Department of Energy Laboratory Plans

FY 2007-FY 2011

March 1, 2006

DEPARTMENT OF ENERGY LABORATORY PLANS

DOE Business Plan for the Office of Science's Fermi National Accelerator Laboratory

Mission and Overview

Fermi National Accelerator Laboratory (FNAL), also known as Fermilab, is the largest U.S. laboratory dedicated to research in particle physics. The University Research Association built Fermilab in 1967 for the Department of Energy and continues to operate the lab today for DOE's Office of Science. Fermilab's mission goal in high energy physics focuses on understanding matter at its deepest level to identify its fundamental building blocks and understand how the laws of nature determine their interactions. Of the 18 fundamental subatomic particles that are known so far, three have been discovered at Fermilab: the bottom quark (1977), the top quark (1995) and the tau neutrino (2000). The original Fermilab Main Ring became the world's highest energy accelerator when it started operation in 1971. The Tevatron, commissioned in 1983, was the first large proton accelerator based on superconducting magnet technology. Since 1985 Tevatron has remained the highest energy proton accelerator in the world, where antiprotons and protons collide with energy of 2 Trillion electron Volts (TeV). Unique capabilities in high energy physics are available to the scientific community that include the Booster and Main Injector pre-accelerators, and the Neutrinos at the Main Injector which operate as part of the Tevatron complex but can be used independently. Fermilab provides leadership and resources for over 2,200 researchers to conduct basic research at the frontier of high energy physics and related disciplines.

Laboratory Focus and Vision

Fermilab has a central role in the field of particle physics, both in the U.S. and worldwide. Fermilab's present and future program relies on maintaining world-leading core competencies in:

1. Construction and operation of experimental facilities for particle physics and particle astrophysics
2. Research, design, and development of accelerator technology
3. High-performance scientific computing and networking
4. International scientific collaboration
5. Theoretical particle physics and particle astrophysics

Lab-at-a-Glance

Location: Batavia, IL

Type: Program Dedicated Lab

Contract Operator: University Research Associates (Consortium of 90 leading research-oriented universities)

Responsible Site Office: Fermi Site Office

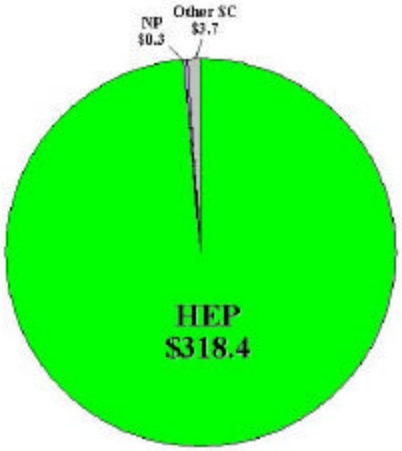
Website: http://www.fnal.gov

Physical Assets:
- 344 buildings
- 6,800 acres

Human Capital:
- 2,085 employees;
- 602 Students (Undergraduate and Graduate);
- 2,258 Facility Users and Visiting Scientists

FY 2005 Total DOE Funding: $322.7M

FY 2005 DOE Funding by Source
PALS data (BA in Millions):



FY 2005 Non-DOE Funding: $0.2M

The Office of Science believes that these five competencies will enable Fermilab to deliver its mission and customer focus, to perform a complementary role in the DOE laboratory system, and to pursue its vision for scientific excellence and pre-eminence in the following areas of particle physics:

- The quantum vacuum, including the Higgs field, supersymmetry, and dark energy;
- The particle zoo, the collection of 57 leptons, quarks and force carriers;
- Unification phenomena, whether all of the forces can be described with a unified theory;
- Origins of space and time, including extra dimensions and quantum gravity.

