboratory-based Tier-2 computing and storage facilities distribute, process, and serve data. Fermilab’s CMS Tier-1 center is the most powerful Tier-1 center for the CMS experiment. US CMS scientists make use of the LHC Physics Center’s Tier-3 facility for analysis of CMS datasets.
- *Lattice QCD Computing*: Quantum Chromodynamics describes how quarks and gluons interact via the strong force and predicts the properties of hadrons. Such predictions require the numerical simulation of QCD on a

lattice of space-time points, known as Lattice QCD, which uses substantial computing resources. Fermilab builds and operates large clusters of computers for Lattice QCD as part of the national computational infrastructure for the Lattice QCD project established by DOE. Fermilab is also a participant in a DOE SciDAC-2 program devoted to the improvement of software for lattice gauge computing.

- *FermiGrid*: Grid computing evolved as an extension of distributed computing to satisfy growing computing needs from science, industry, government and commerce. Grid computing involves the distribution of computing resources among geographically separated sites, thus creating a "grid" of computing resources. Fermilab operates a large Grid Computing Facility with shared computing and storage resources provided to the Fermilab experiments for data processing, storage and analysis. The laboratory makes these computing facilities available to other scientific organizations in a secure manner through the Open Science Grid.

This core capability enables the laboratory to support the DOE's Scientific Discovery and Innovation mission (SC 4, 5, 21, 22, 23, 24, 25, 26, 27, 29, 34, and 35).

#### 4. Science Strategy for the Future/Major Initiatives

Fermilab will continue its program of research at all three frontiers of particle physics and enable the U.S. particle physics community to tackle the most fundamental physics questions of our era. For the U.S. to remain among the leaders in this field of science, it must maintain a laboratory that builds and exploits new facilities in partnership with universities and other national and international laboratories. Facilities for particle physics are global and ever more challenging to design, build and operate. A laboratory with a singular focus and consolidated particle physics facilities will give the U.S. a competitive advantage in the future.

In designing the laboratory strategy for the post-Tevatron era we need to meet the following criteria:

- Address critical and exciting questions
- Be bold and establish world leadership in at least one domain
- Attract partners to leverage our investments through international collaboration
- Fit within a global strategy for the field and within reasonable U.S. funding
- Be broad enough to be resilient against physics discoveries and funding fluctuations

An analysis of the world's particle physics program leads us to the conclusion that the greatest opportunity for U.S. leadership lies in experiments driven by high intensity proton beams. In this area we are sensitive to physics beyond the Standard Model up to energies much greater than reachable at the LHC directly. Whether the LHC is physics "rich" or physics "poor" we need to connect the interpretation of the LHC results to quark and lepton processes where the effects are visible, namely in very rare transitions. In addition, the most intense proton source enables the best set of neutrino experiments. These neutrino experiments would greatly increase our understanding of this still mysterious sector. Thus the centerpiece of the Fermilab strategy is to build a high intensity continuous wave superconducting linac and to couple it to the rest of the existing Fermilab accelerator complex. We call it *Project X*.

The design and construction of *Project X* will take at least the rest of the decade. When completed it will drive a long baseline neutrino experiment (LBNE) with ten times the flux of the present Fermilab NuMI beam, short baseline neutrino experiments with ten times current fluxes, and kaon, muon and EDM experiments with fluxes that are two orders of magnitude greater than the current capabilities. To get there we need to manage the transition from 26 years of Tevatron Collider operations to the world's leading program at the Intensity Frontier. An important element of the strategy is to exploit the present complex for a set of world-class experiments before *Project X* is available. They are current and near-future neutrino and muon experiments, and the simultaneous running of these experiments requires us to improve the injection chain of the current complex to increase the beam intensity by a factor of two. During the *Project X* era the beam intensity up to 3 GeV would be a factor of a hundred greater than the present complex.

*Project X* would substantially re-use existing facilities such as the Main Injector and Recycler Ring, infrastructure that would be very costly to reproduce elsewhere. We have aligned the technology of *Project X* to the ILC superconducting technologies so that the project benefits from the advances developed by the ILC community. We have also placed a requirement that it should be usable with well understood improvements as the front end of a neutrino factory or a muon collider, thus allowing for the very long range development of the complex. The alignment of technology with the ILC also means that by developing *Project X* we will be in a position to take a leadership role if the ILC is eventually built.

The table below summarizes the vision for Fermilab for the next **ten years**. Not included are those facilities like the Tevatron or the MINOS and MiniBooNE detectors that will complete operations within a few years.

Activities	Leadership Areas	New Capabilities	Required Resources
<u>Energy Frontier:</u> Collider Physics	US-LHC; US-CMS; LHC accelerator and detector upgrades; Detector R&D for future lepton colliders	Ability to provide LHC remote operations and physics centers and establishment of a critical mass of expertise at Fermilab in all aspects of LHC and CMS in order to enhance the effectiveness of the US community. Development of radiation-hard electronics for the upgrade of CMS	Continuous upgrade of computational resources. Capital investments for LHC and CMS upgrades are determined nationally. Fermilab competes for DOE allocation of these resources.
<u>Intensity Frontier:</u> Neutrinos, Rare Processes	<u>Neutrino:</u> The NOvA facility; MINERvA detector; MicroBooNE liquid argon TPC detector; LBNE beamline and detectors; <i>Project X</i> construction  <u>Rare Processes:</u> Mu2e experiment; g-2 experiment; SeaQuest experiment; Rare K processes and other high rate experiments with <i>Project X</i>	Most powerful neutrino program in the world. <i>Project X</i> requires the ability to build high gradient, CW, superconducting linacs and the safe handling of very large beam power with the attendant induced radioactivity.  Unique rare process experiments in charged lepton-number violation, the decay of K mesons and other experiments require new capabilities in the design of high rate experiments	Capital over 10 years: NOvA (\$278M), <i>Project X</i> (~\$1.3-\$1.6B in FY11 dollars, not including experiments), and LBNE beamline and detectors (\$1.1B-\$1.6B cost range in FY11dollars including underground laboratory infrastructure and operations during construction). These funds will be distributed to the national community. Part of the capital need offset by the termination of the Tevatron (\$60M/year). For rare process detectors, capital investments of ~\$200M over ten years
<u>Cosmic Frontier:</u> Dark Matter & Dark Energy	Dark Matter Searches (CDMS, COUPP, Darkside); Dark Energy Searches (DES, LSST); Ultra High Energy Cosmic Rays (Auger)	This suite of experiments extends the reach for dark energy and dark matter by an order of magnitude and requires new capabilities in the storing, organizing and serving of large data sets to the astrophysics community	Capital needs determined by the national program. Fermilab competes for part of the allocation
Accelerator R&D	LHC Accelerator R&D (LARP); ILC superconducting RF lead; <i>Project X</i> R&D; Muon Collider R&D lead; Neutrino Factory R&D lead	Requires new capabilities to build niobium-tin magnets and crab cavities for LHC upgrades. <i>Project X</i> requires new capabilities in designing, building, processing and testing high gradient, high Q, RF cavities.	<i>Project X</i> requires an R&D investment of \$82M. Fermilab competes for the allocation of ILC and LARP funds within the national program
Computing	Computing for LQCD; High Throughput computing; Advanced Networking; Grids and Data Storage; Scientific Software; Accelerator Simulation	Optimized use of Grids and Clouds; very high bandwidth data movement and storage; advanced use of local and leadership computing facilities for science; new software frameworks	Capital investments in computing facilities; human capital; core and program-specific IT investments; access to R&D network infrastructure
Theory	Phenomenology and Model Building; Lattice Gauge Theory; Cosmology and Particle Astrophysics Theory	The huge data sets and the large number of analysis in the LHC will require much enhanced efforts in model development, especially in understanding the consequences of QCD in the extraction of signals for new particles	Requires continuous strengthening of the theory groups in particle and particle astrophysics

The paragraphs below provide a more extensive summary for each of the activities organized along the three frontiers. Theoretical efforts supporting the three frontiers are not described separately. Activities in accelerator and detector R&D and user facilities have also been folded under the three frontier areas described below.

## *Energy Frontier*

### *The Vision*

The activities at the Energy Frontier include the running of the Tevatron through FY 2011; the exploitation of the LHC physics opportunities with the CMS detector; the future upgrades for the LHC collider and the CMS detector to allow operations at higher luminosities; and R&D towards future high energy lepton colliders.

The outstanding performance of the Tevatron Collider and the CDF and DØ detectors is enabling about 100 publications and the thesis data for 60 new Ph.D.s per year. The total integrated luminosity delivered so far is about  $11 \text{ fb}^{-1}$  and by the end of FY 2011, we expect about  $12 \text{ fb}^{-1}$ . Discoveries at the Tevatron or at the LHC could usher in an entirely new era in particle physics. The plethora of predictions for possible discoveries only reveals how little particle physicists know about this energy range and how revolutionary the new discoveries will be.

As the national particle physics laboratory, Fermilab has a central and unique role in developing the Energy Frontier in the U.S. Fermilab will continue to be the lead U.S. institution for the physics exploitation and enhancements of the LHC collider and the CMS detector. In particular via the Remote Operations Center and the LHC Physics Center, Fermilab has assembled talent in software engineering and physics analysis that makes it possible for US researchers in CMS to be more productive when they are at Fermilab than at CERN where many thousands of users will be competing for space and technical resources. The LHC will reach higher luminosities as time goes on and increasing the luminosity will require significant upgrades to the collider and to the detectors. The required improvements for the detector upgrades will advance the use of the fast radiation-hard electronics needed to handle the more than 100 million collisions per second (with 400 collisions per bunch crossing). For the accelerator upgrades new technologies are needed for higher field quadrupole magnets, for deflecting mode superconducting RF cavities (“crab-cavities”), and for guiding and control of beams with very large stored energy (the LHC beams are designed to exceed 300 MJoules of stored energy, three hundred times more than the Tevatron). Fermilab will lead the efforts for the collider upgrades in collaboration with BNL, LBNL and SLAC. It will lead the instrumentation improvements for the CMS detector since Fermilab is the only laboratory supporting the US collaboration with engineering and technical resources.

Beyond the LHC, Fermilab is carrying out R&D towards future lepton colliders that will be necessary beyond the LHC. The ILC will be the most straightforward new facility if the energy of 0.5 to 0.75 TeV is adequate. Fermilab leads the effort to develop cryomodules for the linac, the most challenging and costly part of the project. Higher energy colliders at more than a TeV will require new approaches. To develop an approach for these higher energies Fermilab is the lead institution in the development of a multi-TeV Muon Collider, via the Muon Accelerator Program (MAP). The goals of this program are: 1) to complete, with international partners, a Reference Design Report for a Neutrino Factory in 2014; 2) to complete, with national partners and international participation, a Muon Collider Design Feasibility Study in 2016 including demonstration of essential technologies required to support basic feasibility; and 3) to develop a complete R&D plan that would lead to a Muon Collider Technical Design by the end of the decade. Fermilab works together with many institutions as part of the MAP. Fermilab operates a test beam for studying essential technologies for ionization cooling of muon beams in the initial stages of the Muon Collider or a possible neutrino factory.

In addition to the direct efforts to reach a design for these future facilities, the development of *Project X* will establish the technological base for the challenging accelerating structures needed for the ILC or the Muon Collider.

### *Required Resources*

Fermilab currently has a significant fraction of the technical and human resources base to carry out activities at the Energy Frontier. The end of the Tevatron running should correspond to the ramp-up of activities for future projects at the Energy and Intensity Frontiers.

