Annual Laboratory Planning

Fermilab

Fiscal Year 2010

1. Mission/Overview

Fermilab's primary mission is to achieve the high-level goal of the Department of Energy Strategic Plan for high-energy physics: "….to establish world-class scientific research capacity to advance high-energy physics" and to help maintain U.S. global leadership in science and engineering. Fermilab provides a unique focus on the grand challenges of 21st-century particle physics, "understanding the fundamental nature of matter and energy, space and time," through accelerators and associated programs. It is the only US laboratory primarily devoted to this field.

Currently research in particle physics in the world centers around three laboratories; CERN in Switzerland, KEK in Japan, and Fermilab in the U.S. Fermilab was founded in 1967 as a national laboratory. Universities Research Association, a consortium that today encompasses 86 universities, operated the laboratory for 40 years. In 2006, URA formed an alliance with the University of Chicago to create a new corporation, the Fermi Research Alliance, which today manages the laboratory for DOE. Fermi Research Alliance combines the depth and commitment of the University of Chicago with the broad involvement of a consortium of universities for the benefit of Fermilab, the particle physics community and the nation.

Forty miles west of Chicago in Batavia, Illinois, Fermilab site has a 6,800 acre park-like site, much of it open to the public. Some 1,912 employees (1,365 science and engineering research and technical support staff) and 2,300 users carry out a world-leading program of discovery at the three frontiers of particle physics, the Energy, Intensity and Cosmic (particle astrophysics) Frontiers. Fermilab operates the Tevatron proton-antiproton collider at the Energy Frontier, supports the US community in the exploitation of the Large Hadron Collider (LHC) and carries out R&D on future colliders; produces the most intense source of proton beams for neutrino studies and for rare decay processes at the Intensity Frontier complementary to the LHC; and carries out a vital particle astrophysics program using telescopes, underground detectors and cosmic ray arrays at the Cosmic Frontier. Fermilab is the principal US contributor to the Large Hadron Collider, the world's highest proton-proton collider, in Geneva, Switzerland. The overall budget of Fermilab is $375M including Work for Others funding (0.5%). Fermilab's core capabilities include particle physics, accelerator science, and the construction and operation of large-scale facilities including the Tevatron and its experiments, neutrino beams and their experiments, detector development and test beams for detector development, accelerator development and accelerator test facilities, and computing facilities such as the CMS Tier-1 computing center, the Lattice QCD center, and the Grid computing center.

2. Lab-at-a-Glance

Lab-at-a-Glance

Location: Batavia, Illinois

Type: Single-program Laboratory

Contractor: Fermi Research Alliance, LLC

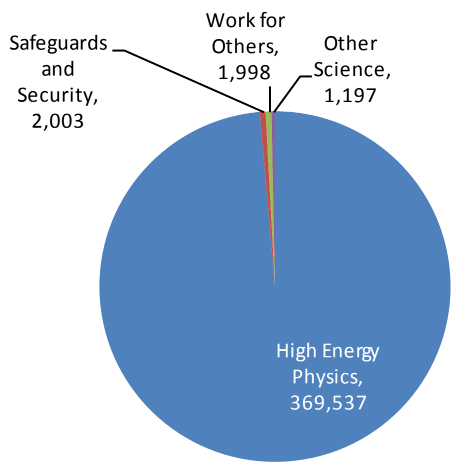
Responsible Site Office: Fermi Site Office

Website: http://www.fnal.gov/

Physical Assets:
- 6,800 acres, 355 buildings, other structures and facilities
- 2.3 Million GSF in buildings
- Replacement Plant Value: $1,623M
- Deferred Maintenance: $35.6M
- Asset Condition Index:
  - Mission Critical: 0.96 (Excellent)
  - Mission Dependent: 0.97 (Excellent)
  - Asset Utilization Index: 0.99 (Excellent)

Human Capital:
- 1,867 Full Time Equivalent Employees (FTEs)
- 8 Joint faculty
- 383 Postdocs (including Facility Users)
- 550/120 Graduate/Undergraduate Students
- 2,300 Facility Users[1]
- 40 Visiting Scientists[2]

FY 2009 Funding by Source: *(Cost Data in $M):*



FY 2009 Total Lab Operating Costs: $374.7M

FY 2009 Total DOE/NNSA Costs: $372.7M

FY 2009 WFO (Non-DOE/Non-DHS) Costs: $2.0M

FY 2009 WFO as % Total Lab Operating Costs: 0.5%

FY 2009 Total DHS Costs: $0.04M

Recovery Act Obligated from DOE Sources in FY 2009: $95.1M

Recovery Act Costed from DOE Sources in FY 2009: $1.8M

3. Current Laboratory Core Capabilities

Fermilab is focused on delivering the Department of Energy's High Energy Physics (HEP) mission and is funded by the Office of High Energy Physics (OHEP). Non-HEP sources of funds make up 1% or less of the laboratory's total funding.

3.1 Particle Physics

Particle physics is a central component of the physical sciences, focused on the fundamental nature of matter and energy, space and time. Discoveries in this field, often called high-energy physics, will 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 in particle physics and thus to deliver on the Department of Energy's High Energy Physics missions, we use a range of tools and techniques at three interrelated frontiers:

- **The Energy Frontier**, using high-energy colliders to discover new particles and directly probe the architecture of the fundamental forces.
- **The Intensity Frontier**, using intense particle beams and high-precision, ultra-sensitive detectors to study rare or very subtle processes in order to discover the fundamental symmetries that govern the interactions of elementary particles.
- **The Cosmic Frontier**, using naturally occurring processes (that do not require particle accelerators) to obtain new insight and information about elementary particles and fundamental forces and to reveal the nature of dark matter and dark energy.

Answers to the most challenging questions about the fundamental physics of the universe will come from combining the most powerful insights and discoveries at each of the three frontiers. These three approaches ask different questions and use different techniques, but they ultimately aim at the same transformational science.

Fermilab's scientific program supports the US community with world-leading research at all three interrelated frontiers. Today Fermilab provides the only HEP accelerator facilities available in the U.S. At the Energy Frontier, the Tevatron collider and the CDF and DZero experiments provide a vital program through 2011, and Fermilab's accelerator, detector, computing and physics facilities support the LHC in Geneva, Switzerland. Fermilab is the principal U.S. contributor to the LHC accelerator and the major CMS detector. Fermilab is a leading institution in developing accelerator technologies for future lepton colliders such as the ILC and the Muon Collider. At the Intensity Frontier, the NuMI neutrino beam, driven by 120-GeV protons from the Main Injector accelerator, is the most powerful in the world and provides a beam to the MINOS detector located in Soudan, Minnesota, and to the MINERvA detector at Fermilab. In the near future, Fermilab will upgrade this beam to double the power and commission a far more powerful detector, the NOvA detector located near Ash River, Minnesota. An additional neutrino beam driven by the 8-GeV Booster Ring provides a beam of neutrinos to the MiniBooNE experiment and soon for a Liquid Argon Time Projection Chamber, MicroBooNE. The 8 GeV proton beam will be use for a major new experiment to establish the conversion of muons to electrons (Mu2e), a critical measurement for any unified theory of particle physics. Fermilab with a large national collaboration is developing the Long Base Line Neutrino experiment, LBNE, a third generation neutrino oscillationexperiment. At the Cosmic Frontier, Fermilab is a critical partner in a number of major non-accelerator experiments. For most of them, Fermilab manages the construction of the projects and manages experiment operations: the Cryogenic Dark Matter Search (CDMS), the Pierre Auger Observatory in Argentina, the Chicagoland Underground Observatory for Particle Physics (COUPP), the Sloan Digital Sky Survey (SDSS), and the Dark Energy Survey (DES). Particle physics and particle astrophysics theory are an essential part of the laboratory. Emphasizing the connection between theory and experiment to advance cutting-edge experiments, theorists guide the development of experiments and elucidate their results.

