Fermilab Draft Institutional Plan ’04-‘08

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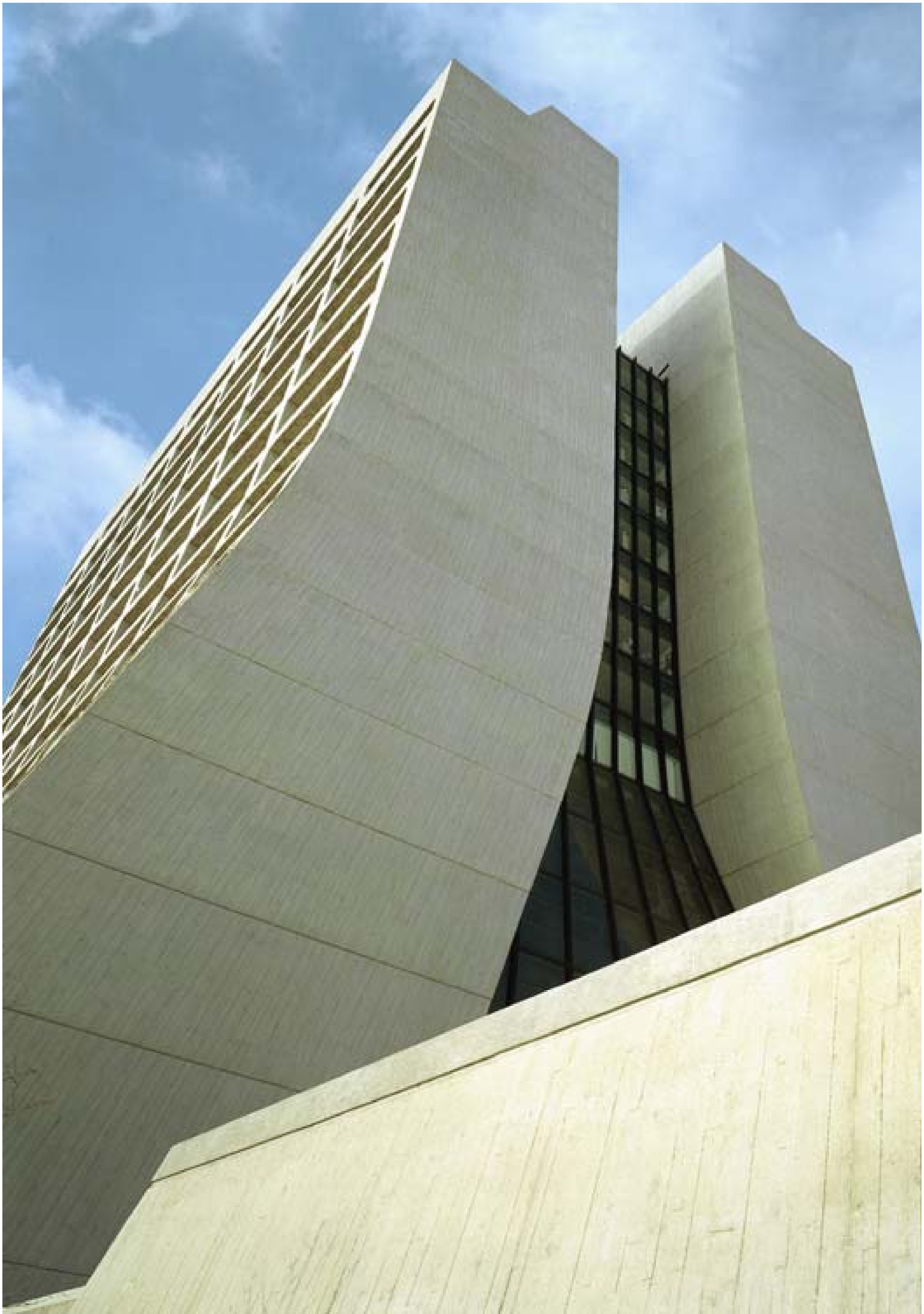

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From the Director:

Fermilab's Compelling Vision

Fermilab's vision of its future is to remain the world leader in particle physics and to advance our understanding of matter, energy, space, and time. The Laboratory develops, builds, and operates the accelerators and instruments needed for research at the forefront of this science. It works with the national and international particle physics community to plan the future of particle physics and to determine which facilities need to be developed to create opportunities for discovery in the future.

Fermilab is adopting the following strategic goals to realize this vision:

- ***Collider Run II of the Tevatron:*** *The goal is to search with unprecedented sensitivity for evidence of new forms of matter or new physical phenomena.*

Fermilab's Tevatron is the world's highest-energy particle accelerator and collider. By observing collisions of protons and antiprotons in the Tevatron, physicists explore the most basic constitutents of matter and the forces acting on them. This provides a unique opportunity to discover new phenomena predicted by theoretical physicists that could lie just beyond the reach of previous experiments – supersymmetric particles, hidden dimensions, and the Higgs boson. Approximately 1,400 scientists from around the world will conduct a wide range of experiments using data from the Tevatron, including precise measurements of the properies of the heaviest particle yet observed, the top quark.

- ***Neutrinos:*** *The goal is to advance our understanding of the nature of neutrinos.*

Neutrino physics is going through a revolution. New experimental data, which show that neutrinos have mass, are forcing theorists to revise the Standard Model of particle physics and to change ideas about the origin of the cosmic baryon asymmetry. The neutrino program at U.S. accelerators consists of two

Fermilab experiments, MiniBooNE and MINOS. The MiniBooNE experiment will either confirm or refute the controversial results of a Los Alamos experiment indicating the existence of a fourth, exotic neutrino. The MINOS experiment will measure neutrino properties needed to understand the underlying physics. It will start operating in 2005, using a beam of neutrinos generated from Fermilab's Main Injector accelerator, sent through the earth beneath Illinois, Wisconsin and Minnesota, and detected in the Soudan Underground Laboratory in northeastern Minnesota. A newly built 5,000-ton neutrino detector will be used to observe neutrinos beamed from Fermilab. Physicists are also exploring novel opportunities for future experiments, making additional discoveries, using the Fermilab neutrino beams.

- ***Large Hadron Collider:*** *The goal is to discover new fundamental physics using the Large Hadron Collider, which is being built at CERN, the European Particle Physics Laboratory in Geneva, Switzerland.*

The LHC will operate at an energy so much higher than existing facilities that dramatic discoveries are certain to occur in the first few years of observation. Two U.S. science agencies, the DOE and the NSF, have made great investments in the LHC program to enable U.S. physicists to take advantage of this historic opportunity in science. Fermilab leads a three-laboratory collaboration building accelerator components for the LHC. In addition, Fermilab is the host laboratory for the 400 U.S. physicists who will do their research using the Compact Muon Solenoid (CMS) detector, one of two large detector facilities designed to explore the higher energy scale accessible at the LHC.