The main new resource needed is capital for a few areas: 1) the development of LHC and CMS upgrades, 2) the production and testing infrastructure to develop superconducting RF technology at Fermilab, 3) the development

of *Project X*, and 4) the feasibility studies for the Muon Collider and a neutrino factory (MAP). Regarding SCRF infrastructure, Fermilab will need to increase its expertise by changing the mix of skills from Tevatron operations to development of superconducting RF technology.

The goal of the MAP program is to provide information required to make an informed decision on the next appropriate step on the Energy and Intensity Frontiers following the initial round of LHC results in approximately 2015. The MAP resource requirements are roughly \$15M annually (national total of which roughly 60% is expected at Fermilab). This includes support for accelerator design and simulation activities, technology development, and the operation of test facilities.

### Risks

*Technical risks.* The main technical risk comes in the operation of the LHC. The first risk is reliability of components. Components that fail and require the warm-up of a sector of the machine would create a downtime of about three months per event. CERN has used extreme care in the development of the LHC to prevent such problems, but surprises as demonstrated in the past years are always possible. The second risk is associated with the stored energy in the beam and in the magnetic fields of dipole magnets. If this energy is released in an uncontrolled way during some abnormal condition, it could damage the machine. In principle, CERN has designed a fail-safe system for the control and collimation of the beams, but it remains to be tested. The quench protection system was found wanting in the initial round of commissioning, but is in the process of being upgraded with assistance from Fermilab and other U.S. laboratories. The mitigation of these risks is a CERN responsibility. Fermilab, with its expertise developed at the Tevatron, contributes in the control of beams and quench protection.

The risks associated with the future collider R&D are simply that the technical goals for the ILC and the Muon Collider may take longer to be developed due to either technical difficulties encountered along the way or delays in funding that would slow the rate at which these technologies and designs will be developed. Additionally the basic technological feasibility of the Muon Collider is yet to be established. The Design Feasibility Study is needed to do the work to determine that such a collider is feasible. However, to answer this basic question on a reasonable timescale requires an increase in funding to approximately \$15M annually.

*Market Risk/Competition.* To continue to be welcome users of the LHC, the US will have to invest in the upgrades of LHC and its detectors. Over 50% of the US high energy community will be focused on the LHC in the next decade, becoming possibly the largest contingent from any country at the LHC. At this time there are very little facilities in the US that Europeans will use, making it difficult to argue that our stay at the LHC is compensated by European use of our facilities. Without contributing to the upgrades, the US runs the risk that CERN would ask us eventually to reduce our participation or propose to charge additional fees for our participation. Development of facilities at the Intensity Frontier at Fermilab would attract additional European and Asian collaborators.

The competition for the multi-TeV Muon Collider is the CERN Compact Linear Collider (CLIC), a multi-TeV electron-positron linear collider based on a different technology than the ILC. The capital investments by CERN on the CLIC R&D have been about a factor of four greater compared to those given to the Muon Collider R&D.

*Financial Management and Other Operational Risks.* The upgrades will be anchored in agreements made by the DOE with CERN. In delivering on these agreements Fermilab will play a leading role. Vagaries in the US funding would impact huge international collaborations and be very visible internationally to the detriment of the US reputation as a reliable partner. If the investment in the technologies needed for LHC upgrades and for the design of the next generation colliders is reduced, competition in Europe and Japan will overtake the efforts in the US.

## *The Intensity Frontier*

### The Vision

Experiments at the Intensity Frontier provide critical and unique tools to address some of the central questions in particle physics that cannot be answered at the Energy Frontier. In the next decade, activities at the Energy Frontier will be centered at CERN. The Intensity Frontier current experiments and future plan at Fermilab provide a major domestic program with world-class experiments. At the Intensity Frontier, the Fermilab program falls in three time frames. In the short term, Fermilab will continue the current neutrino program for the next few years. The intermediate program includes the upgraded accelerator complex, the second generation neutrino

experiments, and a new muon program. While running the short term and intermediate term programs, Fermilab, in collaboration with its partner institutions, would design and start the construction of the third generation neutrino experiment LBNE (Long Baseline Neutrino Experiment), and a multi-MW proton accelerator *Project X* that provides powerful and flexible beams for neutrino, muon, kaon and nuclear physics programs.

The Fermilab neutrino program contributes to the following principle topics: the neutrino Standard Model ( $\nu SM$ ), beyond the neutrino Standard Model (*Beyond  $\nu SM$* ), and precision neutrino physics within the SM (*Precision  $\nu$* ). Within  $\nu SM$ , the questions are the masses and mixings of the three known neutrinos as well as the fermion nature of the neutrino (Majorana or Dirac). Whereas in *Beyond  $\nu SM$* , the questions include: “Are there sterile neutrinos and what are their mixings?”; “Is the three-flavor neutrino mixing matrix unitary?”; and “Are there non-standard interactions of the neutrinos?” In *Precision  $\nu$* , primary interests are neutrino-matter interactions that facilitate the measurements for  $\nu SM$  and *Beyond  $\nu SM$* ,

Within  $\nu SM$ , the physics questions that Fermilab experiments address are: “What is the value of  $\theta_{13}$ ?”; “Is  $\theta_{23} = \pi/4$ ?”; and precision measurements of  $\Delta m^2_{23}$ . These have been or will be addressed by long baseline experiments: MINOS located in the Soudan mine, Minnesota, 735 km from Fermilab (current/short term); NOvA located at the Ash River, Minnesota, 810 km from Fermilab (intermediate term); and then LBNE that could be located at a site such as Homestake, South Dakota, 1,300 km from Fermilab. The mass hierarchy of ordering of the neutrino mass eigenstates will be addressed by NOvA and LBNE, whereas CP violation (matter – antimatter asymmetry) will probably only be addressed by LBNE. *Beyond  $\nu SM$* , Fermilab’s short baseline experiments MiniBooNE (current/short term) and then MicroBooNE (intermediate term) are addressing “Are there sterile neutrinos?”. Questions such as “are there sterile neutrinos at other mass scales?” are being and will be addressed by MINOS, NOvA and then LBNE. Questions such as “Do neutrinos and anti-neutrinos oscillate differently?” are being and will be addressed by MiniBooNE, MINOS, NOvA and LBNE. Precision neutrino physics concerns primarily with precision measurements of cross sections for both neutrinos and anti-neutrinos. While SciBooNE and MINERvA (short and intermediate term) are dedicated experiments to measure them, all neutrino experiments at Fermilab will contribute to our understanding of this topic which is important for extracting both  $\nu SM$  and *Beyond  $\nu SM$* .

Fermilab is developing another scientific facility which can deliver some of the best information about muons to the world as part of the intermediate program. As the construction of the NOvA detector and the MicroBooNE (using a new Liquid Argon time projection detector technology) rolls off in 2013, Fermilab would start the construction of a  $\mu \rightarrow e$  conversion experiment (Mu2e) that would run in mid-decade along with NOvA and MicroBooNE. By moving the muon g-2 detector from BNL to Fermilab and using muons produced by the 8 GeV protons from the Booster, the laboratory plans to measure the muon anomalous magnetic moment to 0.14 ppm, a fourfold improvement over the previous measurement. SeaQuest as another part of the intermediate program is for a fixed-target study of quark and anti-quark structure functions for protons and neutrons using 120 GeV protons from the Main Injector, and will begin a two-year run in 2012.

The accelerator complex is being upgraded and improved in order to support the intermediate program. Fermilab will complete beam upgrades from 300 kW to 700 kW by the end of 2012 as part of the NOvA project. The proton source improvement plan is under way in order to provide the proton flux demanded by the muon experiments. The areas of the improvement include the repetition rate, reliability, and beam handling capability.

The intermediate program is very powerful and unique in the world, but will need to be upgraded to stay world-competitive in the long term.

While running the short term and intermediate term programs, Fermilab, in collaboration with its partner institutions, would design and start the construction of the beamline and detectors of LBNE, and a multi-MW proton accelerator *Project X*, providing the leading neutrino program in the world and a long term future for U.S. particle physics at the Intensity Frontier. The LBNE far-detector with a few hundred kton water-Cherenkov detector or a few ten kton Liquid Argon detector would be located at a site such as Homestake, South Dakota (1,300 km from Fermilab). This large underground detector is also for proton decay, and supernovae measurements. *LBNE* could start running with a 700 kW beam, followed by *Project X*’s 2 MW beam. Because *Project X* provides a proton beam for neutrinos simultaneously with powerful and flexible proton beams at 3 GeV and 8 GeV, it would create an opportunity to markedly enhance the sensitivity for the  $\mu \rightarrow e$  conversion process and to enable precise measurements of rare *K* decays with unique sensitivity in the world, a factor of 10 to 100 better than is possible elsewhere.

*Project X* consists of a 3 GeV CW (continuous wave) superconducting linac followed by acceleration from 3 GeV to 8 GeV using a superconducting pulsed linac that would replace the present >40 year-old injector complex (Linac and Booster) at Fermilab. Coupled to the Recycler and the Main Injector, both modern rings, the new linacs would lead to the most powerful and flexible facility at the Intensity Frontier anywhere in the world. It will be constructed in a manner that would provide a platform for a future Energy Frontier Muon Collider. Specific mission elements associated with the facility include:

- provide MW-class, multi-GeV, proton beams to support multiple kaon, muon, and neutrino based precision experiments.
- provide a neutrino beam for long baseline neutrino oscillation experiments, based on a capability of targeting at least 2 MW of proton beam power at any energy between 60 – 120 GeV. Simultaneous operations of the rare processes and neutrino programs are required.
- provide a path toward a muon source for a future neutrino factory and/or the Muon Collider
- provide options for implementing a program of Standard Model tests with nuclei and/or nuclear energy applications.

By continuing to run an accelerator program throughout the three time frames, Fermilab will maximize the productivity of the domestic program. To carry out this program, the DOE needs to make capital expenditures in particle physics. Other than NOvA, there has been no decision to invest capital in a major domestic accelerator program since 1998 when the NuMI/MINOS project funding started. Thus the particle physics program in the U.S. will be shutting down some \$2B worth of facilities at SLAC and Fermilab, and unless replaced with new capital investments, the U.S. will lose a world leadership position in particle physics. These capital expenditures could be minimally offset by the funds liberated when the Tevatron ceases operation.

For all of the above activities at the Intensity Frontier, Fermilab leads in the design, development, operation and data analysis of the proposed facilities. The laboratory has developed the necessary collaborations to carry out this program. In particular, the largest program, *Project X*, has formed a collaboration consisting of 9 U.S. institutions (Fermilab, ANL, BNL, Cornell, LBNL, MSU, ORNL, TJNAF and SLAC) and four Indian institutions (BARC, IUAC, RRCAT, and VECC). *Project X* reuses a large fraction of the existing accelerator infrastructure at Fermilab. It enables the use of a variety of storage rings at the Fermilab site, making for a very flexible program in which different experiments can use beams with especially tailored time structures. Fermilab will coordinate the types of experiments with the other high intensity machine in the world, J-PARC in Japan. Fermilab and J-PARC have already started discussions on how to coordinate their programs and have made equipment available to each other. There is a major difference between the two facilities. In particular *Project X* can run simultaneously experiments for neutrinos and for rare decays, while in J-PARC, the beam has to be shared. Also, for neutrino experiments the baselines in the U.S. are much longer than in Japan and the neutrino energies are higher than those in Japan allowing very different sensitivities.