As Fermilab attacks the defining questions in particle physics and delivers the DOE HEP mission, it pays special attention to educating future generations of scientists. Primarily Fermilab achieves this function through training about 550 graduate students (more than 100 Ph.D. theses each year) and 383 postdoctoral fellows. Fermilab contributes to science, technology, engineering and mathematics (STEM) education with a broad program for both pre-university students and teachers, and undergraduate university students.

3.2 Accelerator Science

Fermilab undertakes accelerator research, design, and development. The accelerator science program is embedded in, and leverages resources and infrastructure from, the much larger operations and general technology development programs. Fermilab efforts focus on the areas of superconducting radio-frequency (SCRF), superconducting-magnet, ionization-cooling, and high-intensity proton technologies. Fermilab (i) retains unique capabilities in superconducting-magnet development, currently targeted for LHC upgrades and future high field solenoids needed for the Muon Collider; (ii) provides U.S. leadership in the development of high-gradient SC RF technology for the ILC, with application to a multi-MW proton source (Project X); (iii) supplies integrated design concepts and technology development for a multi-MW proton source to support world-leading programs in long-baseline neutrino and rare-processes experiments; (iv) leads U.S. technology development for ionization cooling required for muon-storage-ring based facilities; and (v) supplies integrated design concepts for the Muon Collider and a neutrino factory. In addition, Fermilab pursues comprehensive integrated theoretical concepts and simulations of complete future facilities on both the energy and intensity frontiers.

Advanced accelerator R&D activities, currently centered at the A0 Photoinjector, will move to the AARD (Advanced Accelerator R&D) Users' Facility to be created in conjunction with the New Muon Laboratory superconducting radio-frequency test facility. They 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; 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 provides joint leadership (with BNL, LBNL, and SLAC) of the national Muon Accelerator Program (MAP) and manages through MAP the development of future facilities including a neutrino factory at the intensity frontier and a 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.

Particle accelerators are key resources for DOE's program of scientific discovery. They make up 14 of the 28 facilities in the DOE twenty-year outlook on facilities for the future of science. The Community Petascale for Accelerator Science and Simulation (ComPASS) project, funded by the Offices of High Energy Physics (HEP), Nuclear Physics (NP), Basic Energy Sciences (BES) and Advanced Scientific Computing Research (ASCR), develops a comprehensive computational infrastructure for accelerator modeling and optimization. This project will advance accelerator computational capabilities from the terascale to the petascale to support DOE priorities for the next decade and beyond. Fermilab leads the ComPASS collaboration.

Fermilab carries out a comprehensive program for training of the next generation of accelerator scientists and engineers, targeting younger researchers at all levels from undergraduate students to advanced post-graduates. The program includes the Lee Teng Internship in accelerator science and technology for undergraduate students, two sessions a year by the US Particle Accelerator School (a national consortium hosted at Fermilab) for undergraduate and graduate students, a Joint University-Fermilab Accelerator Ph.D. program, the Bardeen Fellowship in accelerator engineering for master and Ph.D. students, and the Peoples Fellowship in accelerator science for post-graduates.

3.3 Large Scale User Facilities, Instrumentation, and Computing

Large Scale User Facilities

For more than four decades, Fermilab 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. Examples of current user facilities are the Tevatron proton-antiproton collider, NuMI (providing the highest-power neutrino beams in the world), the CDF and DZero Tevatron experiments, and the MINOS and MINERvA neutrino experiments. A second-generation long-baseline neutrino experiment (NOvA) and a third-generation dark energy experiment (DES) are currently under construction. The laboratory has established design concepts and begun technology development for the next generation of world-leading facilities including the ILC, longer baseline (>1000 km) neutrino beams and detectors (LBNE), facilities for the study of rare processes such as muon to electron conversion (Mu2e), and a multi-MW proton facility (Project X). Efforts are underway to establish design concepts for a multi-TeV muon collider (Muon Collider) and a neutrino factory.

Advanced Instrumentation

Developing and employing cutting-edge technology, Fermilab advances particle-detector technology and applies it to the construction of detectors for a variety of science 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 for particle physics and other sciences. 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.

Running simultaneously with the Tevatron collider and the neutrino beams, Fermilab provides a test beam facility used by the international particle-physics community for the development of detector technology. The laboratory is advancing the instrumentation of the test beams through the development of picosecond time-of-flight systems and versatile, integrated data acquisition systems.

Computing

Fermilab provides world-class computing leadership and resources for the particle physics community to deliver science 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 the Tevatron program (CDF and DZero experiments), the LHC program (CMS experiment and the LHC Physics Center), the Sloan Digital Sky Survey (SDSS), neutrino and rare processes experiments; and supports computational cosmology. Fermilab hosts the CMS Tier-1 center, the Lattice QCD (Quantum Chromodynamics) center, and the Grid Computing Center; 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 in particle physics require extreme scale computing: data storage, networks and CPU power. The CMS experiment uses a distributed computing model, in which seven national Tier-1 centers, 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 Tier-3 facility for analysis of CMS datasets.

Lattice QCD Center: QCD describes how quarks and gluons interact via the strong force and predicts in principle the masses of their bound states, known as hadrons. Such predictions require the numerical simulation of QCD on a lattice of space-time points ("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.

Grid Computing Center: Grid computing evolved as an extension of distributed computing to satisfy growing computing needs in the science, industry, government and commerce. Grid computing involves the distribution of computing resources among geographically separated sites (creating a "grid" of 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.

World class skills leading to Fermilab core capabilities: particle physics, accelerator science, and large scale user facilities

Skill	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

World class skills for particle physics at the three interrelated frontiers: energy, intensity, and cosmic 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 TPC	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, JDEM ,…)

World class skills for accelerator science at the three interrelated frontiers: energy, intensity, and cosmic frontiers

Accelerator Science: Skill	Energy Frontier	Intensity Frontier
Theory	Collider beam dynamics (beam-beam, IBS, etc.)	Instabilities, Loss mitigation
Accelerator Technologies	SC Magnets (Nb_3Sn, HTS), SC RF (β=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 Colllider), Energy deposition (MARS)
Data Analysis & Distributed Computing	Shot Data Analysis	

World class skills for large scale user facilities at the three interrelated frontiers: energy, intensity, and cosmic frontiers

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

Table 1. Distribution of Core Capabilities Across the SC Laboratories

Categories of Core Capabilities	AMES	ANL	BNL	FNAL	LBNL	ORNL	PNNL	PPPL	SLAC	TJNAF
Particle Physics		✓	✓	✓	✓				✓	
Nuclear Physics		✓	✓		✓	✓				✓
Accelerator Science		✓	✓	✓	✓	✓			✓	✓
Plasma and Fusion Energy Sciences						✓		✓		
Condensed Matter Physics and Materials Science	✓	✓	✓		✓	✓			✓	
Chemical and Molecular Science	✓	✓	✓		✓	✓	✓		✓	
Climate Change Science			✓			✓	✓			
Biological Systems Science			✓		✓	✓	✓			
Geological Systems Science					✓	✓	✓			
Applied Mathematics		✓			✓					
Advanced Computer Science, Visualization, and Data		✓			✓	✓	✓			
Computational Science						✓				
Applied Nuclear Science and Technology		✓	✓		✓	✓	✓			✓
Applied Materials Science and Engineering	✓	✓	✓		✓	✓	✓			
Chemical Engineering		✓	✓		✓	✓	✓			
Systems Engineering and Integration		✓	✓		✓	✓	✓			
Large Scale User Facilities/Advanced Instrumentation		✓	✓	✓	✓	✓	✓	✓	✓	✓

4. Science Strategy for the Future/Major Initiatives

Particle physicists are on a 21st-century quest to answer profound questions about the universe. Powerful new scientific tools for high energy physics will bring the answers to these compelling questions. As the only national laboratory in the U.S. primarily focused on high energy physics, Fermi National Accelerator Laboratory advances the understanding of the fundamental nature of matter and energy by conducting basic research at the frontiers of high energy physics and related disciplines. Fermilab's broad scientific program pushes forward on three interrelated frontiers of particle physics: the Energy Frontier, the Intensity Frontier, and the Cosmic Frontier. Each uses a unique approach to making discoveries, and all three are essential to answering key questions about the laws of nature and the cosmos.