- ***Global Linear Collider:*** *The shared goal for the consortium of laboratories around the world working on this project is to complete the design of a new electron-positron linear collider with energy in the range of 0.5-1.0 Teraelectron volt (TeV).*

The High-Energy Physics Advisory Panel, which advises the DOE and the NSF on the most important research directions for the field, has recommended that a high-energy, high-luminosity, linear particle accelerator should be designed, built and operated as a collaboration of laboratories from around the world. The panel also has recommended that the U.S. should prepare a bid to host the initiative. Steering committees in the U.S., Europe and Asia are currently working on a common strategy for building a 30-km (18-mile) machine designed to follow up on the discoveries at the Tevatron and the LHC. Fermilab is working as part of the global collaboration to carry out this work and is also exploring possible sites for the facility in northern Illinois.

- ***The Search for Dark Matter:*** *The goal is to take the world lead in determining the nature of dark matter in the universe, a primary scientific goal at the convergence of high-energy physics and cosmology.*

Fermilab is uniquely able to address the dark matter question from three directions: direct detection of dark matter particles interacting with nuclei, through the Cryogenic Dark Matter Search (CDMS); observing the production of dark matter particles at the Tevatron; and exploring the effect of dark matter on the large-scale structure of the universe with the Sloan Digital Sky Survey. The supersymmetric particles being pursued at the Tevatron have just the right characteristics to be the consituents of the dark matter believed to be responsible for the large-scale structure of the universe. CDMS would be able to measure the direct interaction of such supersymmetric particles with germanium nuclei. The CDMS experiment, housed in the same Minnesota mine that holds the MINOS experiment, operates some of the world's most sensitive particle detectors at temperatures just a few thousandths of a degree above absolute zero.

- ***Quark Physics:*** *The goal is to build the world's leading program in quark physics.*

Existing experiments have made great progress in understanding the physics of quarks, and in particular, the violation of particle and antiparticle symmetry (CP violation). BTeV is designed to look for evidence of new physics phenomena that would show up in CP violating decays of particles containing the bottom quark. With adequate funding, BTeV will be ready for first operation in 2009.

Fermilab will continue to advance accelerator technologies as a natural outgrowth of its work at the forefront of high-energy physics research. The impact of accelerators is steadily growing in medicine, materials research, structural biology, and nuclear physics, in addition to particle physics. Fermilab and other particle physics laboratories develop new accelerator technologies and techniques that are then transferred to other applications. We also train accelerator scientists, many of whom take their expertise into fields across the scientific enterprise.

Fermilab will also continue its record of improving science and math education for students throughout the U.S. Each year, thousands of students and teachers visit Fermilab's site for workshops, field trips and classes. Fermilab will continue as host for the very successful Quarknet program, supported by the DOE and the NSF, which connects teachers and students with the world of physics research.

Michael S. Witherell

Director,
Fermi National Accelerator Laboratory

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Mission and Roles

I. Mission Statement

As has been the case from its founding in 1967, Fermilab's mission is to advance the understanding of the fundamental nature of matter and energy, by providing leadership and resources for qualified researchers to conduct research at the frontiers of high-energy physics and related disciplines.

II. Core competencies

Fermilab leads the nation in the construction and operation of large facilities for particle physics research, and in developing the underlying technology for high-energy physics research. The Lab's mission is built on a foundation of eight core competencies:

1. Operation of the world's highest-energy user facility—the Tevatron collider—for university scientists investigating the fundamental structure of matter and energy;
2. Accelerator research, design and development of the frontier machines that are necessary to keep the U.S. among the world leaders in high energy physics;
3. Magnet research, design and development with particular emphasis and expertise extending to leading-edge technology in both superconducting magnets and permanent magnets;
4. Detector design and development for the tracking and recording of trillions of high energy particle collisions;
5. High performance computing and networking to support high-energy physics in on-line data taking, storage, analysis and world-wide data sharing and physics collaboration (the World Wide Web was born from this last requirement by physicists);
6. International scientific collaboration, both at Fermilab and as a contributor to foreign laboratories such as CERN, in particular in assisting in the construction of the Large Hadron Collider and the Compact Muon Solenoid;
7. Construction and management of large scientific and technical projects, including the seven-year, $260 million Main Injector accelerator, completed on time and on budget, and dedicated in 1999;
8. Scientific education of graduate students, and additional science education programs for undergraduates and for K-12 students, with major support from non-DOE sources.

III. Major User facilities

Fermilab, the world's highest-energy particle physics facility, welcomes more than 2,500 users (defined as "qualified researchers") from 214 institutions in 35 states and 29 foreign countries. These users have access to the world's best tools for particle physics research:

- The four-mile-circumference Tevatron, the world's most powerful particle accelerator, creates high energy proton-antiproton collisions. The third generation of quarks was discovered at the Tevatron: the bottom quark in 1977 and the top quark in 1995. The Tevatron is supplemented by the Antiproton Source, the world's largest producer of antimatter, whish is used for proton-antiproton collisions and for research on antimatter; and by the Antiproton Recycler, the world's largest assembly of permanent magnet technology, which also increases the number of possible collisions in the Tevatron.

- The Booster, the first synchrotron in the accelerator chain at Fermilab, is 475 meters in circumference and accelerates protons from 400 MeV to 8 GeV in a period of 0.033 seconds. The Booster provides beam for the MiniBooNE experiment.

- The Main Injector, another powerful and efficient accelerator, can supply experiments on its own, as well as dramatically increase the number of collisions possible in the Tevatron. The two-mile-circumference Main Injector will supply beam for the NuMI (Neutrinos at the Main Injector) experiment.

- Two 5,000-ton collider detectors, CDF and D Zero, each serving an international collaboration of more than 500 university physicists.

- Fixed-target experiments, including the MINOS (Main Injector Neutrino Oscillation Search) and MiniBooNE experiments resolving the question of neutrino mass.

- The CMS (Compact Muon Solenoid) experiment at CERN, for which Fermilab serves as host for the U.S. component (US CMS) and as home for the US CMS research program involving nearly 400 scientists.

- The Lattice Gauge Theory Computing Facility, where approximately 60 user theorists work with the theory of quantum chromodynamics with teraflop computing power.

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Major Program Initiatives

I. CP Violation in the B system: A dedicated program on the physics of the bottom quark at the Tevatron

BTeV (B-physics at the Tevatron) is listed as Priority 12 in the Secretary of Energy's 20-Year Science Facility Plan for the Office of Science, a roadmap for future scientific facilities to support the department's basic science and research missions. The 20-year plan, announced by Secretary Spencer Abraham on November 10, 2003 acknowledges the singificance of BTeV in this way:

> ***"Understanding why and how the universe became asymmetrical is one of the most oustanding, fundamental questions in the study of elementary particle physics today, and has profound implications for understanding how the whole universe evolved from its simple initial state to the complex patterns we see today."***

In its final report to the High-Energy Physics Advisory Panel (HEPAP), posted on October 8, 2003, the Particle Physics Project Prioritization Panel (P5) stated:

> ***"P5 supports the construction of BTeV as an important project in the world-wide quark flavor physics area. Subject to constraints within the HEP budget, we strongly recommend an earlier BTeV construction profile, and enhanced CZero optics."***

The Experiment to Measure Mixing, CP Violation and Rare Decays in Charm and Beauty Particle Decays at the Fermilab Collider (BTeV) is the ideal next-generation experiment on CP violation in the quark sector. With an innovative pixel-based trigger and precise electromagnetic calorimetry, BTeV will undertake a sensitive search for new physics by comparing CP asymmetries. BTeV will compile much larger samples in the critical B_d modes than the best current experiments, and larger samples than all experiments in the B_s modes.