Business Lines

The following capabilities, aligned by business lines, distinguish Fermilab and provide a basis for effective teaming and partnering with other DOE laboratories, universities, and private sector partners in pursuit of the laboratory mission. These business lines and the distinguishing capabilities outlined in the table below provide an additional window into the mission focus and unique contributions and strengths of Fermilab and its role within the Office of Science laboratory complex. Items in italics within the column, Distinguishing Capabilities, identify research facilities that convey particular, strategic strengths and capabilities to the Lab. Descriptions of these facilities can be found at the website noted in the Lab-at-a-Glance section of this Plan.

Business Lines	Distinguishing Capabilities	Distinguishing Performance	Mission Relevance
Collider Physics	· **US-Large Hadron Collider (LHC);** · **US-Compact Muon Solenoid (CMS);** · *Tevatron, the Collider Detector at Fermilab (CDF) and Dzero.*	World leader with highest energy and highest luminosity proton-antiproton accelerator	Explore the fundamental interactions of energy, matter, time, and space
Neutrinos	· *Neutrinos at the Main Injector (NuMI) facility;* • *Main Injector Neutrino Oscillation Search (MINOS);* · *MiniBOONE.*	New experiments give Fermilab unique, world leading capabilities for neutrino research	Explore the fundamental interactions of energy, matter, time, and space
Particle Astrophysics	· **Sloan Digital Sky Survey;** · **Cryogenic Dark Matter Search;** · **Dark Energy Survey;** · **Joint Dark Energy Mission (JDEM);** · **Auger South.**	Fermilab plays a leadership role in many of the major experiments	Understand the cosmos
Quarks	· **B-physics at CDF;** · **Dzero;** · **US Lattice Quantum ChromoDynamics (LQCD) collaboration.**	Only source of B_s mesons needed to complete studies of CP violation of b quarks	Explore the fundamental interactions of energy, matter, time, and space
Accelerator R&D	· **LHC quadrupoles;** · **LARP;** · **ILC superconducting RF lead;** · **Photo-injector facility.**	Operation of the world's most powerful and highest peak luminosity proton-antiproton collider facility	Provide the resources that enable great science
Theory	· **Human capital;** · **High performance computing and networking.**	Calculating the consequences of QCD in high-energy collisions	Explore the fundamental interactions of energy, matter, time, and space

Major Activities

Following is a set of major activities that Fermilab would like to pursue to support aspects of the DOE mission and build on core strengths and capabilities of the laboratory. The Office of Science is examining all of these potential activities and they are at different stages of development. Some are currently underway and some are mere concepts at this time. For those that are still in the conceptual phase, Fermilab has indicated significant interest and is viewed to have current supporting research and mission focus to pursue such activities. Budgets, the Office of Science's strong commitment to a fair and competitive funding process and technical advice from its major scientific advisory committees will ultimately contribute to decisions about which activities can be pursued and at which sites. The companion documents, the DOE's Five Year Plans, provide greater insights into these activities in terms of various five-year budget scenarios.

The major activities are:

1. International Linear Collider
2. Evolution of Fermilab Neutrino Program, NuMI Upgrades
3. Foundation: the Ongoing Program

1. International Linear Collider

- **Summary:** The Linear Collider would allow physicists to make the world's most precise measurements of nature's most fundamental particles and forces by colliding individual fundamental particles rather than particles with a complex structure such as protons or anti-protons. The physics investigations envisioned at the ILC are both broad and fundamental, and will both require and support a leading-edge program of research for many years.
- **Expectations:** Physicists now know enough to predict that a linear collider, operating initially at energies up to 500 GeV, will be needed to understand how forces are related and the way mass is given to all particles.
- **Benefit Perspective:** Potentially *Transformational* Benefits
- **Risk Perspectives:**
  - Technical: *Moderate to High risk* – The technical challenges in the project are exemplified by the transverse beam sizes at collision (a few nanometers), by the requirement of providing very high electric field gradients to achieve the large energies, and by the exceptional control of the beams needed during the acceleration process.
  - Market/Competition: *Low/Moderate risk* as there would be only one such international facility but competition to host this facility could be significant.
  - Management/Financial: *High risk* due to large project costs, technical risk, and international project management issues.