At the Energy Frontier, scientists build advanced particle accelerators to explore the fundamental constituents and architecture of the universe. There physicists expect to encounter new phenomena not seen since the immediate aftermath of the Big Bang. Subatomic collisions at the energy frontier will produce particles that signal these new phenomena, from the origin of mass to the existence of extra dimensions. At the Intensity Frontier, accelerators create intense beams of trillions of particles for neutrino experiments and measurements of ultra-rare processes in nature. Measurements of the mass and other properties of the neutrinos are key to the understanding of new physics beyond today's models, with critical implications for the evolution of the universe. Precise observations of rare processes provide a way to explore high energies, opening an alternate, powerful window on the nature of fundamental interactions. At the Cosmic Frontier, particle astrophysicists use the cosmos as a laboratory to investigate the fundamental laws of physics from a perspective that complements experiments at particle accelerators. Thus far, astrophysical observations, including the bending of light known as gravitational lensing and the properties of supernovae, reveal a universe consisting mostly of dark matter and dark energy. A combination of underground experiments and telescopes, both ground- and space-based, will explore these mysterious dark phenomena that constitute 95 percent of the universe.Fermilab will remain entirely focused on particle physics at all three frontiers. For the U.S. to remain among the leaders in this field, a central laboratory that builds and exploits new facilities in partnership with universities and other national and international laboratories is essential. Facilities for particle physics are global and ever more challenging to design, build and operate. A laboratory with a singular focus to consolidate these facilities will give the U.S. a competitive advantage in the future. The major task in the strategic plan for the laboratory calls for a transition from the operations of the Tevatron to the building of a very long baseline (> 1,000 km) neutrino experiment, LBNE, at a site such as NSF's proposed Deep Underground Science and Engineering Laboratory, DUSEL. It would have a total of a few hundred kton fiducial mass. Along with LBNE, the laboratory proposes to build a unique accelerator facility, Project X, that would position the U.S. as a leader in the study of neutrinos and the rare particle decays. At the same time, Project X would develop much of the technology necessary for future Energy Frontier accelerators, such as the ILC or a muon collider. Project X is thus integral to an overall strategy for achieving world leadership on the intensity frontier, while providing a bridge to a future energy frontier facility. Project X would re-use existing Fermilab facilities, infrastructure that would be very costly to reproduce. The combination of Project X and a large long-baseline detector would create in the long term the most powerful neutrino program in the world. Project X could also serve as the front-end of a future neutrino factory or muon collider.

The overall Fermilab program will continue to have three elements. **At the Energy Frontier** Fermilab will terminate Tevatron operations within a couple of years and concentrate on the exploitation and future development of the LHC and CMS. Fermilab has the lead U.S. role on both LHC accelerator and CMS detector. Fermilab has created a Remote Operations Center (ROC) and the LHC Physics Center (LPC) to make the participation of national institutions in the LHC and CMS more effective. Fermilab plans to form a 10-FTE scale ATLAS group to couple to a large fraction of the U.S. particle physics community when Tevatron operations cease. Also at the Energy Frontier, Fermilab will develop the technology and designs for future machines such as the ILC or a muon collider. Fermilab has taken the lead in establishing a national Muon Accelerator Program (MAP) in order 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.

At the Intensity Frontier, Fermilab's strategic plan contains a short-term, an intermediate-term and a long-term program. Building on the currently operating short-term program, the intermediate program would exploit the present accelerator complex and consist of the NOvA and MINERvA neutrino experiments, a Mu2e muon experiment, an additional small neutrino experiment (MicroBooNE) using a liquid argon time projection chamber, and LBNE. The long range program would exploit the unique capabilities of Project X and would include a beamline for LBNE, with LBNE detectors with a total fiducial mass of a few hundred ktons. Researchers would use these large underground detectors for neutrino, proton decay, and supernovae experiments. The long-range program would also contain a suite of high-rate experiments using various flexible beams from Project X. These experiments would have very different scales, would be an ideal complement to the LHC and would permit the training of many young scientists with a complete experience both in the development of instrumentation and in physics analysis.

At the Cosmic (particle astrophysics) Frontier Fermilab recently terminated participation in the SDSS, although data analysis and Fermilab's role in managing and distributing data for the community will continue in the next few years. The laboratory is focusing on the construction of the Dark Energy Survey, the first 3rd generation dark energy experiment, which will start operation in 2011. Fermilab will be a partner in the construction and exploitation of the Joint Dark Energy Mission (JDEM), where Fermilab's goal is to host the Science Operations Center. Fermilab will continue to participate in the Auger experiment, in particular in operations and data analysis. Fermilab's program in the direct detection of dark matter will be even stronger in the near future with the 60-kg COUPP detector that is currently being commissioned, the construction of the 15-kg CDMS detector together with R&D for the 100-kg CDMS detector, and the development of new detector technology such as liquid argon.

The table that follows 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 two to three years.

Activities	Leadership Areas	New Capabilities	Required Resources
Energy Frontier: 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.	Continuous upgrade of computational resources. Capital for LHC and CMS upgrades determined nationally. Fermilab competes for its allocation.
Intensity Frontier: Neutrinos, Rare Processes	Neutrino: The NOvA facility; MINERvA detector; Neutrino liquid argon TPC detector; LBNE beamline and detectors; Project X construction Rare Processes: Mu2e experiment; Rare K processes and other high rate experiments with Project X	Most powerful neutrino program in the world. *Project X* 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 ($270M), *Project X* (~$1,5B), and *LBNE* beamline and detectors (~$800M shared by DOE and NSF). 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
Cosmic Frontier: Dark Matter & Dark Energy	Dark Matter Searches (CDMS, COUPP); Dark Energy Searches (DES, JDEM); 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; Project X 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, radiation hard electronics for the upgrade of CMS. *Project X* requires new capabilities in designing, building, processing and testing high gradient, high Q, RF cavities.	*Project X* 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 Thoery; 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 quantum chromodynamics 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. The theory line supports the three frontiers and is not described separately. For theoretical HEP Fermilab needs to maintain and moderately enhance human capital and maintain the computational resources on a steady path to support the analysis of massive data sets. The activities under the accelerator and detector R&D line 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 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 DZero detectors is enabling about 100 publications and 60 Ph.D.s per year. The total integrated luminosity delivered so far is about 8.5 fb^{-1} and by the end of FY2011, we expect about 12 fb^{-1}.

Discoveries at the Tevatron and more likely 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 central particle physics laboratory, the role of Fermilab in developing the energy frontier in the US is unique. Fermilab will continue to be the lead U.S. institution for the commissioning, 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 will create a critical mass of talent in software engineering and physics analysis that will make 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 have to 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 quadrupoles, 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 larger energy stored 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 has completed 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 acceleration 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 (a multi MW proton accelerator), and 4) the feasibility studies for a muon collider and a neutrino factory (MAP). In 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 is in the operation of the LHC. There are two types of risks. The first 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 dumped 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 contributes expertise in the control of beams and quench protection gained at the Tevatron.