With the addition of the Main Injector, the Tevatron will produce more than 400 billion b-flavored hadrons per year and 10 times as many c-flavored hadrons per year. These heavy flavored hadrons will be an excellent resource for investigating CP violation, quark/anti-quark mixing and rare decays. BTeV is well positioned to answer the most crucial questions in heavy flavor physics.

On February 5, 1999, after more than a year of painstaking analysis of data collected from particle collisions at the Tevatron, CDF scientists cautiously reported finding “tantalizing,” but not “ironclad,” evidence of CP violation in B mesons (quark-antiquark pairs involving the b or bottom quark)—the first observation outside the neutral kaon system.

Fermilab has been the historic leader in this area of physics since its 1977 discovery of the b quark. With BTeV, the lab has initiated an ambitious experimental program to extend the study of CP violation in the B system, using B and B_s mesons in a new detector at the CZero intersection region of the Tevatron Collider. The BTeV experiment has the potential to make the measurements that will not be completed by the programs currently underway. BTeV can be the definitive experiment that finally clarifies the picture of CP violation.

BTeV will be a central part of an excellent Fermilab physics program in the era of the LHC. The experiment’s main goals are:

- tests of the Standard Model and searches for new physics through the precise measurement of CP asymmetries with B and B_s decay modes that have minimal theoretical uncertainty;
- measurement of rare B and B_s decays to search for effects of new physics;
- measurement of a broad range of B_s decays that become accessible with the particle identification and photon measurement capabilities of the BTeV detector.

We know much more about B_d meson decays than about the B_s meson, largely because of a long program of high-statistics B_d measurements, at the $\Upsilon(4S)$ and the Z resonances, at CESR, SLAC, KEK and CERN.

The origin of CP violation is one of the fundamental questions in high-energy physics. A tremendous effort to measure precisely the basic parameters of CP violation is underway at the e^+e B-factory experiments (BaBar, Belle, and CLEO) and at hadron experiments (CDF and DZero). There should be results over the next five years. But these experiments won’t produce a complete and comprehensive set of measurements in the B_d and B_s systems. New experiments will be needed at the end of this decade to provide crucial pieces of information.

The BTeV experiment will exploit the enormous proton-antiproton cross section (100 μb) at the Tevatron, which yields $2x10^{11}$ proton-antiproton events per year. The existing Tevatron experiments, CDF and D0, have significant capabilities for B physics, notably from silicon microstrip detectors and new, detached vertex triggers. But the BTeV detector is optimized for B physics rather than for the study of high-P_t events. It has sophisticated particle ID and photon-detection capabilities, as well as a pixel-based vertex detector/trigger system with pixels extending down to 6 mm from the beam axis. It is designed to record 1 kHz of b-b_{bar} events and 1 kHz of c-c_{bar} events, with a 4 kHz total event rate.

BTeV's capabilities should give it a significantly greater B physics reach than either CDF or DZero. To reduce costs, the detector is being built with one arm instead of two. Improvements in the detector, including an improved understanding of RICH detector’s importance to muon and electron identification, will maintain a high level of physics sensitivities,

While the experiments at the e^+e^- B factories have some advantages for B_d studies, including very clean and kinematically constrained events, B_s mesons are not produced at the $\Upsilon(4S)$, and any B_s physics program at such experiments would be quite limited. In addition, the large rate of B_d production at the Tevatron, together with the capabilities of the BTeV detector, should allow it to perform measurements of B_d decays that are completely inaccessible or very difficult at the B factories.

In conclusion, Fermilab’s ability to record all b states provides the broadest possible scope as well as significant advantages over other experiments. BTeV will make critical contributions to our knowledge of CP violation, and will move from initial observations to a point of determining whether the Standard Model description is complete. BTeV, however, is not limited to Standard Model physics. It can reveal or help explain new phenomena. BTeV is a critical element in a high-precision flavor program to complement and interpret any new physics discoveries at the Tevatron or the Large Hadron Collider.

II: The Linear Collider: The next global outpost

The Linear Collider is listed as the highest mid-term priority item in the Secretary of Energy's 20-Year Science Facility Plan for the Office of Science. The 20-year plan, announced by Secretary Spencer Abraham on November 10, 2003 acknowledges the singificance of the Linear Collider in this way:

> ***"High-energy physics has always been a frontier discipline in science, driving technological innovation (the World Wide Web was created to share data from accelerator experiments, as an example) and pushing the llimits of what we know in the disparate but interconnected worlds of cosmology and elementary particles. The Linear Collider could be considered the high-tech equivalent of a frontier outpost at the edge of a new world."***

In keeping with the January 2002 recommendations of the DOE/NSF High-Energy Physics Advisory Panel, Subpanel on Long Range Planning For U.S. High-Energy Physics, Fermilab set a priority of becoming a credible host and construction partner for a linear collider.

A world-wide consensus has formed for a baseline Linear Collider project in which *positrons* (e^+) collide with *electrons* (e^-) at energies of 500 GeV, with *luminosity* (the measure of the collision rate) above 10^{34} $cm^{-2}s^{-1}$. The energy should be upgradable to about 1 TeV. Above this firm baseline, future directions and priorities will depend upon the nature of the discoveries made at the Large Hadron Collider, and in the initial Linear Collider operation.

In a June 12, 2001 presentation to the DOE/NSF HEPAP subpanel, Fermilab Director Michael Witherell stated: "We propose to the U.S. and to the international HEP community that we work together to build a linear collider at or near the Fermilab site."

The directors of the U.S. laboratories have publicly stated their support for consrtruction of a linear collider as an international endeavor based on optimum technology. This view is shared by HEPAP and by the corresponding European and Asian advisory panels.

The U.S. is in a unique position as the only region where the technology choice for a linear collider does not appear to be locked in. Furthermore, Fermilab is in a unique position as the only institution having participated in both the NLC and TESLA collaborations.

The lab's strategy is two-fold: 1) develop sufficient familiarity with both x-band and superconducting RF technologies to allow informed participation in the decision on linear collider technology; 2) position Fermilab to play a leading role in the any international collaboration formed to construct a linear collider, whatever the technology chosen.