### Required Resources

The human resources exist both at Fermilab and other national laboratories. In particular, some 100 technical FTEs will roll off the Tevatron when the program terminates. Construction of facilities will involve staff at other national laboratories as well as many industrial contractors.

The main need is the capital investment for the various projects. The NOvA requirements are \$278M including accelerator upgrades. The project has gone successfully through a CD-3 approval and the project is well underway. Fermilab has estimated *Project X* at about \$1.3B-\$1.6B (in FY11 dollars) including contingency but the full cost to the US will only be known after the design is completed and the international partners are on board. Fermilab has estimated a cost range for *LBNE* including a beamline, a few hundred kton water-Cerenkov-equivalent detector, and underground infrastructure of \$1.1B-\$1.6B (in FY11 dollars) which also includes \$88M-\$132M for operations of the underground laboratory through construction. The range spans the low and high estimates for the two different detector technologies under consideration, which employ either water Cerenkov or Liquid Argon. This range was estimated by scaling the experience of the NuMI beamline to the Soudan mine and including large contingency. To have a fairly complete suite of experiments for *Project X* at the end of the decade, an additional \$200M will be needed. While all these programs need not be done by the end of the decade, the total investment eventually would add to about \$2B over the next ten years. Fermilab estimates a savings of about \$0.5B over the decade from the closure of the Tevatron. The net capital investment in Fermilab facilities after discounting the savings from the Tevatron would be \$1.5B over the next 10 to 12 years.

Other than NOvA, the DOE has not made a decision to invest capital in the domestic particle physics program since 1998 when the NuMI/MINOS project was approved. The vitality of a program depends on the renewal and advancement of its facilities. Without capital investment this cannot be achieved and domestic facilities will die off. *Project X* makes use of several rings at Fermilab that would take about \$1B to reproduce. Thus the investment in *Project X* of about \$1.8B together with the use of the existing infrastructure at Fermilab would endow the U.S. program with a world-class facility that would take at least \$2.8B to reproduce.

### Risks

*Technical Risk.* Fermilab understands the technical risks associated with this program and has various mitigation strategies in place. Fermilab mitigates the risks in each project by careful engineering, review, thorough targeted R&D programs, and testing of components. Fermilab adheres strictly to project management and quality assurance protocols.

For NOvA, the design is well developed and has been thoroughly engineered and reviewed. Because the detector is modular, we will have early indications of any problems at the beginning of its construction. For the beamline for *LBNE*, the main risk is the one typical of underground construction: unexpected underground conditions. The strongest mitigation against unknowns in underground construction is a thorough characterization with many bore-holes prior to the start of the construction. The construction is very similar to the NuMI project done at Fermilab only a few years ago. For *Project X*, the gradient requirements are forgiving, and the primary challenges will be achieving a high quality factor (Q) in the CW accelerating cavities, and a careful design that minimizes beam loss. Careful engineering, design and testing of the accelerator will mitigate any problems. Cryomodules will be tested far in advance of the project in conjunction with the ILC R&D program. The main new risks will be the target station capable of handling 2 to 3 MW of power. The decay tunnel following the target station will need to be isolated from the aquifer as was done in the case of NuMI. All the lessons learned on the target hall and decay tunnel will be applied to the new design to eliminate or mitigate all known problems.

*Market Risk/Competition.* The proposed program includes both intermediate and long terms and contains unique world-class experiments. Some of the intermediate-term physics results could be reached by programs in other regions, but long-term measurements (both neutrino measurements and rare process measurements) cannot be made anywhere else if the U.S. builds *Project X*. Europe and Japan are aggressively looking into possibilities of long baseline neutrino programs with high intensity proton beams in their regions. If the rate of capital investment in the U.S. is delayed, however, other projects in Europe and Japan could take the leadership position.

*Financial Management and other Operational Risks.* The largest risk is that the capital investments that are needed to keep the vitality of the domestic program are so stretched out that other regions could set up competitive programs. This could occur with new facilities and upgrades of existing facilities in Europe and Japan if they move towards the development of long baseline experiments. The eventual competition from CERN is the main concern. To build a new facility comparable to *Project X*, for example, CERN has the capital available within its own budget to do it in three years. They could also reach a decision to fund such a project much faster than in the U.S.

The recent decision by the National Science Board to not fund DUSEL adds risk to the *LBNE* project that some assumed infrastructure would need to be constructed as part of the project, thereby increasing the project's cost.

In each of the projects Fermilab has the needed leaders and depth. All of the leaders in place have experience in building and running comparably complex projects.

## *The Cosmic Frontier*

### The Vision

There is a deep connection between the world of the very small and the very large. As we probe with higher and higher energies to reach the smallest scales, we also produce massive particles that were the components of the Universe a trillionth of a second after the Big Bang. Those early moments of the Universe are now imprinted in the large scale structures that we see and possibly in the dark matter and the dark energy that permeate the universe and yet we do not understand. The Cosmic Frontier is one of the three frontiers that enable us to answer the central questions in particle physics. The U.S. has led in the Cosmic Frontier with COBE, WMAP, SDSS, and the

discovery of dark energy. To continue our pre-eminent position in the studies of the Cosmic Frontier, we need timely investments in new probes.

Historically, Fermilab has been a leader in developing the connection between particle physics and astrophysics, first theoretically and then experimentally with the Sloan Digital Sky Survey (SDSS), the Cryogenic Dark Matter Search (CDMS) experiment, the Chicagoland Underground Observatory for Particle Physics (COUPP) experiment, and the Pierre Auger Cosmic Ray Observatory. In 2005 Fermilab has established the Center for Particle Astrophysics to further enhance the connection between particle physics and particle astrophysics. The activities of the center will concentrate mostly on dark matter, dark energy, and ultra-high-energy cosmic particles. The center is a focal point for collaborations with universities and other laboratories.

In the next few years, Fermilab will continue its strong role in understanding the cosmos theoretically and exploring it experimentally. The first new large experimental program will be the Dark Energy Survey (DES) funded by DOE and NSF, a broad collaboration to modify the Blanco Telescope in Chile and add a new CCD focal plane. This is the first third generation dark energy experiment and it is a precursor to larger experiments like the Large Synoptic Survey Telescope (LSST). Fermilab leads the DES collaboration and, in particular, is responsible for the development and construction of the CCD camera at the focal plane of the Blanco telescope in Chile. The construction and commissioning of the camera is well underway and we expect its operations in 2012. Fermilab has expertise that could lead to major involvement in a spectroscopic follow-up to DES to extend the study of dark energy.

While dark matter particles might be produced in accelerators such as the LHC, they would not be directly detected there, and it is important to detect them directly. Detectors need to be sensitive to weakly interacting massive particles and insensitive to all other backgrounds. To accomplish this, they must operate deep underground, where the backgrounds from cosmic rays are smaller the deeper the experiment is sited. Fermilab is a lead institution of the CDMS collaboration, and the 5-kg CDMS detector made up of cryogenic germanium and silicon bolometers has been leading the world in sensitivity. We are currently constructing a 15-kg detector (that will increase the sensitivity by about a factor of ten) and developing a 100-kg (or SuperCDMS) detector. Fermilab managed the construction and operation of the CDMS detectors and manages the facility in the Soudan mine. Fermilab leads in the development of room temperature bubble chamber technology, together with its partners at the University of Chicago (the COUPP collaboration). With the successful running of a 2-kg detector at Fermilab's MINOS near-detector hall and a 4-kg detector at the SNOLab, the collaboration constructed a 60-kg chamber which is being commissioned at Fermilab. In addition to CDMS 15 kg / 100 kg and COUPP 60 kg, Fermilab is exploring the best way to scale detectors up to 1000 kg. This will extend the sensitivity to dark matter particles by a large factor and to well-motivated new physics scenarios. Fermilab scientists also collaborate in the DarkSide experiment at the Gran Sasso underground laboratory in Italy using a high purity Liquid Argon Time Projection Chamber. The synergy between the R&D and detection techniques using Liquid Argon for MicroBooNE and LBNE at the Intensity Frontier and DarkSide at the Cosmic Frontier is clearly evident.

Because interactions with the cosmic microwave background limit the path length, theories predict that the detectable flux of the highest-energy cosmic rays (above  $10^{18}$  eV) originate from relatively nearby galaxies. Observations of the highest-energy cosmic rays offer the opportunity to search for correlations between the measured direction and hypothetical source locations. The Auger experiment, located in Argentina, for which Fermilab managed the construction of the project and manages its operations, has detected such correlations for the first time, opening up the field of particle astronomy. Furthermore, violations of the path-length limitations or anomalies in the air shower development initiated by these fantastically energetic particles, if observed, could be a signal of new physics.

#### Required Resources

The strong team from the SDSS and DES project will deliver on the DES science over the next seven year, and operations funding requests are currently built into the laboratory budget. The construction of the 60-kg COUPP chamber is complete and it is being commissioned. The CDMS collaboration needs modest additional resources from DOE and NSF to reach the goal of 15 kg. SuperCDMS, a 100-kg experiment, would require an MIE (Major Item of Equipment) of \$20M. Other technologies for one-ton scale detectors are also being developed at Fermilab. Fermilab explores to a spectroscopic follow-up of DES that would probably be in the \$20-40M range. Moderate resources will be needed for our participation in LSST and new initiatives such as the Fermilab Holometer.

## Risks

*Technical Risk.* The major risk for 1-ton scale dark matter experiments is the limitation of sensitivity due to backgrounds, thus the requirements for a ton-scale experiment are extraordinarily stringent.

*Market Risk/Competition.* There is substantial competition in dark matter direct detection. A review of the field is likely to occur in FY2011 or FY2012. On the dark energy side, the DES will run at the forefront for a number of years. Beyond that, ground-based observatories such as DES or LSST compete with satellite-based telescopes. PASAG (Particle Astrophysics Scientific Assessment Group) recommended further planning and coordination between ground-based and space-based dark energy experiments. The Astro2010 process is an essential component for defining the national dark matter and dark energy programs.

*Financial Management and Other Operational Risks.* Risks to the dark energy programs could be mitigated by establishing collaboration between a ground-based effort and a space mission.

## *Development of Superconducting Radio Frequency Technologies*

### The Vision

Superconducting Radio Frequency (SRF) is an “enabling” technology applicable for a variety of future accelerator projects at the Energy and Intensity Frontiers in support of the DOE OHEP mission and is crucial to Fermilab’s and the nation’s long term science strategy. Rapid improvements in achievable accelerating gradients now make SRF technology the preferred method of efficiently generating high power particle beams.

SRF R&D is expected to lead to new methods for superconducting cavity fabrication and processing and cost effective high-power radiofrequency power sources. SRF technology development holds the promise of furthering accelerator-based capabilities beyond High Energy Physics, including next-generation light sources, accelerators for isotope generation and medicine, accelerators for industrial use, accelerators for waste water or flue gas treatment, accelerators to transmute and make safe radioactive waste from nuclear reactors, accelerators to drive subcritical reactors to create electrical power while at the same time creating fissile nuclear fuels, accelerators for materials irradiation and a host of other high power beam applications aligned with the DOE and SC goals.

In many ways the situation with SRF is like superconducting magnets in the 1970’s. The development of SC magnet technology and the construction of the Tevatron at Fermilab led to a SC wire industry in the U.S. capable of making wire for such applications as medical MRI magnets, medical cyclotrons, and SC power transmission lines. SRF has the same or even greater potential.