The risks associated with the future collider R&D is 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 – currently we can neither prove, nor disprove, that such a machine is realizable. It is possible that the result of the Design Feasibility Study will be that such a collider is not feasible.

Market Risk/Competition. To continue to be welcome at 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 no 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 fees for our participation. Development of facilities at the intensity frontier at Fermilab that would attract European collaborators would also lead to a more balanced particle physics world.

The competition for the multi-TeV Muon Collider is the CLIC (Compact Linear Collider), a mult-TeV electron-positron linear collider, centered at CERN. The capital investments by CERN on the CLIC R&D have been about a factor of four compared to those given to the Muon Collier 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 would be very visible internationally to the detriment of US reputation as a reliable partner.

If the investment in the technologies needed for upgrades to LHC and for the design of the next generation colliders is reduced, then competition in Europe and Japan will overtake the efforts in the US.

The Intensity Frontier

The Vision

The intensity frontier is a critical and unique tool to address some of central questions in particle physics which cannot be answered by the energy frontier. In the next decade, activities at the energy frontier will be centered at CERN. The intensity frontier plan at Fermilab provides 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 two to three years. The low energy neutrino SciBooNE experiment has completed its run in August 2008 and the MiniBooNE experiment will run through 2010 with an anti-neutrino beam. The MINOS detector will study neutrino oscillations and electron appearance until 2011. All of these experiments are unique in the world. By 2011 their operations will end.

The intermediate program includes the MINERvA, NOvA, MicroBooNE, Mu2e, and LBNE experiments. The MINERvA experiment started taking data with the full detector in March 2010. Fermilab will complete the NOvA beam upgrades from 300 kW to 700 kW by 2012 and start running the NOvA detector in 2013 with more than half its total mass. NOvA is the only experiment in the world with sensitivity to the mass structure of the various neutrinos (mass hierarchy). Fermilab would complete the 15 kton detector by the end of 2013 and run it for the next five years. As the construction of the NOvA detector rolls off, Fermilab would start the construction of a $\mu \rightarrow e$ conversion experiment (Mu2e) that would run in mid decade along with the NOvA detector. In addition Fermilab would develop Liquid Argon TPC detectors for an eventual detector for *LBNE*, but would use the prototype to study in detail the low energy neutrino anomaly observed by the MiniBooNE experiment. This intermediate program is very powerful but will need to be upgraded to stay world-competitive in the long term.

LBNE detectors coupled with the highest intensity neutrino beam produced by *Project X* would be the leading neutrino program in the world. While running the short term and intermediate term programs Fermilab in collaboration with its partner institutions would design and start the construction of *LBNE* beamline and detectors, and *Project X* providing a long term future at the intensity frontier. *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 and 8 GeV, it would create an opportunity to markedly enhance the sensitivity for the $\mu \rightarrow e$ conversion process and to start a new experiment in 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 either a RCS (rapid cycling synchrotron) or a superconducting pulsed linac that would replace the present ancient 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. Because *Project X* uses similar RF cryomodules as the ILC, it would develop the base of US technology for the ILC. It also provides the front-end of a neutrino factory, or the Muon Collider if the future path diverges from the ILC.

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 high energy physics. These capital expenditures could be partially 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 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 KEK/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 beams have to be shared. Also, for neutrino experiments the baselines in the US are much longer than in Japan allowing very different sensitivities.

Required Resources

The human resources exist both at Fermilab and other national laboratories. In particular, some 200 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. However, there is about 5% needed increase in personnel in FY 2010 and FY 2011 before the conclusion of the Tevatron. We will handle this with a mixture of contractors and a few new hires.

The main need is the capital investment for the various projects. The NOvA requirements are $270M including accelerator upgrades. The project has gone successfully through a CD-3a approval and the project is well underway. Fermilab has estimated *Project X* at about $1.5B 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 *LBNE* including a beamline and a few 100 kton detectors (including cavern) at around $800M (shared by DOE and NSF) 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 $1.5B together with the use of the existing infrastructure at Fermilab would endow the US program with a world-class facility that would take at least $2.5B 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 program, 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, Fermilab will have early indications of any problems when the NOvA collaboration completes the full-scale prototype. 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 challenge will be achieving a high quality factor (Q) in the CW accelerating cavities. Careful engineering, design and testing of the accelerator will mitigate any problems. Linear accelerators are less subject to instabilities since they are single pass machines.

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 is long term and contains unique world-class experiments. Some of the physics results could be reached by programs in Japan, but other important measurements cannot be made anywhere else, especially those requiring long baselines for neutrino physics. 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 US is delayed, however, other projects in Europe and Japan could take.

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 built into 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 US.

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 that 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 cosmic rays. The center is to be 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 will be the first third generation dark energy experiment and it is a precursor to larger experiments like the Joint Dark Energy Mission (JDEM) or the Large Synoptic Survey Telescope (LSST). Fermilab leads the DES collaboration and, in particular, is responsible for the development of the camera or focal plane. Beyond DES lies JDEM, a 1.5 meter telescope in space with optical and infrared imaging as well as spectrometric capabilities. Fermilab's principal interests are to construct the Science Operations Center and to develop the data analysis and the serving of the data to the scientific community. Such a data center could also serve one of alternate 4^{th} generation dark energy experiments if JDEM is not selected. Fermilab has expertise that would 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, 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. 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). After the successful running of a 2-kg detector, 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 a ton of material. This will extend the sensitivity to dark matter particles by a large factor.

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. With the recent success of Auger South, the collaboration plans to propose a facility with complementary capabilities in the northern hemisphere, with a preferred site in southeastern Colorado. Improvements to the Auger South experiment are also under discussions.

Required Resources

The development of DES is currently built into our 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.

By far, the largest resource requirements are for the JDEM Science Operations Center. The DOE investment in JDEM is likely to be about $200M. Fermilab proposes to construct and operate the Science Operations Center (SOC) where the data are managed, calibrated and distributed to the community. The required resources for the SOC are primarily computing specialists. If JDEM is not selected, Fermilab proposes to participate in a spectroscopic follow-up to DES that would probably be in the $20-40M range.

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. The major technical risk for dark energy experiments is contained in the JDEM mission, in particular, in the launch of the rocket. All other risks by comparison can be mitigated using standards for space technology and will be thoroughly understood both at NASA and DOE before the launch.

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, there is a similar probe to JDEM proposed in Europe by ESA. Depending on the timing of the mission selection and the funding, DOE and NASA should be in position to establish the mission early and eliminate competition, or could combine their efforts with ESA. PASAG (Particle Astrophysics Scientific Assessment Group) recommended further planning and coordination with ground-based dark energy experiments. The ongoing Astro2010 process is an essential component of this process.

Financial Management and Other Operational Risks. There are financial caps by DOE and NASA on the JDEM and JDEM might exceed those caps. Much of the risk will depend on the mission management that will be carried out by one of the NASA laboratories. Two agencies will be reviewing the selected mission to insure that the cost estimates are adequate and fit within the established caps. The risk could be mitigated by establishing a joint project with ESA for the space mission or by collaboration on a ground-based effort.

Superconducting Radio Frequency Development

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, cost effective high-power radiofrequency power sources, components for 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, 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 International Linear Collider, 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 national and international SRF based accelerator projects.

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.

Required Resources

FNAL proposed an integrated Project X/ILC/SRF development program to OHEP in Feb 2010. In that program it was estimated that financial resources at the level of $42M/year would be required 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 its operatioins from its operating budget via the core research program, a challenge given flat funding to HEP and Fermilab.