The key scientific points establishing the case for the LC are:

1. Physicists now know enough to predict with very high confidence that the linear collider, operating at energies up to 500 GeV, will be needed to understand how forces are related and the way mass is given to all particles.

2. Physicists are confident that new physics beyond the standard model will be illuminated by measurements at both the LHC and the LC, through an interplay of results from the two accelerators.

3. The physics investigations envisioned at the LC are both broad and fundamental, and will both require and support a leading-edge program of research for many years.

The scientific case for the linear collider rests solidly on recent achievements at accelerator laboratories and other experiments around the world. We are confident that new discoveries will emerge within the energy range covered by the first stage of the linear collider operation. This conclusion is supported by studies in all regions of the world. To maximize the understanding of new interactions and particles at high energies, the LC and the LHC should operate concurrently. The results from the first phases of the LHC and LC will surely demand that higher $e^+ e^-$ collision energies will be needed in the future.

The proton-antiproton Tevatron Collider now operating at Fermilab can discover some of the lower mass states involved in electroweak symmetry breaking. The LHC now under construction at CERN will obtain its first collisions later this decade. The LHC, colliding protons with protons at 14 TeV, could discover a standard model Higgs boson over the full potential mass range, and should be sensitive to new physics into the TeV range. The program for the Linear Collider will be set in the context of the discoveries made at the LHC.

Research and development on the linear collider has been conducted continuously for over a decade, leading to very well-understood proposals. The linear collider complex will contain two accelerators, one for electrons and one for positrons, bringing beams into head-on collisions at the location of a large particle detector. To achieve the necessary collision energy, the overall complex will need to be about 30 km long. The 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.

The baseline collision energy dictated by the physics program should be 500 GeV, with the capability to lower the energy to about 90 GeV for some measurements and calibrations. Several physics studies demand that the energy be adjustable so as to scan across particle production thresholds. The machine luminosity dictates the collision rate; to meet the physics goals it should be more than 10^{34} $cm^{-2}s^{-1}$ at 500 GeV. The ability to distinguish many interesting processes from each other, and from backgrounds due to known reactions, is enhanced by providing electrons whose spins are aligned along their direction in a *polarized beam*. The baseline electron beam polarization should be 80% or greater. This should be achievable.

The technical designs of the linear collider have proceeded on two broad fronts. Each technology is mature enough to offer a viable basis for building a reliable accelerator. It is almost certain that the new discoveries made during the initial operation at 500 GeV will lead to the need for subsequent measurements at higher energy, so the ability to upgrade the energy to around 1000 GeV is essential.

Two basic technologies exist that could be chosen for building a linear collider: the TESLA design pioneered at DESY in Hamburg Germany; and the JLC/NLC design that emerged from a joint R&D program between SLAC and KEK. The main difference between the two technologies lies in the frequency of the electric fields used for acceleration. The lower frequency TESLA design employs superconducting radio frequency cavities, while the higher frequency JLC and NLC designs use room temperature accelerating structures. The Technical Review Committee formed by the International Committee on Future Accelerators (ICFA) in 2001 has judged both technologies to be viable, and the costs should be comparable. The choices of technology and site will be addressed in the near future. Meanwhile R&D continues on methods to use a low-energy high-intensity electron beam as the accelerating power source that may allow an even higher energy collider in the future.

The new information gained from the initial LC operation in its baseline configuration, and the results from the LHC and current accelerators, will influence the need for an extended capability of the LC facility. Several options for alternate beam particles and positron beam polarization capabilities could be beneficial for exploring new discoveries made in the early phase of LC operation. The necessary R&D effort and the flexibility to add these should be retained. The physics goals of the LC dictate that new state-of-the-art detectors be built. A vigorous international detector R&D program in the next few years is a high priority.

There is active inter-regional cooperation on linear collider accelerator systems, physics studies and detector development. An International Linear Collider Steering Committee to coordinate scientific, technical and governmental aspects of the project has been formed. The mechanisms developed for managing the international LC project could serve as a template for future world collaboration projects.

In 2001, the NLC Collaboration began to concentrate on a proof of principle demonstration of the fundamental components needed for the rf circuit for the main linacs. Fermilab is making the rf structures for this test. Fermilab is leading the R&D on the girders which support the rf structures for the main linacs. Fermilab provides expertise in civil engineering and beam physics. Fermilab is one of the US centers for university-driven linear collider R&D on accelerators, and conducts R&D on adjustable permanent magnets which can be used throughout a linear collider complex.

III. Proton Driver: Source for the Super Neutrino Beam

A Super Neutrino Beam is listed as Priority 21 in the Secretary of Energy's 20-Year Science Facility Plan for the Office of Science. The 20-year plan, announced by Secretary Spencer Abraham on November 10, 2003 acknowledges the singificance of the Neutrino Super Beam this way:

> ***"The Super Neutrino Beam will be poweredby a new, megawatt class "proton driver" which will be able to provide an intense, well-controlled neutrino beam—with 10 times more neutrinos per second than are available from any existing facility—to detectors hundreds or thousands of miles distant…The 2002 Nobel Prize in physics was shared by two scientists—one American and one Japanese—for their path-breaking measurements of solar and atmospheric neutrinos.Their research strongly suggested that neutrinos have mass and oscillate among three types as they travel through space. These oscillations have recently been confirmed, andthe properties and behavior of neutrinos are now ripe for measurement. The results will have profound implications for our understanding of the fundamental properties of matter and the evolution of the early universe."***

With the prospect of a Proton Driver to produce intense neutrino beams, the High Energy Physics Advisory Panel Facilities subcommittee has stated:

> ***"Coupled with a long baseline and a large detector …the neutrino super beam 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 baryon asymmetry of the universe."***

Through the NuMI (Neutrinos at the Main Injector) Project, Fermilab will soon have the long baseline neutrino beam needed to start this program. In addition, concepts are being developed for this new, very high intensity proton facility. The "proton driver" would enable a number of research initiatives including, but not limited to, next generation neutrino experiments, rare kaon decays, neutron scattering, and ultimately support of a muon storage ring based "neturino factory" and/or perhaps a free electron laser. Two schemes are being investigated, one based on a large aperture, rapid cycling synchrotron, the other on a superconducting linac. The synchrotron would provide $3x10^{14}$ protons/sec at 8 GeV (~400 KW), corresponding to close to 2 MW when accelerated to 120 GeV in the Main Injector. The linac could provide 8 MW at both 8 and 120 GeV.

The proton driver is a new source for generating intense, short proton bunches to replace the current Booster accelerator; to serve a new physics program based on high-intensity proton beams; to serve as a neutrino factory at Fermilab; and to serve a possible future muon collider. The primary requirement is high beam power, with a proton beam of 2 MW. (Phase II: 4 MW). This level of power is similar to other high-intensity proton machines, such as the Spallation Neutron Source, and would enable Fermilab to form a world-wide collaboration. The short bunch length at the exit (3 ns; Phase II, 1 ns) is unique for the proton driver and raises a number of interesting and challenging beam physics issues. It is essential to have small longitudinal emittance; large momentum acceptance in the rf and lattice; and bunch compression at the end of the cycle.