The shared goal for the consortium of laboratories around the world working on the International Linear Collider (ILC) is to complete the design of a new electron-positron linear collider with energy in the range of 0.5-1.0 Tera electron volt (TeV). The near term goal for the worldwide ILC effort is to establish all technical components, costs, engineering designs, and management structures to enable a go/no-go decision to start construction. For Fermilab, the additional goals are to prepare for a bid to host the ILC on behalf of the U.S. and to be in a position to take leading roles in developing the detector and the research program. There are many scientific, technical, and economic challenges to this project that must be addressed before a decision to proceed.

To improve its position as a competitor for the ILC, Fermilab must establish world-class expertise in superconducting radio frequency (SCRF) technology. The buildings that would serve as the conventional

infrastructure for large SCRF facilities already exists, in the form of large experimental halls that are now not being used in the accelerator-based research program. However, Fermilab will needs to increase power and add cryogenic and radiofrequency infrastructure to these buildings. All of this will need to be done in collaboration with the Global Design Effort (GDE), the organization that coordinates ILC R&D worldwide. The R&D program needed to develop SCRF capability for the ILC would take place over the next few years. This includes a module assembly facility, module fabrication, a test facility, and operations of the test facility. Fermilab plans to develop, in parallel, the SCRF capability needed for a potential high intensity proton accelerator for the neutrino program should the ILC not proceed to construction.

For high energy physics, the energy frontier is the source of new discoveries, confirmations and surprises. The ILC is being designed to maximize scientific potential and minimize costs. If the ILC is built and Fermilab is chosen as the ILC site, it will assure the scientific productivity of the laboratory for many years.

2. Evolution of Fermilab Neutrino Program

- **Summary:** Maintain the leading position in neutrino physics through at least the middle of next decade with the Neutrinos at the Main Injector (NuMI) beam through a combination of efforts to increase beam intensity and add new detectors which are larger and more capable.
- **Expectations:** The neutrino activity would permit a comprehensive neutrino science program over a decade or more that would include the precision measurement of neutrino mass differences and oscillation parameters, plus very possibly the measurement of matter-antimatter asymmetries (CP violation) that could connect the neutrino sector to leptogenesis as a source of the matter-antimatter asymmetry of the universe.
- **Benefit Perspective:** Potentially *Transformational* Benefits
- **Risk Perspectives:**
  - Technical: *Moderate risk* - With a proton beam of 2 megawatts (MW), the level of power is similar to other high-intensity proton machines, such as the Spallation Neutron Source.
  - Market/Competition: *Moderate/High risk* - The Japanese are heavily invested in neutrino physics and will be the primary source of competition in this area. Collaboration will significantly reduce market risk.
  - Management/Financial: *Moderate to High risk* - With a Proton Driver, Fermilab would operate two high-power proton facilities: the driver itself (0.5-2 MW), and a 2-MW Main Injector. This would also entail a world-wide collaboration. The full-scale Proton Driver is also a ~billion-dollar-class project and could not proceed in parallel with an aggressive ILC schedule. This activity could be scaled according to availability of funding to mitigate these risks.

Fermilab has the only accelerator-produced neutrino beam operating in the world today, the Neutrinos at the Main Injector (NuMI) beam. It is also the most powerful neutrino beam that has ever operated, with 0.2 MW of proton beam power directed at the NuMI target. The Main Injector Neutrino Oscillation Search (MINOS) collaboration operates two detectors, one at a distance of 730 km in the Soudan mine - necessary to disentangle the effects of neutrino interactions with matter from the possible effects of CP violation. The sensitivity of an experiment is proportional to (beam power) x (detector mass) x (detector efficiency). Fermilab would like to increase the NuMI beam intensity through a series of steps to a total beam power of 0.6 MW on target by 2010 and to 1 MW or more by 2012 through either improving the present accelerator complex in two stages, or through building a Proton Driver based on SCRF technology if the ILC does not proceed to construction. The first path makes efficient use of the existing infrastructure, and will be chosen if that is seen as the final stage of proton accelerators for High Energy Physics before the ILC. The second path shares R&D with the ILC and provides a suitable platform for further evolution of the proton accelerator complex.