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 tumble polish 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.

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

Work for Others is not a significant factor in the laboratory's strategic plan. The current level of WFO activity does not strain the laboratory's resources, does not require significant staff or subcontracting, nor does it require infrastructure or other improvements above normal levels. The major WFO efforts at the laboratory are described below and we expect a similar funding level in the future, with the exception of an agreement related to State of Illinois funding for the Illinois Accelerator Research Center (IARC) building discussed in Section 6 under "Strategic Site Investments".

The Neutron Therapy Facility, a cancer treatment facility, opened in 1976. Initially NTF was operated under an NCI grant, however, after that grant ran out it has been operated by work for others customers. It is currently operated by Northern Illinois University as the NIU Institute for Neutron Therapy at Fermilab. Neutron therapy is an effective form of radiation therapy, specializing in treating inoperable radioresistant tumors anywhere in the body.

The Laboratory has eight active Cooperative Research and Development Agreements (CRADAs) amounting to $870k. Approximately 3 new CRADAs are begun each FY. All the active CRADAs are with small businesses all of which received SBIR/STTR awards. These awards were for work on advanced accelerator and detector concepts. Of particular importance to the Fermliab future program are the CRADAs with Muons Inc. for research on muon beam cooling and related muon beams research.

The last category of Fermilab WFO activity is related to funding from other agencies. In FY10 NASA provided $239k for specialized portions of Fermilab's astrophysics research. This activity augments the DOE program.

Table 2. Work for Others Funding and Trends (BA in $M)

Sponsors	FY 2010	FY 2011
NSF	0.2	0.2
DOT		
DOD		
EPA		
DHHS/NIH		
Non-Federal	0.9	0.3
NRC		
All Other Federal	0.2	
Total WFO[1]	**1.3**	**0.5**
Lab Operating[2]	395.1	387.7
Total WFO as % of Lab Operating	0.3%	0.1%
DHS	0.1	
WFO + DHS as % of Lab Operating	0.3%	0.1%

1. Do not include DHS funding when computing the WFO total funding.
2. "Lab Operating" refers to the total funding received/expected, and does not include construction.

6. Infrastructure/Mission Readiness

Overview of Site Facilities & Infrastructure

The Fermilab real property is sited on 6,800 acres of land located 42 miles west of Chicago in Batavia, Illinois. Assets include 355 buildings and 73 real property trailers comprising 2.3 million gross square feet and hundreds of miles of utility infrastructure, including roads, electrical, natural gas, industrial cooling water, potable water and sanitary systems with a total real property replacement plant value (RPV) of $1.6 billion, including its programmatic accelerator and tunnel assets. The detailed property information and capitalized value detail associated with each of these assets is maintained in the United States Department of Energy's (DOE) 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. The most significant infrastructure need is the lab's underground piping systems that are categorized as poor. Planned investments over the next several years are proposed through GPP and SLI.

Table 3. Fermilab Infrastructure Data Summary

<table>
<tr><td colspan="2">Total Replacement Plant Value ($M)</td><td>$1,623</td></tr>
<tr><td colspan="2">Conventional Replacement Plant Value excluding OSF 3000 facilities ($M)</td><td>$788</td></tr>
<tr><td colspan="2">Total Deferred Maintenance ($M)</td><td>$36</td></tr>
<tr><td rowspan="3">Asset Condition Index</td><td>MC</td><td>0.96</td></tr>
<tr><td>MD</td><td>0.97</td></tr>
<tr><td>NMD</td><td>N/A</td></tr>
<tr><td rowspan="4">Asset Utilization Index</td><td>Office</td><td>0.99</td></tr>
<tr><td>Warehouse</td><td>0.94</td></tr>
<tr><td>Laboratory</td><td>1.00</td></tr>
<tr><td>Housing</td><td>1.00</td></tr>
<tr><td colspan="2">FY2009 Actual Maintenance ($M)</td><td>$15</td></tr>
</table>

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

Fermilab's Conventional Equivalent RPV, used as the baseline RPV in this Plan, is $788M, 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**.

At the administrative center of the Fermilab campus and comprising 17% of the building RPV is Wilson Hall. This 16-story office building is 18% of the total Fermilab gross square footage and 61% of the site's office space. Nineteen percent of the remaining square footage, in over 100 accelerator service buildings, have grade level access and provide mechanical support along the length of the accelerator chain. A table of key infrastructure data is shown above.

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 infrastructure 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 supporting infrastructure, and improvements in 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, it is expected that some level of new facilities will be required but reuse of existing facilities will be considered as well. Known real property needs for both the current mission and future that are not anticipated in projects are identified and prioritized. SLI funding has been identified for the most critically required upgrades to the Industrial Cooling Water system, the High Voltage Electrical System, and for a major facility consolidation project in FY18. Other work can be accomplished with GPP funds and third party agreements.

The age of Fermilab's buildings varies widely. Of the total Fermilab square footage, 62% represents buildings more than 30 years old, with 6% of those buildings being over 100 years old (20 buildings). The buildings less than 40 years old were constructed specifically for Laboratory operations in the early 1970s, while the buildings older than 40 years were part of the original land acquisition for the site and included a residential village complete with utility systems. These older facilities present different operational and maintenance challenges in comparison to the buildings less than 40 years old (151 buildings or 43% of total number of buildings are over 40 years old). Generally, these newer buildings fare well when the ratio of deferred maintenance to RPV, or the Facility Condition Index (FCI), is considered. When measured by gross square footage, rather than number of buildings, 92% of the facilities rate Excellent (<2% FCI). In March 2010, 72 real property trailers were added to the FIMS inventory. Previously classified as personal property, many of these trailers house people and all have a permanent utility connection or are affixed to the ground. This change was to meet the guidance of the 23 February 2010 memo from Paul Bosco, DOE's Office of Engineering and Construction Management. Deferred maintenance reporting in FIMS will be initiated for these assets in FY10.

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 99.02% (Excellent). Recent work at a number of buildings has enabled facility reuse to meet programmatic needs. The CZero Experimental Hall was converted to a programmatic storage facility, complete with electrical, fire protection and overhead crane enhancements. The reconfigured space will house the NuMI horns, allowing for remote repair of this equipment. A series of enhancements were accomplished at the Meson Detector Building to house a test beam for Superconducting Radiofrequency cavities. The former Wide Band Counting House Building has been enlarged and converted to a state of the art computing facility, the Grid Computing Center. In each of these situations, Laboratory management works to identify and satisfy 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 to efficiently utilize existing utilities or easily expand such facilities. Deferred maintenance requirements of the Laboratory's utility infrastructure currently comprises 85% of the site's total FY09 Deferred Maintenance backlog, or $30M of the $35.6M. Most significantly, the underground piping and electrical systems are in need of additional investment. While substantial GPP efforts are identified in the FY11 Integrated Facilities and Infrastructure crosscut budget plan, investment via the Office of Science's SLI Modernization Initiative will improve the reliability of the most critical utility systems beginning in FY11. Fermilab has already initiated CD-0 work on the SLI Utilities Upgrade Project for Industrial Cooling Water and High Voltage Electric.

Subsequent to the FY09 FIMS Validation, changes were made to the Fermilab Condition Assessment process. Assessments are managed by the Facilities Engineering Service Section, utilizing landlord and building manager knowledge as well as results of inspections, audits, studies, and reviews by other specialists. The Condition Assessment Inspector also considers repair or fault history, performance of the component, age compared to life cycle expectation, operating efficiency compared to contemporary equivalents, and suitability for the current mission.