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. Fermilab would be in a solid leading position in neutrino physics for the foreseeable future, with wide-ranging prospectst for its physics programs.

IV. Future Accelerator R&D: Creating and expanding options

Fermilab is also expending effort in other areas to expand its options, and to continue to play a leading role in the U.S. contribution to any of the next-generation accelerators in any location with its overall overall accelerator R&D program:

- Superconducting RF beyond a linear collider, including the Fermilab NICADD Photoinjector Laboratory (FNPL);
- Superconducting magnets;
- Muon facilities.

In response to an environment of limited funding, the laboratory has been placing an increased priority on linear collider activities, with decreasing emphasis on muon facilities and low field superconducting magnet R&D.

Supercondcuting RF

A number of activities relating to both warm and cold superconducting RF are being carried out in concert, and Fermilab has established a collaboration between the Technical Divison and the Accelerator Division in these areas.

Cold superconducting RF cavities are being developed to produce a separated kaon. A pure K^+ beam will be produced using approximately 6 meters of cold superconducting RF cavities operating at 3.9 GHz in TM_{110} at 5 MV/m $P_{(transverse)}$.

The Fermilab/NICADD Photoinjector Laboratory (FNPL) is Fermilab's advanced accelerator research and development facility. FNPL is operated jointly by Fermilab and the Northern Illinois Center for Accelerator and Detector Development. Participating institutions in FNPL are Fermilab, NIU, the University of Chicago, the University of Rochester, the University of California-Los Angeles, Lawrence Berkeley National Laboratory, and DESY. There are currently two Ph.D. students researching at FNPL, in the areas of Flat-Beam Optimization (U. of Chicago) and Laser Acceleration (U. of Rochester). Upgrades to the facility in the near term include addition of 3.9 GHz (accelerating mode) cavity for production of short bunches and an energy upgrade (to about 40 MeV) based on a high gradient superconducting cavity supplied by DESY.

Superconducting magnets

Superconducting magnets are the enabling technology for high-energy hadron colliders. Fermilab is the US center of excellence for superconducting magnet research and development, and intends to maintain that position.

The lab's goals are to develop superconducting magnet technology that could support a Very Large Hadron Collider in the post-LHC era, support LHC luminosity upgrades, and maintain the US leadership in superconducting magnets to benefit both Fermilab and the world-wide HEP program. The major components of the Fermilab program are LHC low-beta quadrupoles, quadrupoles for a new interaction region at CZero for BTeV, High-Field dipole R&D, and high gradient large aperture quadrupoles for an LHC luminosity upgrade. The high-field program and the LHC accelerator research program are forging a strong connection in the near future, and Fermilab intends to reinforce that connection. But as the result of severe financial pressures, the low-field program is ending with the completion of low-field magnet/power supply tests.

Muon facilities

Fermilab hopes to establish an R&D path to develop the technologies required to support the construction of a neutrino facility based on a muon storage ring by the end of this decade. The lab would also like to explore options for interim facilities to support R&D and programmatic goals. At Lab G, Fermilab is conducting R&D on high-gradient accelerating cavities.

Fermilab has constructed, with the help of the Muon Collaboration, a MuCool Test Facility at the end of the present 400 MeV Linac, to pursue the development of a muon ionization cooling channel for a high luminosity muon collider. Ionization cooling has been proposed as a method to intense beams of positive and negative muons. This technique inolves passing the beam through an absorber in which the muons lose transverse- and longitudinal-momentum by ionization loss. The longitudinal momentum is then restored by re-acceleration, leaving a net loss of transverse momentum (transverse cooling). The process is repeated many times to achieve a large cooling factor.

A fully international collaboration (US-Europe-Japan) has been formed to propose a cooling demonstration experiment. However, the program at Fermilab is under severe funding pressure.

4

Scientific Vision and Strategic Plan

I. The Next 20 Years: Fermilab's Long Range Planning Committee

Particle physics stands at the threshold of a new era of discovery, made possible by experiments now operating or starting up in the next few years. As the largest U.S. laboratory dedicated to High Energy Physics, and dedicated to being the world leader in High Energy Physics, Fermilab has a special responsibility to optimize the opportunities for making new discoveries about the nature of matter, energy, space, and time.

The 2001-2 HEPAP Subpanel on Long-Range Planning for U.S. High Energy Physics recommends that "the United States take steps to remain a world leader in the vital and exciting field of particle physics, through a broad program of research focused on the frontiers of matter, energy, space, and time." The Subpanel also recommended that the U.S. participate in the linear collider, wherever it is built in the world, and that the U.S. prepare to bid to host such a facility. Finally, the HEPAP Subpanel argued persuasively that to address the range of compelling scientific issues the field needs a broad range of experimental strategies and techniques.

Fermilab's Long-range Planning Committee is charged with developing in detail the realistically achievable options for the lab's program in the next decade under each possible outcome for building an internaional linear collider: the collider project will be built here, starting late in this decade with international support and organization; or the linear collider will be built elswehere with substantial participation from U.S. High Energy Physics in the international effort.

The goal for each option is to optimize the opportunities available at Fermilab in this period for high energy physicists to answer the most important questions in our field, guided by the priorities of the HEPAP Subpanel and of the HEPAP response to the Office of Science facilities plan. The goal for each option stems from two assumptions: Fermilab will have a central role in an active U.S. research program at the LHC, both as host of the US-CMS collaboration and as developer of accelerator upgrade plans; and Fermilab will carry out the presently approved program of experiments following approval from the national program.

The plan should fit into, and be a major component of, the 20-year roadmap for the field described in the HEPAP Subpanel report. The recent HEPAP submission to the Office of Science for the facilities plan is another important planning document to consider. The existing facilities at Fermilab, the strengths of the existing Fermilab staff, and the active participation of a strong Fermilab user community are all critical assets in building a strong future with available resources.

The Working Groups of the Long Range Planning Committee will pursue these goals:

Physics Landscape

1. Understand and summarize the possible scenarios for the international field of elementary particle physics in 2010-2020.

2. Summarize the existing plans for the Fermilab HEP facilities and likely upgrades into the era 2010-2020.

3. Identify interesting yet reasonable targets of opportunity for the Fermilab HEP program.

4. Understand the role Fermilab can play, in terms of likely available facilities and reasonable goals for upgrades of new facilities and addressing these scenarios.

5. Understand and summarize the need for, and the potential for, new general HEP accelerator based initiatives in the time frame 2010-2020

6. For different funding levels, explore the potential scope of the future HEP activities at Fermilab.

7. Recommend a particular areas of interest, targets of opportunity and plans of action.

Linear Collider

1. Understand the ramifications of successfully competing to bring the linear collider to northern Illinois and make recommendations on the steps that should be taken to assure the strongest possible Fermilab presentation within the U.S. "bid to host."