Currently European laboratories and industry are in the lead in SRF capabilities. It is Fermilab’s goal to develop world-class SRF infrastructure and expertise at Fermilab that complement that at other U.S. SRF institutions such as TJNAF, ANL, and Cornell. This SRF infrastructure and capability is needed to construct and support SRF accelerators for high energy physics like *Project X*, the ILC, or the Muon Collider as part of Fermilab’s core mission as the lead U.S. HEP laboratory. This capability also will permit the DOE Office of Science to participate in other SRF based accelerator projects outside of HEP.

Fermilab already has world class expertise in the design, construction and operation of accelerators. In addition Fermilab has experienced cryogenic and high power RF engineers, all disciplines needed for success with SRF. Developing laboratory SRF expertise will also permit technology transfer and the development of a U.S. SRF industrial capability that will allow the U.S. to be competitive in transformational SRF applications in the future. Indeed, Fermilab has been aggressive in engaging domestic vendors in SC cavity and component production so that domestic capability will be established and ready to support the next generation accelerator facilities based on SRF technology.

### Required Resources

FNAL proposed an integrated *Project X*/ILC/SRF development program to OHEP. The program was intended to prepare the laboratory for a *Project X* construction start in 2015. Additional funds at the level of \$5M/year would support continued development of U.S. SRF industrial capability. Partnerships with ANL, TJNAF, Cornell, and international SRF institutions like DESY and KEK serve to reduce development costs through shared R&D. The laboratory is currently attempting to fund this activity from its operating budget via the core research program, a

challenge given flat funding to HEP and Fermilab. Lower funding levels may delay the readiness date for *Project X* construction and/or increase the associated project risk.

### Risks

*Technical Risks.* Current risks include uncertainties in the mechanisms that limit cavity gradient performance and yield, cost uncertainty in raw materials like high purity Nb, a small and fragile U.S. industrial base, complicated and eco-unfriendly cavity fabrication and surface processing methods. Fermilab is attempting to mitigate performance and yield risks via basic SRF materials research into the mechanisms leading to degraded performance. Similarly Fermilab is funding R&D to fabricate cavities without complicated electron beam welding via hydro-forming cavities from fine grain high purity Nb tube. Similarly, we are engaged in studies of cavity polishing by tumbling and chemical mechanical polishing to eliminate caustic acids currently used for cavity surface processing. We also work to increase the number of U.S. cavity vendors and to initiate cavity surface processing in industry.

*Market Risks/Competition.* There is worldwide competition to improve SRF technology. We mitigate risks by cooperative work with DESY, KEK, India, China, etc. insuring that the U.S. helps develop and has full access to the latest technical improvements. Engagement of U.S. vendors helps mitigate risks associated with large foreign procurements.

*Financial, Management, and Other Operational Risks.* While highly effective, SRF technology requires extensive infrastructure and staff with extensive training. Recent ARRA support of this effort has been very positive in acquiring infrastructure, but came closely on the heels of large cuts in SRF funding and staff which were highly disruptive and caused significant delays and inefficiency. The uneven year-by-year fluctuations in SRF funding make it difficult to develop depth in the staff and/or hire and maintain the desired SRF workforce. In many places the organization is only one person deep. Fermilab has pursued collaboration with India as a possible path to advancing the schedule of *Project X* and improving the overall load on our staff by joint engineering of some components and infrastructure. In the longer run the solution to this problem is strong and steady SC funding support for laboratories conducting basic research.

## 5. Work for Others

### Baseline WFO Program

Although it has grown over the last few years, the Fermilab Work for Others portfolio remains small. When a formal WFO/CRADA proposal is received it is evaluated not only for the required uniqueness of the laboratory's capability to do the requested work but also for availability of laboratory resources and potential interference with the laboratory's primary mission. With the exception of two specific agreements, all WFOs and CRADAs are of short duration (1 or 2 years) or are small in terms of monetary value. The two specific agreements are: 1) operation of the Neutron Therapy Facility, a stable 30+ year operation that does not stress the laboratory's scientific talent or equipment, and 2) the State of Illinois grant (\$20M) to construct the Illinois Accelerator Research Center (IARC), which is a construction project largely utilizing external resources. The latter represents a unique opportunity and is an anomaly to the routine WFO processes at the laboratory. All other projects are small enough that their presence or absence does not affect staffing levels. As of September 30, 2010 there were 6 active WFO/CRADAs at Fermilab, with an annual value of about \$500k excluding the State of Illinois grant. As of March 31, 2011 there remained 4 active agreements.

**Table 1. Work for Others Funding (BA in \$M)<sup>1</sup>**

Sponsors	FY 2010 Actual Funding Received <sup>2</sup>	FY 2011 Estimated Funding Level	FY 2012 Request
DOD			
NRC			
DHHS/NIH			
All Other Federal Work	0.3	0.4	0.4
Non-Federal Work	0.3	0.8	0.9
State of Illinois - Illinois Accelerator Research Center	20.9	-	-
<b>Total WFO<sup>3</sup></b>	<b>20.6</b>	<b>1.2</b>	<b>1.3</b>
Lab Operating <sup>4</sup>	418.1	410.0	393.4
<b>WFO as % of Lab Operating</b>	<b>4.9%</b>	<b>0.3%</b>	<b>0.3%</b>
DHS	0	0	0
<b>WFO + DHS as % of Lab Operating</b>	<b>4.9%</b>	<b>0.3%</b>	<b>0.3%</b>

1. Numbers are for planning purposes only.

2. Include FY 2010 WFO funding received as part of the ARRA.

3. Do not include DHS funding when computing the Total WFO funding level.

4. Lab operating refers to the funding programs and others send to the laboratory to perform R&D, etcetera, including capital equipment and GPP (general plant projects), but excluding construction.

### WFO Strategy for the Future

Fermilab's WFO strategy is to leverage the investment of the State of Illinois in the Illinois Accelerator Research Center (IARC) and current collaborative activities between Fermilab and industry in superconducting radio frequency (SRF) technology development. State investment in IARC was motivated by the goal of growing accelerator-based industry in the State by enhancing current collaborations and technology transfer between Fermilab and industry. To that end, Fermilab will further engage industrial vendors who are interested in the capabilities at the NML SRF test and research facility and IARC and who would like to collaborate with Fermilab accelerator scientists and engineers to develop their products. Opportunities exist to engage industrial vendors to continue the development of technology for interrogation and inspection, medical applications, production of superconducting radio frequency systems, and environmental applications of electron beam processing. Additional WFO opportunities include National Security applications using accelerator technology. This WFO strategy seeks opportunities that are closely aligned with the laboratory's core competency in accelerator technology, and which serve to broaden the impact of accelerator technology. We expect the future WFO portfolio will be growing as the IARC program becomes a reality, but the overall scale will be relatively small.

## 6. Infrastructure/Mission Readiness

### Overview of Site Facilities & Infrastructure

Fermilab is sited on 6,800 acres of land located 42 miles west of Chicago in Batavia, Illinois. Laboratory assets include 356 buildings and 74 real property trailers comprising 2.4 million gross square feet and hundreds of miles of utility infrastructure including roads, electrical, natural gas, industrial cooling water, potable water and sanitary systems. The total real property replacement plant value (RPV) is \$1.7B, including the laboratory’s programmatic accelerator and tunnel assets. The detailed property information associated with all assets is maintained in the DOE’s Facilities Information Management System real property database. All of the laboratory’s buildings are used and owned by DOE; the usage is predominately divided among research and development space and administrative areas. Fermilab’s most significant infrastructure needs are the underground piping systems and electrical distribution system, with their overall conditions categorized as poor. Investments over the next several years have been proposed through GPP, SLI and third-party investments. The delay of SLI funding for the Utility Upgrades initially slated to start in FY 2011 has for the first time in Fermilab history created a mission readiness status of “Partially Capable” for utility infrastructure.

**Table 2. Fermilab Infrastructure Data Summary**

Total Replacement Plant Value (\$M)		\$1,699
Conventional Replacement Plant Value <i>excluding OSF 3000 facilities</i> (\$M)		\$846
Total Deferred Maintenance (\$M)		\$44.7
Asset Condition Index	MC	0.91
	MD	0.98
	NMD	N/A
Asset Utilization Index	Office	0.99
	Warehouse	0.94
	Laboratory	1.00
	Housing	1.00
FY2010 Actual Maintenance (\$M)		\$15.7

*MC = Mission Critical, MD = Mission Dependent, NMD = Non-Mission Dependent*

Fermilab’s Conventional Equivalent RPV, used as the baseline RPV in this Plan, is \$846M, for buildings, real property trailers, utilities and the conventional portion of the accelerator (OSF 3000) assets. Additional RPV data and discussion, including projections for the 10-year planning period, is included in the table in Trends & Metrics.

Fermilab’s Ecological Land Management (ELM) Plan (available electronically at <http://www.fnal.gov/cgi-bin/ecology/frame?TYPE=PLAN&YEAR=NOW>) is updated annually. The ELM Plan identifies near-term goals and long-term objectives for cost-effective planned management and fulfillment of Fermilab’s stewardship responsibility for the undeveloped portions of the laboratory’s 6,800-acre campus.

### **Facilities and Infrastructure to support Laboratory Missions**

The core capabilities identified in this Plan represent the current mission whose specific needs are being met within the existing facilities, and whose condition is excellent based on real property criteria considering deferred maintenance. The size and scope of most proposed large experimental projects at Fermilab will likely require considerable additional investment in new facilities and infrastructure, and improvements to existing infrastructure. Future mission programs will evolve based on developments in the high energy physics field, and will continue to provide upgrades and improvements to facilities and infrastructure as required. In support of future programs reuse of existing facilities will also be considered. SLI funding previously identified to address the most critically required upgrades to the Industrial Cooling Water system and High Voltage Electrical System is no longer in the Office of Science budget plan that if not reinstated will require significantly increased GPP levels. The major facility consolidation project remains part of the SLI funding program at some point in the future. Other work is expected to be accomplished with GPP funds and third party agreements.

The existing building facilities are meeting the current operational and experimental needs of the site, which is currently operating with a building Asset Utilization Index of 99.0% (Excellent). Work at a number of buildings has successfully enabled facility reuse to meet programmatic needs. The CZero Experimental Hall was recently converted to a programmatic storage facility, complete with electrical, fire protection and overhead crane enhancements. The reconfigured space will house the NuMI experimental focusing horns, allowing for remote repair of this equipment. Other successful reuse efforts include: a series of enhancements at the Meson Detector Building to house a test beam for Superconducting Radiofrequency cavities; the former Wide Band Counting House Building enlarged and converted to a state of the art computing facility, the Grid Computing Center; the former Muon Lab expanded to serve as the superconducting radio frequency (SRF) cryomodule testing center at the new Cryomodule Test Facility (CMTF). In each of these situations, Laboratory management identifies and meets facility needs through re-assignment and modernization. However, as future mission opportunities continue to develop, additional new experimental facilities will likely be needed.

Similarly, the laboratory's utility infrastructure may require expansion as future mission is identified. When siting future projects, Fermilab's Facilities Engineering Services Section (FESS) works closely with experimental planning groups, the Lab's Master Planning Task Force and the Directorate's newly-created Office of Integrated Planning to efficiently utilize existing utilities or easily expand such facilities. Deferred maintenance requirements of the laboratory's utility infrastructure currently comprises 78% of the site's total FY 2010 Deferred Maintenance backlog, or \$34.8M of the \$44.7M. Most notably, the underground piping and electrical systems are in need of additional significant investment. While substantial GPP efforts are identified in the Lab's five year infrastructure budget plan, investment via the Office of Science's SLI Modernization Initiative would have provided improved reliability of the most critical utility systems. In 2010, Fermilab initiated work on the SLI Utilities Upgrade Project for Industrial Cooling Water and High Voltage Electric, called the Utilities Upgrade Project, achieving CD-1 in November 2010, though the project was absent from the FY 2012 President's Budget Request in February 2011. The laboratory is hopeful that this project scope will be reinstated in the SLI program. In the interim, attempts will be made to mitigate the most significant vulnerabilities by use of GPP or other investments.