Strategic Site Investments

SLI Modernization Initiative

Two Fermilab projects are slated for funding as part of the Office of Science initiative to address infrastructure modernization needs at its laboratories. Each of these projects satisfies general infrastructure requirements and solidifies Fermilab's potential mission capabilities.

- Utility Upgrade Project; TPC of $34.9M with FY 11 start
- Industrial Facilities Consolidations; TPC of $33.8M with FY18 start

GPP

The IFI crosscut represents 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 under construction at Industrial Building 3 (IB3), MI-8 Service Building, and New Muon Laboratory. Computing enhancements at the Feynman Computing Center are also underway and funded by ARRA. An upgrade of the Wilson Hall Emergency Generator is also being funded by ARRA. In February 2010, construction was completed on the Main Injector Neutrino Upgrade (MINU) GPP. Small programmatic enhancements continue to be funded through the GPP program as prioritization decisions are made with the HEP office.

In addition to mission requirements, infrastructure needs and plans, FY10 through FY16, are summarized in the appended FY12 IFI crosscut. 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 IFI submissions will likely 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 $20M of GPP level projects necessary over the next 5 years in support of expanding data center requirements. Currently, only $8M has been planned within the 5-year budget planning window based on projected overall lab funding levels. This situation will continue to be monitored.

Illinois Accelerator Research Center

Fermilab, in conjunction with DOE, is pursuing a grant opportunity with 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 was 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, ANL, 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, one Canadian company has even decided to open a new facility near Fermilab.

The 2010 Illinois Capital Bill contains $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 replacement cost of this refurbished building is estimated to be $37M. Fermilab has submitted a draft Statement of Work to DCEO, engaged an architect and engineering firms to develop a conceptual design and is awaiting project funding from the sale of State bonds.

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. Risks are being mitigated by closely working with ANL which has built several DCEO funding buildings on their site.

Maintenance

The Facilities Engineering Services Section provides preventive and corrective maintenance for Fermilab's conventional electrical and mechanical equipment. 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.

Future maintenance expenditures will continue to exceed 2% of conventional replacement plant value. Fermilab's planned maintenance expenditures will be also adjusted based on overall facility condition evaluations and/or when actual replacement plant values differ from those currently projected.

Deferred Maintenance

Fermilab's total deferred maintenance (DM) increased by $3.3M from $32.4M reported in FY08 to $35.6M for FY09. Seventy four percent of FY09 DM rests with Mission Critical Other Structures and Facilities (OSF), and 54% of the total site DM, $19M, 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 appended FY12 IFI Crosscut submittal reflect the current plans for this reinvestment, which will maintain the overall condition of building components and infrastructure systems, specifically with respect to ACI. As a single-program laboratory with a single source of funding, Fermilab's GPP infrastructure expenditures support general purpose assets. The FY12 IFI Crosscut 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 and environmental compliance, 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 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 by the Chief Operating Officer. Prioritization of these projects is based on risk levels associated with safety, mission, and environment and the probability of operational impacts from a particular system.

Fermilab's partnership with the neighboring City of Batavia resulted in the recent replacement of Fermilab's aging high voltage Pi-poles. This effort significantly helped reduce the overall site deferred maintenance and helps ensure uninterrupted electric utility service in the future. In FY08, Fermilab's Deferred Maintenance reduction associated with the Pi-pole replacement totaled $5M.

Excess Facilities

Iinitial planning is underway to demolish a number of small beamline enclosures in the neutrino area as well as a small service building, NS8. In addition, Fermilab is considering the operational needs of many of its buildings following the end of collider operations in 2012. As plans develop further, they will be vetted within the lab, HEP, SC and documented in future laboratory planning documents.

Trends & Metrics

The Mission Readiness Assessment Process was initiated at Fermilab during FY08. 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 table titled, *Facilities & Infrastructure to support Laboratory Missions* on the following page.

The next step of the mission readiness process involves the analysis of the support facilities and infrastructure, and integration of a mission readiness review into the Division and Section annual planning process. After updating the future mission profile, a matrix was developed which associates each facility with the appropriate respective mission requirement(s).

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^a	M^b	P^c	C^d				Laboratory	DOE (Line Item)
Particle Physics	Now				√	CDF, D0, 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 as the planning commences.
	In 5 Years				√					
	In 10 Years				√					
Accelerator Science	Now				√	Meson Detector Building, New Muon Lab (NML), A0, Wide Band, Industrial Facilities (IB)	Develop the technology and the 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.	ARRA GPP expansion of IB-3 and NML is underway. No dedicated infrastructure line item investments necessary at this time, related facility and infrastructure investments will be needed for future experiments and will be included in future plans as the planning commences.
	In 5 Years				√					
	In 10 Years				√					
Large Scale User Facilities / Advanced Instrumentation	Now				√	Accelerator Complex, Beamlines, and FCC, GCC, and LCC computing facilities	Establish world-class scientific research capacity to advance high-energy physics including high performance computing to attack highly non-linear problems in lattice QCD, and collective effects in beams and cosmological simulations.	Tevatron decommissioning and development of LBNE and Project X 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. Current computing facilities are considered capable. Future investments will be needed to meet the 5-year and 10-year requirements. Master planning is done with program offices to assure adequate capacity growth	As needed, incremental infrastructure improvements and facility upgrades will continue to be supported with GPP investment in these areas.	ARRA GPP expansion of MI-8 is underway as well as power and cooling improvements at Feynman Computing Center. No additional dedicated line item infrastructure investments necessary at this time. As facility and infrastructure investments are needed for future experiments thay will be included in future plans as the planning commences.
	In 5 Years				√					
	In 10 Years				√					

Mission Readiness Assessment: N^a = Not, M^b = Marginal, P^c = Partial, C^d = Capable

Support Facilities and Infrastructure						
Assumes TYSP implemented						
Real Property Capability	**Mission**			**Facility and Infrastructure Gap**	**Action Plan**	
	N[a]	P[c]	C[d]		**Laboratory**	**DOE**
Work Environment						
Maintenance			√			
Offices			√			
Cafeteria			√			
Science Center			√			
Recreational/Fitness			√			
Child Care			√			
User Accommodations						
Visitor Housing			√			
Visitor Center			√			
Site Services						
Library			√			
Medical			√			
Warehousing			√			
Fire Station			√			
Railhead			√			
Conference and Collaboration Space						
Auditorium			√			
Utilities						
Communications			√			
Electrical			√	Oil switches, Unit substations	GPP	SLI; ARRA GPP underway for emergency generator
Domestic Water			√	Pipe and valve replacement	GPP	
Industrial Cooling Water			√	Pipe, valve replacement, pumping	GPP	SLI
Fueling Station			√			
Sanitary Distribution			√	Piping and lift stations	GPP	
Storm Water			√			
Chilled Water			√			
Water Control Structures			√			
Road & Grounds						
Parking			√			
Roads & Sidewalks (improved & paved surfaces)			√	Reconstruction and resurfacing	GPP	
Vehicle Bridges			√			
Pedestrian Bridges			√			
Grounds			√			
Note: As future experiments are developed increased capacity and improvements of support facilities will be considered						
[a]N = Not [c]P = Partial [d]C = Capable						

Division/Section management annually evaluates the technical facilities and infrastructure capabilities based on the mission plan and the five and ten year investment plan. Through a series of workshops or reviews and with the input of the Fermilab Master Planning Task Force, capability gaps will continue to be identified for management consideration and mitigation.

Fermilab's mission is evolving with the end of the current Tevatron accelerator operation on the near planning horizon. 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 three reviews.