2. Understand Fermilab's role in gaining approval for an internationally based linear collider. Outline the options for Fermilab involvement in construction and operations, both in the case of a linear collider sited in northern Illinois and one sited elsewhere, and make recommendations on the scope of activities and level of laboratory effort that should be devoted to these activities.

3. Review the physics opportunities defined within the Physics Subcommitee and outline a "physics strategy" based on illumination of areas of opportunity beyond the reach of the LHC.

4. Outline a program that establishes Fermilab as the leading contender for siting a linear collider, including accelerator R&D, siting studies, and outreach. Explore options for Fermilab's role in the construction of a linear collider in the scenarios in which it is constructed in northern Illinois or elsewhere. Recommend the scope of activities and desirable level of Fermilab resource allocation in both scenarios.

5. Define the essential elements of the Fermilab component of a U.S. "bid to host." Recommend possible lab restructuring that might optimize the prospects for hosting a linear collider and/or for playing a leading role in its construction elsewhere. Areas to consider: outreach; implications of Fermilab's status as an international laboratory; modeling the Fermilab effort required to support a bid to host and subsequently construct a linear collider in northern Illinois, or at another site.

6. Define Fermilab interests in participation in detector R&D, construction, and operations, based on particular areas of interest in the physics program and/or areas of expertise.

Proton Driver

1. Understand and summarize the physics, operational, and technical arguments for constructing a new high intensity proton source at Fermilab (the Proton Driver).

2. Summarize the arguments pro and con for the two options for a Proton Driver, a circular booster replacement or a superconducting linear accelerator

3. Define the steps including R&D program that would allow Fermilab to gain approval for

such a machine, including considerations of funding, scheduling and staffing; and recommend a plan of action and a near-term level of necessary laboratory effort.

4. Summarize the Proton Driver physics opportunities, including possible rare K decay experiments, and possible fixed target experiments using intense 120 GeV proton or secondary beams.

Particle Astrophysics

1. Plan to maintain a leadership presence for Fermilab's vibrant astrophysics efforts, both theoretical and experimental, in the growing convergence of cosmology and particle physics through the Sloan Digital Sky Survey, the Pierre Auger Cosmic Ray Observatory, the Cryogenic Dark Matter Search, the Super Nova Acceleration Probe of the Joint Dark Energy Mission (JDEM), and other possible experiments

2. Reinforce the increasing recognition within the community that particle astrophysics as conducted at Fermilab is strongly linked to high-energy physics, and is indeed integral to the laboratory's mission, offering complementary probes of the same fundamental physics questions

3. Explore the possibilities for physics beyond the Standard Model suggested in the combined areas of dark energy, dark matter and neutrino mass

4. Play a leading role in uncovering the nature of dark matter, through the potential of CDMS to detect dark matter particles and gather information on its mass and cross section, complementary to searches for Supersymmetry at the Tevatron; and through SDSS and future JDEM measurements of large-scale structure and weak gravitational lensing, which are sensitive to both the amount and properties of dark matter in the universe

5. Play a leading role in solving the mystery of the universe's highest-energy cosmic rays through the Pierre Auger Cosmic Ray Observatory

6. Play a leadership role in probing the nature of the dark energy through SNAP/JDEM

Neutrinos

1. Plan a Fermilab neutrino program capable of providing definitive measurements of the currently-unmeasured neutrino oscillation parameters, □$_{13}$, sine(□m_{13}^2), and □.

2. Determine the capabilities of the NuMI beam line with increased proton intensity on the proposed off-axis detector, at site in Minnesota or Canada, and determine additional capabilities added by a second off-axis detector sited to study the second oscillation maximum.

3. Determine the optimum division between funds spent on increasing the proton intensity and funds spent on building new detectors.

4. Determine additional experiments or facilities for Fermilab to consider in the event MiniBooNE has a positive signal.

5. Determine the capabilities of long-baseline experiments using a beam from the present Booster accelerator, or from a new booster.

6. Determine the capabilities of a new Fermilab conventional neutrino beamline to a longer baseline detector, and determine whether such a detector should be sited on- or off-axis.

7. Assess the conditions under which Fermilab should consider a muon-ring neutrino factory, and investigate its parameters and capabilities.

8. Assess the non-oscillation physics that could be investigated at these facilites.

Large Hadron Collider

1. Define a role in the LHC that is commensurate with the scale of Fermilab now and with the lab's continued leadership in world HEP

2. Plan for a CMS Physics Analysis Center that makes Fermilab the best place to be if you want to do the physics,

enhancing U.S. physics potential overall and improving the return on U.S. investment in CMS and LHC.

3. Determine the requirements to establish Fermilab as the leading center for LHC theory/phenomenology, and the leading center for for detector development and accelerator development for the LHC luminosity upgrades

4. Plan for the computer infrastructure needed with Fermilab established as a regional center.

5. Develop the idea to provide U.S. LHC computing by linking a Grid of Tier-1 to Tier-n centers, to an open Grid-services infrastructure

6. Starting with the U.S. LHC grid resources, build and operate a fully functional and production quality grid, that supports Peta-scale operations, and that extends internationally to create a global grid for LHC science.

7. Open the grid to include Run II computing and other communities, at Fermilab and University facilities, easing transition for University groups to LHC Fermilab Tier-1 and Open Science Grid

Accelerator R&D

1. Understand and summarize the case for accelerator R&D at Fermilab, and the role Fermilab should play in facilitating the accelerator R&D program needed to keep High Energy Physics healthy.

2. Summarize the existing accelerator R&D program at Fermilab (excluding explicit Linear Collider R&D, LHC-related R&D, and Proton Driver upgrade related R&D), and its possible evolution in the future.

3. Understand and summarize the need for, and the potential for, new general accelerator R&D initiatives at Fermilab.

4. For different funding levels, explore the potential scope of the future general accelerator R&D program at Fermilab.

5. Recommend a plan of action that would enable an increase in the scope and effectiveness of the accelerator R&D program at Fermilab.

Non-Particle Physics

1. Express clearly the advantages to Fermilab, the user community, and the DOE of limited of involvement in areas that are not particle physics.

2. Discuss and define criteria and decision mechanisms that can be used to determine what projects Fermilab should be involved in. This should include discussions of how closely the projects should conform to our existing set of skills, and how closely they should relate to the core part of the program.

3. Discuss how to evaluate the benefits and costs of a particular program to Fermilab, the user community, and DOE.

4. Identify an initial group of outstanding projects that can be pursued and can be used as test cases, and propose an ongoing method for identifying new projects. Project areas identified for initial consideration:
    a. Computational Physics
    b. Computer Science
    c. Uses of existing machines
    d. Possible uses of a future linear accelerator (low energy built for the proton source)
    e. Medical Physics/Therapy
    f. Biophysics

5. Discuss how to fit these projects into the overall program to provide maximum benefit to the lab, the user community, and the DOE as a whole.