The following tables depict the Mission Readiness status of Facilities and Infrastructure in support of the laboratory core capabilities. The status reflects the overall results of the Facility Mission Matrix, in which Division/Section management evaluate the technical facilities and infrastructure capabilities based on the known and projected mission and the five and ten year investment plan. Through discussions with the input of the Directorate, capability gaps are identified for management consideration and mitigation. The mission readiness status of all core competencies is summarized as mission "Capable". However, loss of SLI funding for the Utility Upgrades initially slated to start in FY 2011 has for the first time in Fermilab history created a mission readiness status of "Partially Capable" for utility infrastructure.

## Technical Facilities and Infrastructure

Core Capabilities		Mission Ready Assumes TYSP Implemented				Key Buildings	Key Core Capability Objectives	Facility and Infrastructure Capability Gap	Action Plan	
		N <sup>a</sup>	M <sup>b</sup>	P <sup>c</sup>	C <sup>d</sup>				Laboratory	DOE
Particle Physics	Now				X	CDF, DØ, MI65 & MINOS, NOvA, miniBooNE	Establish world-class scientific research capacity to advance high-energy physics	The facilities and infrastructure in support of this area are considered adequate. Additional investment in supporting infrastructure (both new and restoration or expanded capacity of existing systems) will be included in each new experiment project scope.	As needed, incremental infrastructure improvements and facility upgrades will continue to be supported with GPP investment in these areas.	No dedicated line item infrastructure investments necessary at this time, related facility and infrastructure investments will be needed for future experiments and will be included in future plans
	In 5 Years				X					
	In 10 Years				X					
Accelerator Science	Now				X	Meson Detector Building, New Muon Lab, CMTF, Wide Band, Industrial Facilities	Develop the technology & design for future accelerators to expand the research capacity of high energy physics	The facilities and infrastructure in support of this area are considered adequate. Additional investment in supporting infrastructure (both new and restoration or expanded capacity of existing systems) will be included in each new experiment project scope.	As needed, incremental infrastructure improvements and facility upgrades will continue to be supported with GPP investment in these areas. Third-party investment will construct IARC.	ARRA GPP at IB-3, NML & CMTF underway. Industrial Facilities Consolidation SLI will solidify R&D capability. Related facility and infrastructure investments will be needed for future experiments and will be included in future plans.
	In 5 Years				X					
	In 10 Years				X					
Large Scale User Facilities / Advanced Instrumentation	Now				X	Accelerator complex, beamlines, FCC, GCC & LCC computing facilities	Establish world-class scientific research capacity to advance high-energy physics including high-performance computing to attach highly non-linear problems in lattice QCD, and collective effects in beams and cosmological simulations	Tevatron decommissioning and development of mu2e, LBNE and <i>Project X</i> will usher in a new era of accelerator operations. Planning is underway to assure support facilities associated with managing and maintaining the accelerator complex are either incorporated into each project, or identified for other funding. The real property assets are considered adequate including the conventional portions of the underground asset.	As needed, incremental infrastructure improvements and facility upgrades will continue to be supported with GPP investment in these areas.	ARRA GPP at MI-8 and FCC is underway. No additional dedicated line item infrastructure investments necessary at this time, facility and infrastructure investments will be needed for future experiments and will be included in future plans.
	In 5 Years				X					
	In 10 Years				X					

N<sup>a</sup> = Not, M<sup>b</sup> = Marginal, P<sup>c</sup> = Partial, C<sup>d</sup> = Capable

## Support Facilities and Infrastructure

Assumes TYSP Implemented

Real Property Capability	Mission Ready Current				Facility and Infrastructure Capability Gap	Action Plan	
	N <sup>a</sup>	M <sup>b</sup>	P <sup>c</sup>	C <sup>d</sup>		Laboratory	DOE
<b>Work Environment</b>							
<i>User Accommodations</i>				X			
<i>Site Services</i>				X			
<i>Conference &amp; Collaboration Space</i>				X			
<i>Utilities</i>			X		Industrial Cooling Water system piping, valves & pumping capacity; Electrical oil switches & unit substations; Domestic Water System piping & valve replacements; Sanitary distribution system piping & lift stations	GPP	Capability gaps can be closed by reinstatement of the SLI UUP
<i>Roads &amp; Grounds</i>				X	Reconstruction & resurfacing	GPP	
<i>Security Infrastructure</i>				X			

N<sup>a</sup> = Not, M<sup>b</sup> = Marginal, P<sup>c</sup> = Partial, C<sup>d</sup> = Capable

## **Strategic Site Investments**

Facilities and Infrastructure needs are identified by a variety of mechanisms, including the annual effort accomplished on the Facility Mission Matrix (FMM). Distributed to each division/section facility landlord, the FMM provides alignment of core capabilities to each asset (building, trailer, OSF) current and projected use. The Directorate analyzes the landlord input to create the mission readiness scores identified elsewhere in this Plan. Identified capability gaps are evaluated and programmed for accomplishment via appropriate funding mechanisms, including SLI, GPP, 3<sup>rd</sup> Party investment or operating funds.

### *SLI Modernization Initiative*

Two Fermilab projects had been slated for funding as part of the Office of Science initiative to address infrastructure modernization needs at its laboratories. Each of these projects helps to satisfy general infrastructure requirements and would help solidify Fermilab's current and future mission capabilities.

- Utility Upgrade Project (UUP); TPC of \$34.9M with FY 2011 start – delayed  
The UUP is needed to improve the site's industrial cooling water system (ICW), a critical system that provides fire water supply for building sprinkler systems and hydrants. The ICW system also provides water for experimental cooling. The project also improves the high voltage electric system by replacing legacy oil switches with air switches. Unit substations would also be replaced since much of the equipment is at the end of life and replacement parts are not available. It is hoped that this project will be reinstated as part of the SLI program.
- Industrial Facilities Consolidations; TPC of \$33.8M with FY 2014 proposed start  
This project consolidates multiple machine shops into one state of the art machine shop and demolishes legacy Butler buildings that housed the existing shops. This facility also allows modernization and relocation of crucial accelerators and detector technology development activities.

### *GPP*

The five year infrastructure budget plan summarizes the laboratory's best understanding of outyear GPP funding levels based on information from the HEP program office and the laboratory's planning for infrastructure improvements. As part of the 2009 American Recovery and Reinvestment Act (ARRA), three building additions are currently in the final phases of construction at Industrial Building 3 (IB3A), MI-8 Service Building, and New Muon Laboratory. Computing enhancements at the Feynman Computing Center and an upgrade of the Wilson Hall Emergency Generator are also underway and funded by ARRA. The ARRA-funded Crymodule Test Facility (CMTF) is under construction and will allow testing of state-of-the-art full scale cryomodules to be used for future development of accelerators. Small programmatic enhancements continue to be funded through the GPP program as prioritization decisions are made with the HEP office. Projects funded with FY 2011 and FY 2010 funds include and ICW Sectionalization project, a road reconstruction & paving project, improvements to the Wilson Hall Atrium and west parking lot, and a sanitary sewer improvement project in the vicinity of the Feynman Computing Center. A project to upgrade the Batavia Road gate funded by Safeguards & Security monies was closed early in FY 2011.

Requests for GPP facility and infrastructure alteration and improvement funding are submitted annually through the Fermilab internal budgeting process and the FMM. Additional urgent requests are also considered throughout the year. Upon receipt, needs are prioritized based on regulatory compliance and risk to safety, mission, environment, and operational efficiency.

In addition to mission requirements, the prioritized infrastructure needs and plans, FY 2010 through FY 2016, are summarized in Lab's five year infrastructure budget plan. GPP investments are directed toward the utilities which present the highest vulnerability to the scientific operation as well as those in the greatest need of repair. Future infrastructure budget plans include additional projects as planning continues for future mission. Historically, significant GPP investment has been directed toward expanded computing capacity. There are projected to be \$9.8M of GPP level projects necessary over the next 5 years in support of expanding data center requirements. Currently, less than \$3M has been planned within the 5-year budget planning window based on projected overall lab funding levels. This situation will continue to be monitored.

### *Third-Party Investments*

Fermilab, in conjunction with DOE, has received a grant from the State of Illinois Department of Commerce and Economic Opportunity (DCEO) for construction and ownership of the Illinois Accelerator Research Center (IARC). The IARC's basic goal is to make northern Illinois a center for accelerator development and to initiate, promote, and support related industry in Illinois.

IARC is conceived of as a center of excellence for accelerator research and development in northern Illinois. Located on the Fermilab site, IARC will bring together scientists and engineers from Fermilab, Argonne National Laboratory, Illinois universities, and industry with the goal of encouraging development of accelerator based industry and accelerator projects in Illinois and at Fermilab. In collaboration with nearby universities, IARC would also serve to educate and train a new generation of scientists, engineers, and technical staff in accelerator technology. The opportunities for Illinois are many and several companies and university groups have already expressed their interest in IARC.

The 2010 Illinois Capital Bill included \$20M to be provided via a DCEO grant to fund a portion of the costs of constructing the IARC building. In addition, Fermilab expects from the Office of High Energy Physics (OHEP) in DOE \$13M of Federal funding to be used for project initialization, site preparation, project oversight, and outfitting of the newly constructed state building. We plan to refurbish an existing heavy assembly building (CDF) for use as an integral part of IARC.

The project is well-aligned with both the accelerator-based research mission of the laboratory as well as the mission of the OHEP as the "stewards" of accelerator technology within the Office of Science. Risks include differences in state and federal requirements, coordination of Federal funding with State funding, and the normal risks associated with the construction of any building. The project is currently in the design phase.

### *Maintenance*

Facilities at Fermilab are assigned to a program, including responsibility for maintenance, recapitalization, and the process operations. In a hybrid maintenance program, the Facilities Engineering Services Section provides preventive and corrective maintenance for Fermilab's conventional electrical and mechanical equipment and the occupant organizations identify, fund, and accomplish the remainder of facility sustainment requirements, including those activities accomplished in concert with other GPP or line item projects. . Centralized maintenance data scheduling and tracking activity, end-of-life replacements, and no maintenance zone identification ensure coordinated and consistent application of lab maintenance.

Future maintenance expenditures may continue to exceed 2% of conventional replacement plant value and will be adjusted based on overall facility condition evaluations. Maintenance plans for conventional components of the Tevatron are still in development and will evolve as the work of the Tevatron decommissioning task force makes determinations about the future of the facilities and their contents.

### *Deferred Maintenance*

Fermilab's total deferred maintenance (DM) increased by \$9.1M from \$35.6M reported in FY 2009 to \$44.7M for FY 2010. Seventy-five percent of FY 2010 DM rests with Mission Critical Other Structures and Facilities (OSF), and 54% of the total site DM, \$24M, is in the electric and industrial water distribution systems.