The first step in building better neutrino detectors is NOvA, a proposed detector that would be built in northern Minnesota at a location that can use the NuMI neutrino beam. The NOvA detector is much larger than MINOS and is optimized for clean and efficient identification of electron-neutrino scatters, since the oscillation of muon neutrinos into electron neutrinos has not yet been observed. For the next step, Fermilab is starting a long-term R&D program to develop a liquid argon detector that could be scaled up to the size needed for neutrino experiments. A liquid argon detector could be built adjacent to NOvA to extend the scientific reach of the neutrino program.

Neutrinos permeate the universe and hardly interact with matter. The recent discovery of neutrino mass has important consequences both for particle astrophysics and for unification. The Fermilab activity would maintain U.S. and Fermilab leadership in this important area of research.

3. Foundation: The Ongoing Program

- **Summary:** Enhance long term laboratory success by delivering scientific opportunities that are possible in the current Fermilab program. The laboratory's goal is to achieve the greatest sensitivity possible to discoveries of new physics, and to do so as quickly as possible.
- **Expectations:** Possible discoveries include the Higgs boson or any new physics (beyond the present theory) at the 1 TeV mass scale. These discoveries would also include supersymmetry, either through seeing supersymmetric particles or one of the five Higgs bosons that exist in supersymmetric models; extra dimensions; new dynamics (technicolor, new gauge bosons), and quark or lepton compositeness.
- **Benefit Perspective:** Potentially *Transformational* Benefits
- **Risk Perspectives:**
  - Technical: *Moderate risk* -It is critical to the scientific success of the program and to the future of the laboratory, that Fermilab deliver as much luminosity as possible to the detectors every year.
  - Market/Competition: *High risk* - the LHC, at CERN in Geneva, Switzerland, will overtake Fermilab ~2009.
  - Management/Financial: *Moderate to High risk* - Fermilab's capability in pursuing physics in Run II depends on the funding available to carry it out.

The Tevatron currently provides the only window into supersymmetry, Higgs physics and quark physics with the B_s meson until the LHC turns on. The key to the success of this program is delivering integrated luminosity to the detectors. The laboratory is in the middle of a campaign to build and install luminosity upgrades and reliability improvements. The two large detectors also must operate reliably. This requires support not only from the laboratory but also from the international collaborations, which have to remain strong.

The LHC program is the largest particle physics program for the U.S. in the next 10 years. Fermilab should maintain forefront capability in detectors, accelerators, theory, and computation such that, in any area, scientists can do LHC research at Fermilab as productively as at CERN. In addition, Fermilab must manage the transition from the DZero and CDF collaborations to the CMS and ATLAS collaborations in a way that keeps excellent physics coming from the Tevatron program through 2009. These actions should position Fermilab to contribute to the development of the proposed accelerator and detector upgrades for increasing LHC luminosity in the next decade.

In astroparticle physics, Fermilab must complete the extended operation of the Sloan Digital Sky Survey and with it make possible new discoveries. Fermilab needs to complete the Cryogenic Dark Matter Search program in the Soudan mine and contribute to the design for the Super-CDMS facility. Fermilab would like to build the Dark Energy Survey, both for the science it produces and as a basis for larger projects in the future, including the Joint

Dark Energy Mission. Finally Fermilab needs to complete construction of the Auger South observatory, operate it well, and find out what it tells us about the source of the highest energy cosmic rays.

These efforts seek to maximize the return on investment in Fermilab while providing a role for the laboratory in some of the most important experiments internationally. This is critical to maintaining the high caliber staff and visiting scientists that will be critical to future endeavors.