6. Describe mechanisms by which the progress of such projects can be tracked, and the costs and benefits assessed, for decisions on continuing projects, terminating them, spinning them off, or other considerations.

II. The most important program now operating in particle physics

At approximately 6:53 a.m. on Friday, August 22, 2003 the integrated luminosity at the Tevatron collider exceeded 225 inverse picobarns—thus surpassing the luminosity goal for the entire fiscal year, with more than a month to spare.

The physics of the CDF and DZero experiments at the Tevatron collider represents the most important program now operating in particle physics. Run II is the only program with sufficient energy available to address many of the central scientific questions. The lab needs to do as much science as possible with the CDF and DZero experiments, each and every year until the end of Run II. A major discovery of such important new physics as supersymmetry or extra dimensions would clearly reshape our understanding of particle physics. Evidence for or against the existence of a low-mass Higgs will also be very important. Run II will greatly improve our understanding of top quark physics, electroweak physics, heavy quark physics, QCD, and Higgs physics.

The laboratory's goal is to achieve the greatest sensitivity possible to discoveries of new physics, and to do so as quickly as possible. It is critical to the scientific success of the Tevatron Collider Run II, and to the future of our laboratory, that we deliver as much luminosity as possible to the detectors every year. So far in Run II, we have delivered twice the integrated luminosity of Run I, greatly extending the physics reach of the experiments. To maximize the Tevatron luminosity and hence the scientific potential of Run II, Fermilab completed an accelerator plan for through mid-2009. The plan was reviewed by a Department of Energy panel, which offered its congratulations on progress so far, along with several recommendations for the work ahead. The review panel stated in its report: "In summary, Fermilab is being responsive to its stakeholders by taking steps to improve the reliability of the Tevatron complex; by developing a preliminary Plan that lays out the technical scope of work and associated resources; and by making management changes to effectively execute their plan."

To optimize the scientific results and to increase the data samples of the two collider experiments, the lab will take these steps by early 2005:

1. make continuous operational improvements designed to increase the efficiencies for proton and antiproton beam transfers;
2. implement a series of maintenance projects to improve reliability of operations;
3. upgrade instrumentation throughout the accelerator complex;
4. improve alignment of accelerator components;
5. upgrade the Antiproton Source to increase antiproton production rate;
6. complete new damper systems in the Main Injector and Tevatron;
7. optimize the orbits of beams in the Tevatron;
8. commission the Recycler Ring; and
9. introduce slip-stacking, a new technique that will increase Main Injector beam intensity for antiproton production.

These steps will allow the experiments to nearly double their data by mid-2004, with another doubling by late 2005. The longer-term goal is to maximize the opportunity for discovery throughout the period of Run II.

The lab has also made a major decision focused on maximizing the Tevatron's experimental potential, by not including silicon detectors in the continuing detector upgrade projects. The decision was made in order to optimize the science in Run II by minimizing downtime and concentrating the lab's available resources on the accelerator upgrades and the other parts of the detector upgrades.

The lab's capability in pursuing physics in Run II depends on the funding available to carry it out. The funding for Fermilab and High Energy Physics in recent years has not kept up with the real effects of inflation. Since research at Fermilab is dominated by projects and programs committed to five years ago or more, the budget shortfalls have had a very large impact on the rest of the laboratory effort. This follows a larger pattern of funding for the Office of Science at the Department of Energy and for physical sciences across the board. After years of this funding trend, even the highest priority programs are not escaping the negative effects.

As a result of this larger pattern, despite the acknowledged importance of the Run II program, the lab has been been unable to secure a funding level that keeps up with inflation. Since FY2001 the lab has diverted resources from all other efforts to ramp up the Run II effort. The lab remains strongly committed to Run II, and the decision not to include silicon detectors represents an attempt to ensure achieving the highest level of science with the real resources available. The accelerator effort has been reorganized to improve delivery of luminosity in the short term, and the new team is working well. The lab will now have the resources necessary to make immediate luminosity improvements, execute the luminosity upgrade program, make improvements to reliability, and hire additional accelerator physicists to fill specific outstanding needs. The lab will be able to carry out out this accelerator work without delaying items for budget reasons and still have the modicum of budget flexibility needed to overcome unexpected problems with the Run II effort. The lab also will support rapid completion of the nonsilicon parts of the detector upgrades.

Run II: Already more data than Run I

The upgraded Tevatron has continued to achieve new milestones. Since the onset of physics data in the spring of 2002, the Tevatron has generated more data to its significantly revamped detectors than was generated during all of Run I from 1992 to 1996.

Among the early results: CDF and the Tevatron already have established some of the best measurements in B-physics, with a prime goal of measuring mixing in the Bs sector. The Tevatron has a unique program in B-physics, enabled by the development of the secondary vertex trigger (SVT) through the work of CDF and Italy's INFN-Pisa. The SVT triggers on B-mesons, allowing the exploration of states not available at the B-factories. The SVT will also facilitate exploration in the CP violation studies that are currently the domain of the B-factories.

DZero has established the most sensitive limit to date in the search for large extra dimensions, surpassing limits set during Run I, and by the Large Electron-Positron (LEP) collider at CERN. DZero has also reported the first results from its new silicon detector close to the interaction region. Again, DZero's Run II results are drawn from more data than was produced during all of Run I.

The discovery reach of the Tevatron has already extended into uncharted territory, with improved data resulting from improved detectors, and with a 10 percent increase in energy making a significant impact on cross-section. The Tevatron has been establishing luminosity records with regularity, reaching 4.9E31 initial luminosity on Sunday, August 10, 2003. It will remain the world's highest-energy collider until LHC begins producing physics. The CDF and DZero detectors are offering combined results in top quark measurements that extend the understanding of the particle discovered at Fermilab in 1995.

Top quark measurements offer tools applicable to several other areas—for example, offering constraints in the electroweak sector, on the Higgs boson. Because the top quark is so massive, top quark measurements also represent major areas to search for new physics; it may decay into as-yet unknown particles. In addition, the Tevatron is the only top quark "factory" until the LHC turns on.

So far, Run II results have agreed with Run I results on top mass, and close study of the top offers a whole area of new knowledge—as intense studies of strange, charm and bottom quarks have generated new knowledge and new directions. With top samples already larger than Run I, CDF, DZero and the Tevatron are positioned to answer questions approachable only at Fermilab's high-energy frontier: Is the top quark what it appears to be in the Standard Model? Or is there actually new physics lurking around this heaviest of the quarks?

Only colliders address elctroweak unification

The goal of particle physics is to understand the nature of matter, energy, space and time. The overarching questions faced by the field today are at the scale of electroweak unification: What sets the mass scale of the weak interactions to be about 100 GeV? This question is addressed solely with colliders operating at the energy frontier.