Fermilab recognizes that continued additional reinvestment will be required to control deferred maintenance growth. Many of the GPP projects identified in the Lab's five year infrastructure budget plan, reflect the current plans for this reinvestment, which will maintain the overall condition of building components and infrastructure systems. As a single-program laboratory with a single source of funding, Fermilab's GPP infrastructure expenditures support general purpose assets. The Lab's five year infrastructure budget plan also reflects a reduced GPP expenditure profile based on outyear budget constraints.

Routine maintenance responsibilities for OSFs are assigned to specific system owners, typically the Facilities Engineering Services Section. OSF assessments are periodically updated to represent their current operating condition. This ongoing process considers system or component age, efficiency, safety, environmental impacts, maintainability, failure history, locations and conditions found during repairs, current mission needs, and future requirements. Utility

system deferred maintenance is due in large part to end of life conditions identified during ongoing inspections validating increased deterioration of these systems. Requirements for deferred maintenance are identified and scoped by the system owner, and, if appropriate, prioritized for GPP funding, based on risk levels associated with safety, mission, and environment and the probability of operational impacts from a particular system.

The cancellation of the SLI UUP will not allow for a reduction of utility deferred maintenance of \$16M over the next three years. Further, the cancellation of the SLI project will require increased operating funds to satisfy urgent repair projects to enable experimental operations.

*Excess Facilities*

Fermilab is considering the operational needs of many of its buildings following the end of collider operations. As plans develop further, they will be vetted within the Lab, Office of High Energy Physics, Office of Science and documented in future laboratory planning documents.

**Trends & Metrics**

The Mission Readiness Assessment Process was initiated at Fermilab during FY 2008. An initial overview assessment was conducted with the Directorate to evaluate technical facilities and infrastructure capabilities relative to the planned mission. The assessment results, with consideration for the currently planned investments, are shown in the tables titled, *Technical Facilities & Infrastructure* and *Support Facilities and Infrastructure* below.

Fermilab’s mission is evolving with the imminent cessation of the Tevatron accelerator operations in FY 2011. With the mission readiness initiative, Fermilab is integrating long term facility planning with mission planning, both at the overall laboratory level, as well as the Division and Section level. As new mission is identified, this process will help assure that facility and infrastructure needs are considered early in the process. Fermilab’s Mission Readiness peer review is scheduled for July 2011 and will highlight the planning associated with new mission developments. Fermilab has participated in each Mission Readiness peer review at other labs, including serving as team members in five reviews.

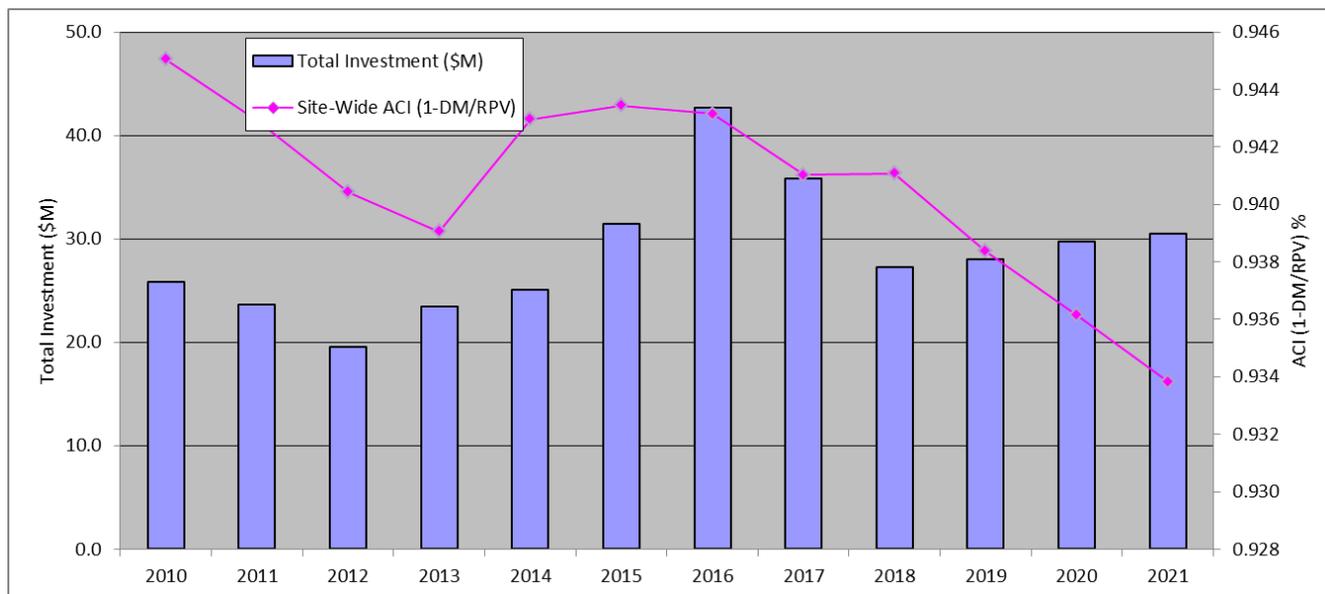
Building management responsibilities are assigned to landlord organizations at Fermilab a cost effective and accurate means to insure facility management investments are well-aligned with mission need, while fulfilling the stewardship responsibility of efficiently managing, using, and preserving real property assets. Extension of the new mission facility planning by use of the Facility Mission Matrix to the landlord organization level strengthens the effectiveness of the overall planning effort.

The projected trends for infrastructure investments and asset condition are presented in Table 3 as summarized in the Lab’s five year infrastructure budget plan.

**Table 3. Facilities and Infrastructure Investments**

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Maintenance	15.0	15.7	14.9	16.3	16.9	17.3	17.9	19.0	19.4	19.9	20.4	21.9	22.4
DMR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Excess Facility Overhead	0.0	0.0	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
IGPP	0.0	0.0	5.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
GPP	29.0	10.1	2.9	2.9	6.2	6.3	6.5	6.6	6.8	7.0	7.2	7.4	7.6
Line Items						1.1	6.7	16.7	9.3				
Total Investment (\$M)	44.0	25.8	23.6	19.5	23.5	25.0	31.5	42.7	35.8	27.3	28.0	29.7	30.5
Estimated RPV	745.0	813.8	846.0	865.5	897.4	948.0	969.8	997.1	1,020.0	1,092.5	1,117.6	1,143.3	1,169.6
Estimated DM	36.0	44.7	48.3	51.6	54.7	54.1	54.8	56.7	60.2	64.4	68.9	73.0	77.4
Site-Wide ACI (1-DM/RPV)	0.952	0.945	0.943	0.940	0.939	0.943	0.943	0.943	0.941	0.941	0.938	0.936	0.934

**Figure 2. Facilities and Infrastructure Investments**



**Site Sustainability Plan**

GHG emissions at Fermilab are dominated by fugitive emissions, primarily SF<sub>6</sub>. After the Tevatron is shutdown, the use of SF<sub>6</sub> will be dramatically reduced (see specific discussion of SF<sub>6</sub> goal below). Scope 2 GHG emissions result entirely from purchased electrical power, of which over 90% is used to operate the accelerator complex and associated equipment to produce scientific results. Reductions in electrical power usage would reduce the ability of the Lab to accomplish its science mission. After the Tevatron is shut down after 2011, new projects will likely eclipse present consumption of energy, increasing rather than reducing Scope 2 emissions of GHG. Fermilab plans to offset Scope 2 emissions with the purchase of renewable energy certificates (RECs) equivalent to 28% of power usage. Consistent with the Secretary’s call for applying our technological knowledge to searching for creative solutions, Fermilab will continue to explore innovative solutions to make accelerator operations more efficient. We are committed to search aggressively for new opportunities to improve the efficiency of high energy physics and reduce GHG emissions.

Fermilab is pursuing another ESPC initiative in FY 2012 to implement additional retrofits, some of which were identified under the prior ESPC Initial Proposal audit. The impact of concluding another ESPC initiative is clearly contingent on understanding of the future usefulness of other facilities on site and therefore dependent upon a clear vision of future program initiatives at the site.

Fermilab submitted a request for waiver of the renewable energy goal to have 7.5% of the site’s total annual energy consumption provided by on-site renewable energy sources, which was supported by a study performed by the DOE National Renewable Energy Laboratory (NREL). Fermilab currently has a small number of operating renewable energy systems on the site, although none account for a significant proportion of electrical or thermal energy use. During 2010 two additional small systems were deployed. Fermilab will continue to look for technical or market developments that would make renewable energy projects cost-effective on site, however, given the power costs for the foreseeable future, this does not seem promising.

Fermilab currently has a fleet of 223 vehicles. Of the light duty vehicles, 80% are alternatively fueled, and the goal is to increase that percentage to 100%. It has several medium and heavy-duty vehicles operating on biodiesel fuels. The lab has recently acquired 11 hybrid vehicles with plans to purchase more hybrid and E85 vehicles and maintain its use of biofuels where feasible. Fermilab continues to work to meet the increasingly difficult challenge of finding suitable

alternatively fueled replacement vehicles that meet our goals for petroleum reduction and that also fulfill operational needs.

Fermilab has made continuous progress on implementation of its metering plan, however, new metering guidance from DOE may necessitate new requirements. Additional advanced meters may be required to meet the Guiding Principles in existing buildings, even if not life cycle cost effective under the criteria applied for the metering plan. Such meter installations would be evaluated under a plan to utilize metering data to drive the behavior of occupants to reduce consumption. The high risk of non-attainment is due to the absence of funding for outyears.

Fermilab has not historically invested in cool roofs due to high process-related thermal loads in the many of its buildings, and cooling in process spaces being typically achieved through ventilation. The advantages of cool roofs in this climate are marginal, and life cycle cost analyses are typically not favorable. However, the roof of Wilson Hall, the main administrative building on site, qualifies as a cool roof by the Cool Roof Rating Council (CRRC) criteria. Fermilab will continue to evaluate replacing roofs with cool roof technology. For all new construction in the future, cool roofs, including R30 insulation will be specified unless it is demonstrated to be infeasible or not life cycle cost effective. The Fermilab Housing Department has identified a composite shingle with a Solar Reflective Index (SRI) of 31, sufficient to meet the Secretary's goals. This product will be used in the routine roof maintenance program that results in replacing from 1 to 4 roofs in the Fermilab Village annually until all of the approximately 80 roofs are compliant. This product will also be evaluated for use on all high slope shingle roofs on site. Anticipated compliance with the DOE goal is limited to cost-effective installations.

Training at seminars, workshops and conferences related to energy management is received by site personnel responsible for managing water and energy on site. Personnel responsible for the operation of energy and water systems and direct digital controls received approximately 180 person-hours of formal training in 2010, and less-formal training is regularly received during weekly toolbox meetings. Fermilab reaches out to employees to educate them on energy and water conservation through training (New Employee Orientation) and biannual Environment, Safety and Health Fairs. The site energy manager will be re-certified as a CEM prior to September 2012.

A contractor with the capability of capturing nearly 100% of the SF6 will be retained to carry out maintenance/repair of electrical equipment as needed. Accelerator components will continue to be monitored for SF6 leaks and repaired as necessary to minimize fugitive emissions. Accelerator Division personnel will continue to use the SF6 capturing and monitoring system to minimize fugitive emissions from the pelletron. The pelletron is integral to the operation of the Tevatron, so there will be no further operational use for it after FY 2011 and Fermilab will develop plans for reclamation of the pelletron's SF6. The reduction in SF6 releases will also likely result in the necessary 28% reductions in Scope 1 emissions.