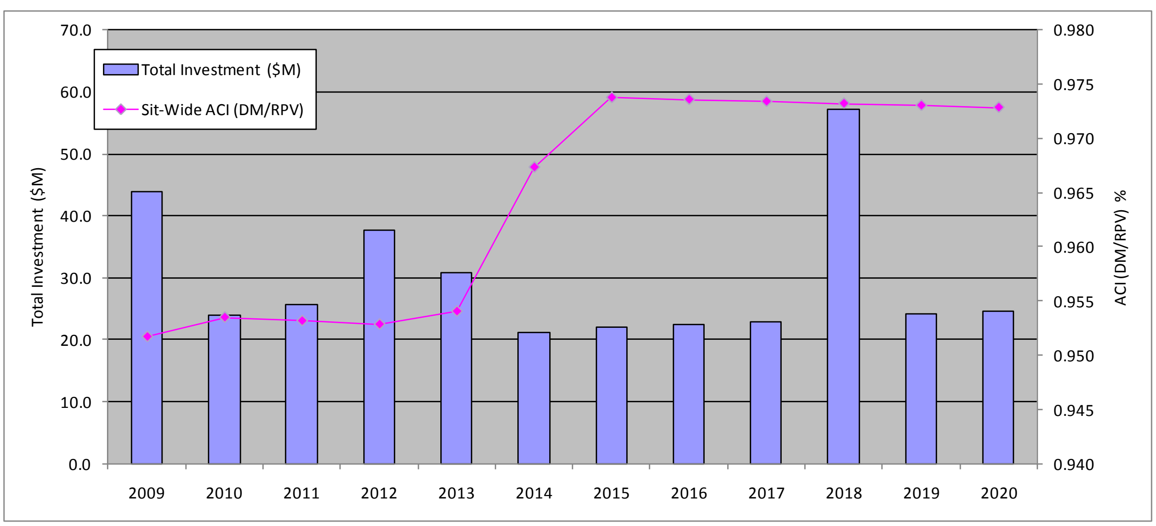
Building management responsibilities are assigned to landlord organizations at Fermilab. This has proven to be a cost effective and accurate means to insure facility management investments are well aligned with mission need, while fulfilling the stewardship responsibility of efficiently managing, using, and preserving real property assets. Extending the new mission facility planning to the landlord organization level will further strengthen the effectiveness of the overall planning efforts at Fermilab.

The projected trends for infrastructure investments and asset condition are presented below as submitted in the FY12 IFI cross-cut budget.

Table 4. Facilities and Infrastructure Investments (BA in $M)

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Maintenance	15.0	13.8	14.9	15.8	16.2	16.5	17.2	17.6	18.0	18.4	18.9	19.3
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
Excess Facility Disposition (overhead)	0.0	0.0	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
IGPP	0.0	0.0	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	4.0	4.1	4.2	4.2	4.3	4.5	4.6	4.7	4.9
Line Items	0	0	7.5	17.4	10.0	0.0	0.0	0.0	0.0	33.8	0.0	0.0
Total Investment	44.0	23.9	25.8	37.7	30.8	21.2	21.9	22.4	23.0	57.3	24.1	24.7
Estimated RPV	745.0	790.3	808.5	827.1	861.1	880.9	901.1	921.9	943.1	964.8	987.0	1,009.7
Estimated DM	36.0	36.8	37.9	39.0	39.6	28.8	23.6	24.4	25.1	25.8	26.6	27.4
Site-Wide ACI	0.952	0.953	0.953	0.953	0.954	0.967	0.974	0.974	0.973	0.973	0.973	0.973

Figure 1. Facilities and Infrastructure Investments



Sustainability

Fermilab is currently in conformance with meeting its FY 2010 TEAM goals as outlined in its December 18, 2009 annual update to the Executable Plan. Its Energy Savings Performance Contract (ESPC) through DOE is now in the implementation phase and should be completed this year. This work should reduce Buildings energy intensity by 6%.

Another ESPC initiative is anticipated in FY 2012 to help meet the TEAM goals by FY 2015, when the future of lab facilities should be better understood. Additional items requiring funding that are not under ESPC financing include additional AFV replacement vehicles for the lab's fleet, additional metering in buildings, additional upgrades to 15% of existing building to meet the sustainability requirements of the DOE Guiding Principles, and the annual purchase of Renewable Energy Credits.

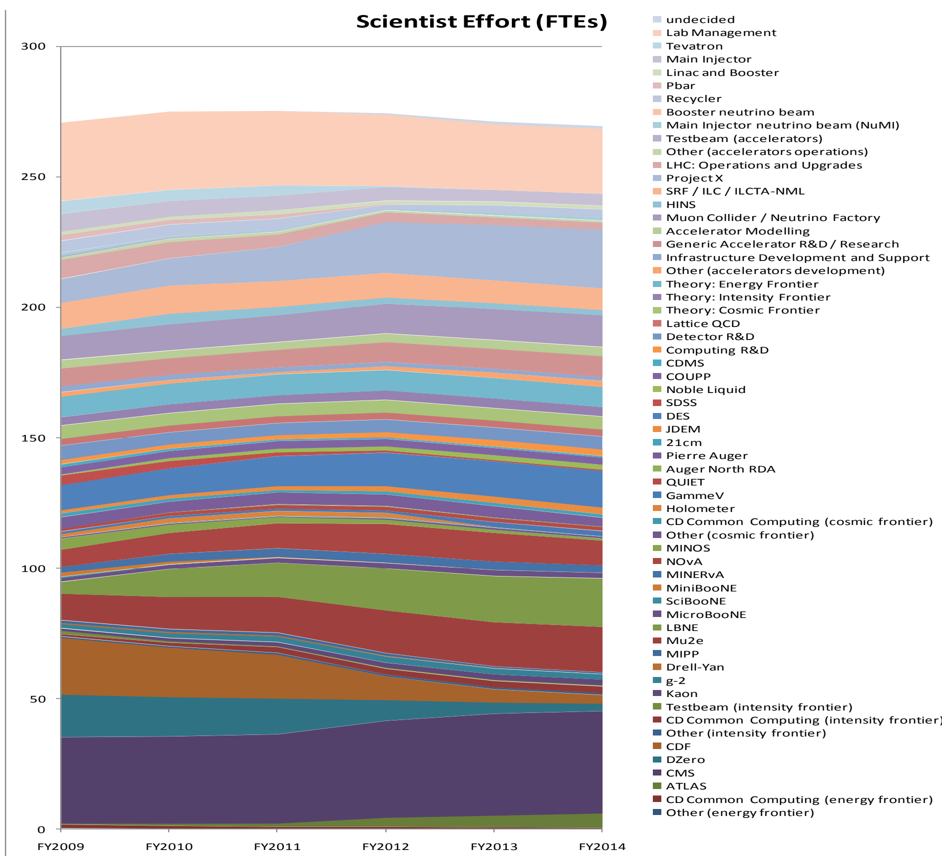
Table 5. Progress Against TEAM Goals

Requirement	DOE Corporate Goal	Status
Energy Reduction	30% from FY 2003 to 2015.	18% lower in FY 2009 than in FY 2003
Renewable Energy	At least 7.5% of annual electricity and thermal produced on-site by FY 2010	Renewable Energy Credits are purchased to meet the annual electricity and thermal requirements, which were 3% in FY 2009 and 7.5% in FY 2010.
Fleet	Maximize use of Alternative Fuel Vehicles	Use of biodiesel fuel this year, insuring that dual fual vehicles run primarily on alternative fuel, use of CNG infrastructure, replacing fleet with AFVs
Water Reduction	16% by FY 2015 relative to FY 2007 use	Exceeded the 16% goal of lower usage in FY 2009 than in FY 2007
Buildings	15% of existing space meets guiding principles by FY 2015 (baseline excludes buildings of 5,000 sf or less)	Assessing existing buildings to develop actionable recommendations to meet 15% goal by FY 2015
	All new construction LEED Gold certified	As applicable, any new construction will be LEED Gold certified

7. Laboratory Workforce Trends

Required skill mix may vary with time, in particular with ending the Tevatron operation and starting new projects. Fermilab has initiated a workforce planning process, Organizational and Human Resources Asset Plan (OHAP), in December 2006. This lab-wide annual OHAP process identifies current and future programs/projects, and skills needed to accomplish the laboratory's mission, studies available human resources and resource needs in the next ten years, analyses differences between available resources and resource needs, and applies this information to the new hiring process and the retrain and redirection plan of current staff. As we do not yet have the full go ahead to proceed with new projects, it is not entirely accurate to project our future workforce needs. Our key challenge is to provide the human capital resources needed to run the Tevatron until program termination but at the same time staff up the projects that will become the future of Fermilab.