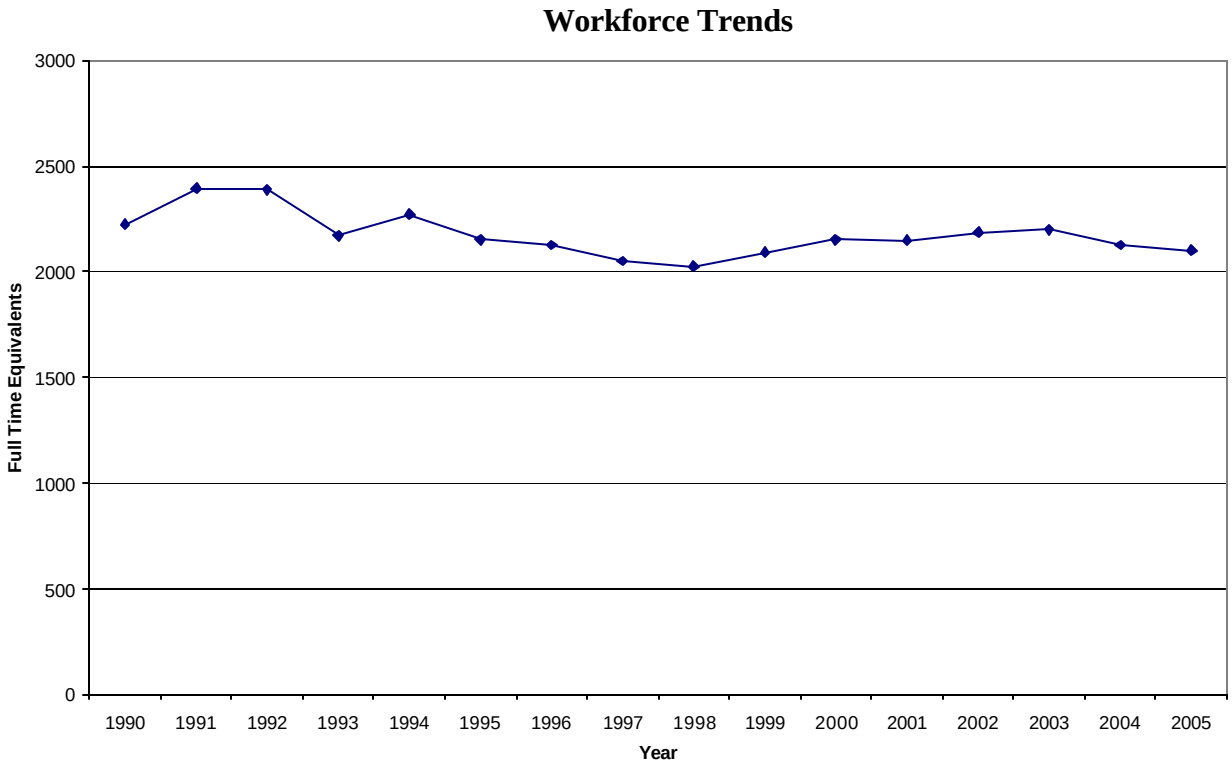
Financial Outlook

Detailed information regarding the financial outlook for the Fermi National Accelerator Laboratory is subject to 1) competition and merit review, 2) the availability of appropriated funds and 3) programmatic decisions. The first two factors can not be predicted or estimated in advance. The third, programmatic decisions, are developed in accordance with the planning targets reflected in the Department of Energy programmatic Five Year Plans, a companion document to these strategic laboratory business plans. In addition, because of the Office of Science commitment to competition and merit review, there is often a time lag between programmatic decisions and the determination of which research provider can best deliver the greatest value in conducting the research. Thus, it is not always apparent how programmatic decisions unfold for particular laboratories. Nevertheless, some decisions, such as the plans for large scientific user facilities, show clear paths to individual labs and therefore inform their business plans.