Fermilab's Scope 3 emissions are dominated by T&D losses, which are proportional to electricity purchased off site. The remainder, dominated by employee business travel and commuting to and from work, is overwhelmed by the T&D proportion, with regard to attaining the goal. Losses due to the transmission and distribution of purchased electrical power were stipulated by DOE to be calculated based upon a national average that is inappropriate when receiving power at 345kV. Fermilab will seek concurrence from DOE to recalculate and use actual site T&D losses, which are much lower. The high risk of non-attainment of this goal is based on the lack of technical means to accomplish the Lab's mission without increased electrical power usage.

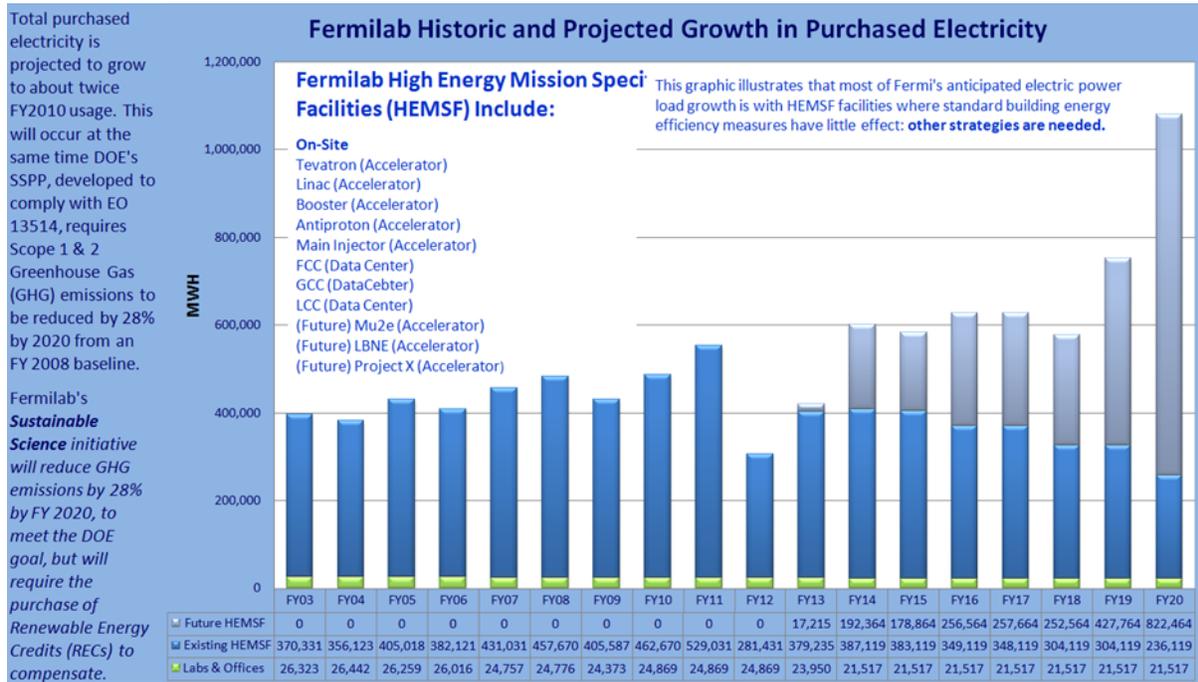
Fermilab has identified and initiated assessment of 15 buildings for their potential to meet the guiding principles. The high risk of non-attainment for this goal is due to lack of funding. This project is suggested as the site's key sustainability related project that would be recommended for funding. Completion of this project would result in the best return on investment, should it be included in the SC sustainability portfolio approach. The new Office, Technical and Education Building at the Illinois Accelerator Research Center (IARC) will be designed to achieve LEED-Gold certification.

Fermilab has exceeded the reduction in potable water use of 16% by FY 2015 and 26% by FY 2020 from a FY 2007 baseline through aggressive leak management for its underground distribution system, and will continue to implement these measures on this aging system.

DOE has established 2010 as the baseline for Industrial/Landscaping /Agriculture (ILA) water, with a goal of a 20% reduction of consumption by FY 2020. The volume of water usage varies somewhat from year to year, depending on

conditions and demand, which accounts for the expected increase in FY 2011. Additional reductions are planned after the shutdown of the Tevatron at the end of the year, and through ongoing attenuation at sources. Other factors will be evaluated as future program initiatives at the lab are better understood.

**Figure 3. Historical and Projected Purchased Electricity**



**Table 4. Progress Against Office of Science Sustainability Goals**

<b>Requirement</b>	<b>DOE Corporate Goal</b>	<b>Status</b>	<b>Risk of Non-attainment (H, M, L)</b>
Scope 1 and 2 Greenhouse Gas (GHG) Emissions	28% reduction from 2008 to 2020	On track to meet goal	Low – Plan to continue to use RECs
Energy Reduction	30% from FY 2003 to 2015.	On track to meet goal	Medium – Plan for new ESPC
Renewable Energy	At least 7.5% of annual electricity and thermal produced on-site by FY 2010	Achieved	Low – Plan to continue to use RECs
Fleet – Alternative Fuel Consumption	10% increase in Alternative Fuel consumption from 2005 to 2015	Achieved	Low – Plan to implement
Fleet – Petroleum Consumption	2% annual reduction from 2005 to 2015	Achieved	Low- Plan to implement
Fleet – Light Duty Vehicles	75% of light duty vehicles purchased must be alternative fuel vehicles by 2015	Achieved	Low – Plan to implement
Advanced Metering	Use to the maximum extend practical, for electricity by October 2012, steam and natural gas by October 2016. Standard meters for water.	Completing cost effective power metering but new requirements and HPSB outstanding	High – Seek to find funding for new requirements
Cool Roofs	Use for new roofs per Secretarial memo of June 1, 2010	One building on site	Medium – Plan to implement where cost effective
Training & Outreach	DOE facility energy managers to be Certified Energy Managers (CEM) by September 2012.	Training and outreach regularly implemented	Low – Plan to re-certify CEM
Sulfur Hexafluoride (SF6 capture)	Implement capture program by September 2012	On track to meet goal	Low – Plan to implement
Scope 3 GHG	13% reduction from 2008 to 2020	Large HEMSf power use T&D losses outweigh other sources when using national average T&D loss figures	High – Plan to request use of actual site T&D losses
Buildings	15% of existing space meets guiding principles by FY 2015 (baseline excludes buildings of 5,000 sf or less)	Percentage as of the end of FY 2010 was 0%and is estimated to remain so through FY 2013	High – Seek funding to implement upgrades
	All new construction LEED Gold certified	1 building planned	Low – Plan to comply
Water Intensity Reduction	16% by 2015 relative to FY 2007 use	Achieved	Low – Plan to continue
Water Consumption Reduction	20% reduction of industrial, landscaping & agricultural use by 2020 relative to 2010	Expected increase in FY 2011 relative to the baseline established in FY 2010	Medium – Plan to asses requirements

## 7. Human Resources

### Current and Future Workforce

Fermilab's current workforce consisting of

- Scientists – experimentalists and theorists in accelerator physics and particle / particle-astro physics (19%)
- Engineers (14%)
- Technicians (24%)
- Computing professionals (16%)
- Facilities management staff (10%)
- ES&H staff (3%)
- Administrative support, finance and business, and other laboratory support staff (14%)

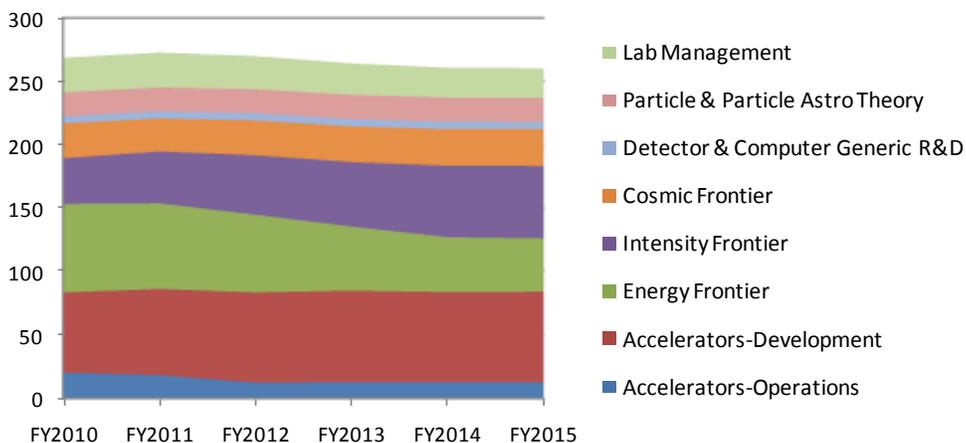
successfully maintains the core capabilities of the laboratory and accomplishes the present mission of the laboratory. However, the required skill mix varies with time, in particular with ending the Tevatron operation at the end of FY 2011 and starting and developing new accelerator and detector projects. For example, approximately 125 full time equivalent staff spread over approximately 200 individuals (corresponding to 6.5% of the current workforce), are exclusively engaged in accelerator / detector / computing operations and data analysis at the Tevatron. Although many of these employees possess skills that are required to support development, design, construction and operations of new projects at the Intensity Frontier, there will be some mismatch between the current workforce and workforce needed for the future mission of the laboratory.

Fermilab has a mechanism (Organization and Human Asset Plan) to review the skills across the entire laboratory and guide the evolution of the workforce needed to carry out the Laboratory's future mission. The OHAP process combined with efforts of workforce optimization task forces:

- Identifies the current people and skill sets (more than 200 skill sets are identified),
- Reviews current and future programs and projects, and skills needed for them, and
- Analyses the differences between current skill sets and skill sets needed for future programs and projects.

In FY 2009 and FY 2010, this process identified the gap in specific skill sets, such as mechanical and cryogenic engineers and project support staff, and the laboratory handled the gap with a mixture of contractors and a small number of new hires. The same process will guide a realignment and potential reduction of the workforce beyond FY 2011. The figure below is one of the outcomes of the process showing Fermilab scientists' past, current and intended activities between FY 2010 and FY 2015. The transition from the Tevatron to the Intensity Frontier projects is evident.

Number of current scientists at Fermilab in various activities between FY10 (past), FY11 (current), and FY15 (intended)



Our key challenges are:

- to provide the human resources needed to run the Tevatron and at the same time to staff the projects that will become the future of the laboratory
- to estimate future workforce needs accurately and to retain specialized skills not readily available in the labor market when the uncertainties on the timeline for new projects and programs are large.

The laboratory will have to operate on a matrix model in order to make employees with the appropriate skills available during different phases of projects.

### *Diversity*

One third of the laboratory's top management team (4 out of 12) are females. Fermilab has made progress in increasing female and minority applicant flow for many job categories. In FY 2010 female and minority hires were 26.9% and 23.1% of all hires, respectively. The laboratory has increased representation in engineer and computer professional job categories, but continues to be challenged in locating and recruiting females and minorities for physics positions. The laboratory participates at the annual National Conference for Black and Hispanic Physicists to reach out to these diversity candidates. The laboratory continues to strengthen relationships with colleges. For example, the laboratory is represented on the Minority Engineering Advisory Board, College of Engineering at the University of Illinois at Chicago.