The OHAP process currently identifies over 200 skills and over 50 programs and projects that are needed to accomplish the laboratory's mission. We create database that contains each employee's skill and the lead person for each program or project. For each program or project, the lead person provides resource needs (FTEs in each skill) for the next ten years and we combine this information. Construction facilities will involve staff at other national laboratories as well many industrial contractors which are identified but excluded in the process. Task forces are commissioned to do a gap analysis. With the FY09 OHAP process, we identified a few % needed increase in personnel in FY10 and FY11, in particular, engineering and project support before the conclusion of the Tevatron. We handle this with a mixture of contractors and a few new hires, and plan to maintain a constant level of human resources. On the scientific side we have recently (December 2009) conducted a survey of all of our scientists to determine how we will redeploy the talent to the new projects and the outcome of the survey is shown below. A slight increase in FY10 reflects a few new hires.



We will continue to assess our own talent and skill pool through the OHAP workforce planning process.

Table 6. Laboratory Workforce Trends

Total Number of Employees at your laboratory[1]:								1912
Total Number of Employees who compose the Science & Engineering Research and Technical Support Staff [2] *(those directing/conducting or supporting the research mission of the laboratory)*								1418
Laboratory Employees[3]								
Subject	**Male**	**Female**	**Caucasian**	**Asian American**	**African American**	**Hispanic**	**Native American**	**Other**
Chemistry/Chemical Sciences								
Physics/Astrophysics/ Astronomical Sciences	86.7%	13.3%	83.78%	9.80%	3.39%	2.96%	0.07%	
Computer Sciences								
Life Sciences (and related biological/ medical sciences)								
Earth Sciences (geological/ atmospheric research/ environmental)								
Other Science Fields								
Materials Science/Engineering								
Nuclear Engineering								
Other Engineering Fields								
Social Sciences (including Economics)								
Laboratory Workforce Changes								
Number of S&E Employees hired over last 5 fiscal years *(FY2004 – FY2009)*								248
Number of S&E Employees that have departed the Lab, but not retired, over last 5 fiscal years *(FY2004 – FY2009)*								191
Number of S&E Employees retirements over last 5 fiscal years *(FY2004 – FY2009)*								62
Average length of service in years for all S&E Employees for the last 5 fiscal years *(FY2004 – FY2009)*								14.0

1. *Please exclude guests, students, graduate students, postdoctoral researchers, and other short-term appointments. The term "laboratory employees"is often referred to by different names at different laboratories, including but not limited to "permanent," "career," or "term" employees.*
2. *Please include those individuals directing/conducting research. Technical support staff includes those individuals provide support to the S&E staff ofa technical nature, including, but not limited to, mechanical/electrical technicians, computer operators, and other support personnel . Administrative support and management are not included in S&E staff.*
3. *Please enter the percent of your S&E staff to the category that best matches their area of research/contribution to an interdisciplinary research area (i.e., a chemist in biofuels research should be listed under Chemistry). The sums of individual columns or individual rows need not be 100%*

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 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 Work Breakdown Structure 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 FY10 budget are discussed in "*Decisions and Trade-offs*" below.

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

Metrics.

Table 7 presents 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 7. Laboratory Overhead Trends (Cost Data in $M)

	FY 2007	FY 2008	FY 2009	FY 2010 Est.	FY 2011 Est.
1. Direct FTE Ratio					
Numerator: Direct FTE's[1], which represent time charged to client funded work[2], including capital but excluding LDRD	1,242.1	1,206.3	1,177.3	1,241.2	1,242.2
Supplemental Data: Indirect FTE's (all non direct FTE's, to include LDRD and organizational burden[3])	752.0	748.2	721.1	713.3	717.8
Denominator: Total FTE's (subtotal of direct and indirect FTE's)	1,994.1	1,954.4	1,898.4	1,954.5	1,960.0
Direct FTE Ratio (%): Direct FTE's/Total FTE's	62.3%	61.7%	62.0%	63.5%	63.4%
2a. Total Overhead/Total Lab Cost					
Numerator: Total overhead cost, which includes institutional overhead, LDRD and organizational burden[3] to the extent this overhead is allocated to client funded work.[2]	98.4	105.1	116.0	119.1	121.5
Denominator: Total lab cost includes all cost charged to client funded work[2] (operating and capital). Includes subcontracts and procurements[4] and line item construction costs.	337.2	340.5	376.5	436.7	443.8
Total Overhead/Total Lab Cost (%):	29.2%	30.9%	30.8%	27.3%	27.4%
2b. Total Overhead/Total Lab Operating Cost					
Numerator: Same as preceding metric.	98.4	105.1	116.0	119.1	121.5
Denominator: Same as preceding metric, but exclude line item construction costs.	337.2	340.5	376.5	436.7	443.8
Total Overhead/Total Lab Operating Cost (%):	29.2%	30.9%	30.8%	27.3%	27.4%
2c. Total Overhead/Total Internal Lab Operating Cost					
Numerator: Same as preceding metric.	98.4	105.1	116.0	119.1	121.5
Denominator: Same as preceding metric, but exclude subcontracts and procurements[4] charged to client funded work[2].	241.3	239.7	261.5	268.0	274.7
Total Overhead/Total Internal Lab Operating Cost (%)	40.8%	43.9%	44.4%	44.4%	44.2%
3. Fringe Rate					
Numerator: Total cost of employee benefits (including statutory benefits), not including paid absences.	48.0	48.5	50.3	52.8	53.9
Denominator: Total base salary cost.	148.2	149.2	154.7	159.9	163.1
Fringe Rate (%):	32.4%	32.5%	32.5%	33.0%	33.0%

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 2007, FY 2008, and FY 2009 data reflect actual costs. FY 2010 and FY 2011 estimates are adjusted for escalation.*

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.

<u>Electric Power</u> - The primary driver for the cost of electric power is the planned running time of the accelerator complex during the fiscal year. 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 has been consolidating 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.

Facilities Maintenance **-** The primary driver for the cost of Real Property maintenance is the age and resulting condition of the lab's utility systems including underground piping systems, high voltage electric switches, and unit substations. SLI funding expected in FY11, FY12, and FY13 will eliminate a large portion of the deferred maintenance on these systems, mitigate system vulnerabilities, and allow maintenance funding to better satisfy existing requirements.

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. Last year 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. The laboratory is working to understand the effects of the recently-passed health care reform legislation.

Decommissioning – The turn-off of the Tevatron, currently scheduled for the end of FY2011, 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 FY2010, the requests for additional funds totaled $20M against available reserve funding of $7M. Additional resources were allocated for indirect efforts associated with high-priority initiatives, including the Quality Assurance program and the completion of the Time and Labor system, both notable outcomes; and IT services improvements. Unfunded requests included network improvements, IT consolidation efforts, and certain lower-priority accelerator improvements, which were deferred to future year.