Uncertainties and Risk Management

External Factors: The U.S. could be poised to recapture the energy frontier through the development of ILC, with a strong role at the Large Hadron Collider (LHC) in the interim. The U.S. is also poised to have the world-leading neutrino program at accelerators in the near term. However, there are major risks to this future scenario that are scientific, technical, management and financial. Possible delays in starting construction on the ILC, and funding uncertainty can halt the development of the rest of the program. One complication of this is the impact on foreign institutions and funding agencies that have made large investments to the current program. These international partners are needed to build the ILC. Fermilab has had a history of excellent relations with the surrounding communities. However, if the ILC is to be built near Fermilab it will be outside the boundary of the present FNAL site. As a result, a FNAL Community Task Force was formed, including 20 members from local government, business, civic organizations, schools, and neighborhood associations. The committee made recommendations for local community participation in planning and decision-making at Fermilab. This represents a critical first step toward involving the community in having the ILC at Fermilab.

S&T Workforce: Fermilab already has the requisite human resources in all of the core competencies needed to carry out the activities described above with the exception of the experts on SCRF technology. Because of the scale and complexity of the needed R&D program, the laboratory will have to add scientists and engineers to its staff in this area.



Employee Diversity: The Laboratory works to attract a diverse workforce, although this is more difficult in an era of downsizing the staff size. Fermilab maintains a presence at diversity job fairs and national conferences, such as the National Society of Black Engineers, the Sorority of Hispanic Professional Engineers, the Joint Meeting of Black and Hispanic Physicists, and the Society of Women Engineers. Fermilab also conducts educational programs designed to reach populations underrepresented in science and engineering.

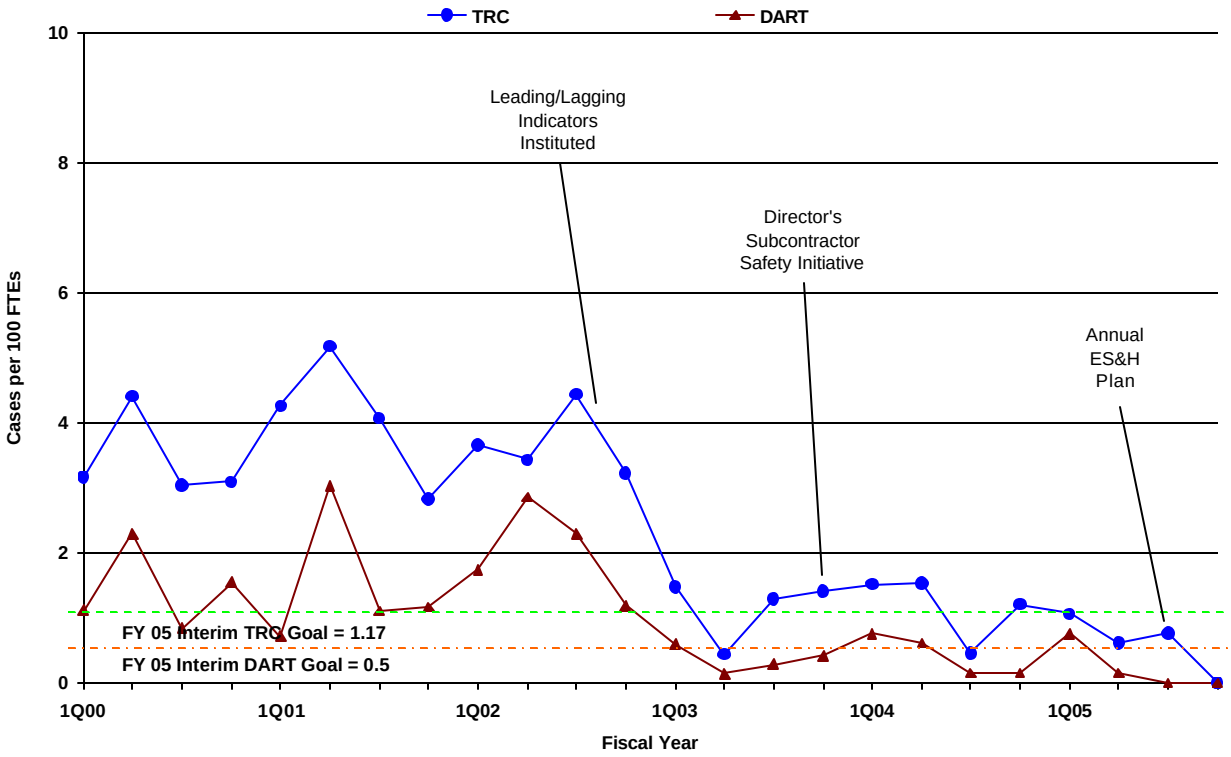
Fermilab has the following goals to improve diversity:

- Recruit underrepresented minorities for Research Associates. This group serves as the feeder for Scientific positions. The Laboratory will partner with University Research Association, Inc. (URA) member institutions for increased recruitment efforts on the undergraduate and graduate levels.
- In FY06, increase the number of Masters trained underrepresented minority professionals in Electrical/Mechanical engineering and computer science. The Laboratory will increase its support of the GEM program. Our recent history with this program is that we realize an acceptable ROI in attracting these interns as professional hires.
- In FY06, move to become a partner in the DOE Office of Science Faculty and Student Teams Program (FaST) which targets colleges and universities serving women and minorities underrepresented in the fields of science and technology.
- In FY06, establish the FNAL Diversity Council for which a proposal has been written. Its mission is to focus on the functional areas detailed in DOE guidelines for a Strategic Plan for Diversity.

Safety: Fermilab has an ambitious and effective program to continuously improve safety in the workplace. As figure 9 shows, the major benchmark accident rates have been reduced by a factor of about eight over the last eight years.

Fermilab recently published an Annual ES&H Plan stating their ES&H Vision & Strategy for improvement in CY05. *"As a result of our deep and unwavering commitment to the safety of all who work here, Fermilab will be recognized internationally and within the ranks of the U.S. national laboratories as 'best in class' in environment, safety & health. We want Fermilab to be 'First in Science & Safety.'"* As the first step in this process, the Laboratory Director wrote to all division and section heads asking them to assess the hazards in their organization and to submit a plan to reduce accidents in 2005. The laboratory management and staff have embraced Integrated Safety Management and have worked hard to bring the accident rates down. It is a greater challenge to integrate contractors into the safety culture we maintain. Fermilab has made progress on this issue by giving it special attention, including a Director's advisory committee on subcontractor safety.

DART and TRC Rates and Major Safety Initiatives



Physical Infrastructure: Fermi is located on a 6,800 acre Federal reservation approximately 45 miles west of Chicago, Illinois. Established in late 1967, it has 2.3M sf of space in 351 buildings. Sixty-three percent of its space as well as most of its utility systems and roads are over 30 years old. Fermi's AUI is 1 (excellent).

Maintenance, recapitalization, and modernization are supported with overhead, operating, and GPP funds and with line item funding. Fermi will attain a maintenance investment level of 2.2% of replacement plant value (excellent) in FY 2006 which will be continued in FY 2007 and the outyears. Fermi's deferred maintenance backlog is $44.6M resulting in an ACI of .925 (adequate). A deferred maintenance reduction initiative was initiated in FY 2006 and will continue in FY 2007 with funding of $1.98M.

The FY 2007 GPP funding request is for $8.2M. Fermi's future recapitalization and modernization challenge is to upgrade its aging utility systems. In addition to capital investments, DOE is considering granting a burdened, public-utility easement to the City of Batavia for its power transmission needs that may allow replacement of a portion of Fermi's high voltage electrical distribution system. Also, the purchase of domestic water from the City of Warrenville will eliminate the need to operate and maintain Fermi's on-site water wells.