One of the laboratory's most successful strategies in developing and hiring diversity candidates has been internal pipeline programs and programs developed in conjunction with DOE. The laboratory has hosted two FaST teams in the last two years where professors from a historically underrepresented college have worked with student teams on a project at Fermilab. We have also worked with DOE on the Community College Initiative to develop a technical track and to offer internships to diversity candidates. We continue to be active with GEM, the National Consortium for Graduate Degrees for Minorities in Engineering. Each year we place graduate level minority engineers and computer professionals in work projects at the lab. Every summer we offer internship programs to diversity undergraduates and a work/education program for minority high school students who have an interest in science.

The laboratory sponsors a successful diversity council that has produced recruiting tools, post-doc informational videos, sponsored training and development and cultural diversity events. The Council also developed FermiLINK, a mentoring program to enhance employee skills and professional development.

### *Obstacles and Strategies*

Budget cuts along with potential workforce reductions, the salary freeze, and lack of commitment for a major construction project will have a negative impact on retention and morale, and will hinder our ability to attract the best and brightest to the laboratory in the future. While difficult there are several things that the laboratory can do to mitigate the situation. The laboratory can attract and retain early career staff members by strengthening existing prestigious Fellows programs and co-op programs. Quality of life and work/life options will become more important to attract early career staff. Options for flexible and alternate work schedules are being explored at the laboratory. The laboratory will strengthen recruiting to attract new talent primarily through increasing partnerships with universities.

The retention of core capabilities is important to the laboratory's future. An aging workforce, possible workforce restructuring and lack of financial commitment to new projects could result in the loss of these skills. There are several key strategies the laboratory can pursue. The laboratory can matrix employees with critical skills to projects as needed to maximize the use of those skills and rely on contractors for standard technical work. The laboratory can strengthen succession planning, not only for management positions, but for critical technical skills.

As the laboratory changes emphasis from Tevatron operations to design and construction of new projects at the Intensity Frontier, there may be a shortfall of required skills. Some skills may be new to the laboratory so there will be a focused effort to recruit new talents to the laboratory. An example of this is the recent recruitment of an underground tunneling expert for the LBNE project. There will also be a need for skill flexibility and retraining. During workforce restructuring the laboratory will aim to retain the employees with the skills needed for the future. We will also find mechanisms to increase and develop new skills that will be needed. An example of this is the development and installation of new engineering design and drafting software. All laboratory engineers will be trained on this software which will result in updated skills that will be able to be used in the design work for new projects.

## 8. Cost of Doing Business

### *Overhead Budget Process*

As a single-program basic research laboratory, virtually all Fermilab costs, direct and indirect, are borne by the High Energy Physics program. In the laboratory's budget processes, the overhead pools are treated as direct program categories and the same budget formulation and execution processes are applied across the entire laboratory.

Each year the Director makes an initial budget allocation to each organizational leader for the next fiscal year based on the best information available from the Office of High Energy Physics regarding program priorities and funding levels. The initial allocation is made with significant input from the Senior Management Team, including the Deputy Director, COO, CIO, CFO, and Associate Lab Directors. General operations funding for ongoing activities, including most indirect activities, is allocated on a prior-year + inflation basis, with specific adjustments for known fluctuations in staffing levels or M&S (materials & services) needs. Organization leaders are then charged with optimizing their programs, direct and indirect, and formulating a financial plan within the constraints of the initial allocation.

A key control in the laboratory's budget formulation process is the "Director's Budget Review". Each organizational head, including the Directorate, presents the organization's financial plan to the Director, with the Director's senior staff and all other organizational heads in attendance. Each organizational leader specifies what planned activities can and cannot be accomplished in the coming year with the initial allocation of funding. Additional budget allocations can be requested at this time, and attendees may register challenges to planned expenditures elsewhere in the laboratory as well. Financial data is required to be presented at the DOE B&R category level, with further breakdowns by the laboratory's activity-based categories, in order to provide consistency and comparability. Organizational leaders are free to supplement this data to fully explain his/her plan.

Once all presentations are completed, the Director and Senior Management Team meet to discuss the additional requests. Both direct and indirect requests are considered together at this time. Trade-offs in formulating the FY 2011 budget are discussed in "*Decisions and Trade-offs*" below.

Fermilab does not currently have a Laboratory Directed Research and Development program.

### *Metrics*

Table 5 presents requested information regarding the laboratory's overhead trends and labor fringe rate. The figures include funding received from the American Recovery and Reinvestment Act (Recovery Act).

**Table 5. Laboratory Overhead Trends (Cost Data in \$M)**

	FY 2008	FY 2009	FY 2010	FY 2011 Est.	FY 2012 Est.
<b>1. Direct FTE Ratio</b>					
<i>Numerator:</i> Direct FTE's <sup>1</sup> , which represent time charged to client funded work <sup>2</sup> , including capital but excluding LDRD	1,206.3	1,177.3	1,183.0	1,151.0	1,101.0
<i>Supplemental Data:</i> Indirect FTE's (all non direct FTE's, to include LDRD and organizational burden <sup>3</sup> )	748.2	721.1	742.0	719.0	703.0
<i>Denominator:</i> Total FTE's (subtotal of direct and indirect FTE's)	1,954.4	1,898.4	1,925.0	1,870.0	1,804.0
<i>Direct FTE Ratio (%):</i> Direct FTE's/Total FTE's	61.7%	62.0%	61.5%	61.6%	61.0%
<b>2a. Total Overhead/Total Lab Cost</b>					
<i>Numerator:</i> Total overhead cost, which includes institutional overhead, LDRD and organizational burden <sup>3</sup> to the extent this overhead is allocated to client funded work. <sup>2</sup>	105.1	116.0	121.6	127.0	128.5
<i>Denominator:</i> Total lab cost includes all cost charged to client funded work <sup>2</sup> (operating and capital). Includes subcontracts and procurements <sup>4</sup> and line item construction costs.	340.5	376.5	419.3	440.3	430.8
<i>Total Overhead/Total Lab Cost (%):</i>	30.9%	30.8%	29.0%	28.9%	29.8%
<b>2b. Total Overhead/Total Lab Operating Cost</b>					
<i>Numerator:</i> Same as preceding metric.	105.1	116.0	121.6	127.0	128.5
<i>Denominator:</i> Same as preceding metric, but exclude line item construction costs.	340.5	376.5	419.3	440.3	430.8
<i>Total Overhead/Total Lab Operating Cost (%):</i>	30.9%	30.8%	29.0%	28.9%	29.8%
<b>2c. Total Overhead/Total Internal Lab Operating Cost</b>					
<i>Numerator:</i> Same as preceding metric.	105.1	116.0	121.6	127.0	128.5
<i>Denominator:</i> Same as preceding metric, but exclude subcontracts and procurements <sup>4</sup> charged to client funded work <sup>2</sup> .	239.7	261.5	260.7	269.0	273.3
<i>Total Overhead/Total Internal Lab Operating Cost (%)</i>	43.9%	44.4%	46.6%	47.2%	47.0%
<b>3. Fringe Rate</b>					
<i>Numerator:</i> Total cost of employee benefits (including statutory benefits), not including paid absences.	48.5	50.3	51.6	53.0	54.1
<i>Denominator:</i> Total base salary cost.	149.2	154.7	163.3	165.7	168.2
<i>Fringe Rate (%):</i>	32.5%	32.5%	31.6%	32.0%	32.1%

1. A Full Time Equivalent (FTE) is calculated as actual hours charged divided by the expected hours to be charged by a normal employee during a year.
2. "Client funded work" refers to "direct charges"/"direct funded work."
3. "Organizational burden" refers to an overhead pool that accumulates the cost of managing and operating an organization or group of organizations and is usually allocated on a rate established specifically for recovering the cost of the organization and/or grouping. It includes space charges.
4. "Subcontracts and procurements" includes services performed for and purchases made by the laboratory that are charged directly to programmatic work, e.g., subcontracts for consulting, postdoctoral R&D fellowships at national laboratories, construction, architect and engineering services, material and equipment purchases, inter-entity work orders to other DOE laboratories, R&D at universities, and etcetera.

\* FY 2008, FY 2009, and FY 2010 data reflect actual costs. FY 2011 and FY 2012 are estimates (adjusted for escalation using a factor that is appropriate to the individual laboratory).

### Major Cost Drivers

The major cost drivers at the laboratory are: Electric power; IT Services and Cybersecurity; Facilities maintenance; Employee Benefits for health care; and Decommissioning. Following is a description of each, including how we are managing their effects on the laboratory's budget.

**Electric power** - The primary driver for the cost of electric power is the planned running time of the High Energy Mission Specific Facilities (HEMSF) including the accelerator complex during the fiscal year. Even with the cessation of TeVatron operations, electricity consumption is expected to increase considerably over the next decade as new scientific facilities begin to come online. A secondary driver is the market price of power. The Laboratory employs two main strategies to mitigate the cost of electric power: Competitive procurements through the DOD Defense Energy Supply Center (DESC), which locks in power costs in advance and avoids price fluctuations in the real-time or day-ahead markets; and a Dollar-Cost-Averaging procurement strategy through DESC that consists of multiple procurements for portions of the total annual requirement. This approach provides reasonable prices by mitigating market volatility without speculation. Fermilab also participates in power curtailment programs with its utility providers.

IT Services and Cybersecurity - There is a large unsatisfied demand for information systems and productivity tools that would improve the efficiency of operations; provide information for management and decision-making; manage documents, records, designs and projects; and automate complex workflows that currently are paper-intensive. In addition, diligence and care in the administration of IT systems in a hostile cyber security environment is essential and makes this activity increasingly time consuming and expensive. The laboratory continues to consolidate fragmented IT operations and expects to reap efficiencies over time through standardization and centralization. In addition, the laboratory has set a goal to become ISO20000 certified for core IT services by the end of 2011, instituting industry best practices in delivering IT services which is expected to result in cost savings and efficiencies.

Infrastructure Modernization - Aging infrastructure, and principally the laboratory's utility systems, are at or nearing the end of useful life. These systems create operational vulnerabilities and introduce increased levels of risk so require increasing investments in maintenance and improvements. Improvements to underground piping systems, high voltage electric switches, and unit substations were planned to be funded from the DOE SLI program in FY11 and FY12 that has since been cancelled. This will require increasing levels of GPP and indirect dollars in the near future to begin to mitigate the vulnerabilities.

Employee Benefits for Health Care - Health care costs for active and retired employees continue to increase. The Laboratory has an aging workforce resulting in increasing medical problems. In 2009 the laboratory changed the cost share structure of the retiree medical plan for significant savings, and conducted aggressive negotiations with the insurance carriers to reduce renewal rates. We also increased the active employee cost-share of medical plans by raising co-pays and increasing deductibles. As a result, health-care fringe benefits increased only 4% in FY2010 over FY2009. The laboratory continues to evaluate the potential cost effects of the recently-passed health care reform legislation.

Decommissioning - The turn-off of the Tevatron at 9/30/2011 will result in the need to decommission both the CDF and D0 detectors and a portion of the accelerator complex. Decommissioning plans are currently under development.

#### *Decisions and Trade-offs*

As a single-program laboratory, Fermilab's direct and indirect activities compete for the same High Energy Physics dollars. In FY2011, the requests for additional funds totaled \$15M, of which only \$3M of the highest—priority requests were funded in the first half of the year due to the significant budget uncertainties. One-third of that amount was allocated for indirect efforts associated with management of a facilities project to improve the Industrial Area infrastructure in anticipation of the State of Illinois-funded IARC building; a restructuring effort in Human Resources; and project management software. Unfunded requests to date include IT improvements, research equipment upgrades, and certain lower-priority accelerator improvements deferred to future years.

Attachment 1. Fermilab Site Map