Through the 1990s, four colliders operated at or near the energy frontier:

- The Tevatron at Fermilab, a proton-antiproton collider operating at a center of mass energy of 1960 billion electron volts

(GeV). For proton-antiproton collisions, 1960 GeV is comparable to more than 200 GeV for electron-positron collisions. The Tevatron has produced the discovery of the top quark, and measurements of top quark and W boson masses.

- The Large Electron-Positron (LEP) collider at CERN, operating at a center of mass energy of 90-210 GeV. LEP has measured Z boson properties and W boson mass, and has set an upper limit on the Higgs mass.

- SLC at Stanford Linear Accelerator Center, an electron-positron collider operating at a center of mass energy of 90 GeV. SLC has measured Z boson properties.

- HERA at DESY in Germany, an electron-proton collider operating at a center of mass energy of 300 GeV. HERA has explored proton structure and Quantum Chromodynamics (QCD), and is less suited to electroweak physics than the other machines.

The Tevatron is the only collider able to address these central issues in the field of high-energy physics from 2002 to 2007. SLC and LEP have closed, and HERA will end its run in 2006. Additionally, the Tevatron's increased luminosity and slightly higher energy level make a new round of experimentation possible in five critical areas:

- **The Fundamental Scales of Mass and Energy:** What causes the Higgs effect, breaking the electroweak symmetry and giving the W and Z boson their mass? Are all the precise measurements of the fundamental parameters consistent with the Standard Model, in which there is a single Higgs boson?

- **Supersymmetry and superstrings:** Is there a supersymmetry that is broken at this scale? If so, is it connected with the quantization of gravity? Do supersymmetric particles make up a significant component of dark matter?

- **Alternative new physics at the 1 TeV scale:** Are there observable effects of large hidden dimensions? Is there a new strong dynamics among the W and Z bosons?

- **Quarks and CP Violation:** Are all measurable examples of CP violation consistent with a single source?

- **QCD and the Strong Interactions:** Are the strong interactions of quarks and gluons described by QCD at the highest energy? Do the quarks themselves have substructure at a smaller scale?

There will be important new results every year from the Tevatron.

Electroweak symmetry

The electromagnetic and weak interactions are connected by an electroweak symmetry. They are different manifestations of a single, electroweak interaction. The couplings are the same. However, the range of the weak interaction is very short, leading to its apparent weakness at low energies.

The mass of the intermediate W and Z bosons determine the range of the weak interaction. If the electroweak symmetry were unbroken, the masses of the W and Z would be zero, as for the photon. In the Standard Model, the masses are proportional to the average value of the Higgs field in the vacuum, which is 246 GeV.

What breaks the electroweak symmetry and gives masses to the W and Z?

This central issue has confronted particle physics for 30 years. In the Standard Model of particle physics, the Higgs field is distributed everywhere in space. The interaction of the W, Z, quarks, and leptons with this Higgs field gives them their mass. The quantum of this field is the Higgs boson, with a mass calculable from other measurements within the Standard Model, including the masses of the top quark and W boson.

Alternatives to the Standard Model

Although the standard Higgs boson explains the present data well, its existence has not been experimentally verified. It has not been observed directly. Something must generate the W and Z masses, and it must look exactly like the Higgs field at low energies.

The Standard Model cannot be the whole story. The Higgs mass diverges quadratically without some other new physics. Alternative theories exist in which other phenomena cause the same effect as the standard Higgs boson.

Supersymmetry is the most-studied alternative, a necessary part of string theory. Supersymmetry cancels the divergence in the Higgs mass; naturally provides a dark matter candidate; provides a framework for the unification with gravity, and leads to the unification of gauge couplings. Extra dimensions can explain important features of the standard model, and would also have observable effects at Tevatron energies. A new strong dynamics, some variation of technicolor, can do the same.

The most important result at the Tevatron would be discovery of physics beyond that described in the Standard Model.

Other Major Areas of Research at the Tevatron

CP violation and quark flavor physics: Are all the possible measurements of CP violation in the quark sector coming from a single CP parameter? We know there must be at least one other source of CP violation from the predominance of matter in the universe. Precise measurements of CP parameters and elements of the quark mixing matrix will provide a sensitive test for new sources of CP violation. A good measurement of Bs mixing is the most urgently needed result.

QCD – The strong interactions of quarks and gluons: We will look for non-pointlike structure of quarks and gluons using the highest-power microscope in the world by measuring jet production at high transverse energy. We will measure the quark and gluon structure of the proton in regions that have been inaccessible. We will compare production and decay of heavy quarks with perturbative and lattice gauge calculations. We will measure the spectroscopy of new mesons and baryons containing heavy quarks.

The Tevatron Research Program

CDF and DZero, two large research collaborations, use the Tevatron collider as the source of their research program. Each collaboration is composed of more than 600 physicists from about 60 universities and laboratories around the world. Together these two collaborations include about 25% of the experimental particle physicists in the U.S. Approximately one-third to one-half of the members are from institutions outside the U.S.

Each collaboration, working with the Laboratory, has built and operates a multipurpose detector. Each massive detector contains state-of-the-art systems capable of observing up to 107 collisions per second and selecting about 50 of them to be written to tape. The events collected are reconstructed offline and used as the raw data that feeds perhaps 100 separate experiments simultaneously. As with the Hubble space telescope, a wide range of physics problems are addressed with the same apparatus.

Data samples past and present

Run I refers to the period 1992-6 in which an integrated luminosity of about 0.16 fb^{-1} was delivered to each detector.

*(**Note:** The event rate R in a collider is proportional to the interaction cross section σ_{int} and the factor of proportionality is called the **luminosity L**:*

$$R = \sigma_{int} L$$

The total number of events N over a period of time is then given by

$$N = \sigma_{int} \int L \, dt$$

*where $\int L\,dt$ is the **integrated luminosity.**)*

This is the sample used to discover the top quark and to produce many other important results. Run II refers to operations of upgraded CDF and DZero detectors supported by the collider configuration envisioned during the Main Injector construction.

Physics prospects in Run II

The most important new results will come either from precise measurements of fundamental quantities or from discoveries (or definitive exclusion) of new physical phenomena that would indicate new physics beyond the Standard Model. Precise measurements of fundamental quantities, usually to look for inconsistencies that would indicate a breakdown in the Standard Model, include measurements of the top quark and W boson masses and couplings; and measurements of the parameters needed to test new sources of CP violation.

Possible discoveries include the Higgs boson or any new physics (that is, 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.

The Tevatron program has the potential for a discovery that would change the direction of particle physics. It would clarify the parameters needed for a future Global Linear Collider.

Science prospects increase with the size of the data sample. Every doubling of the integrated luminosity makes possible a new round of important physics results. This has been true in the past at the Tevatron, LEP, and other colliders operating at the energy frontier.

The sensitivity of the Higgs search, as for any search for a rare signal above background, is proportional to the square root of the integrated luminosity. The following pages contain a short list of physics highlights expected at given values of the integrated luminosity. Each entry represents a major advance. This is a small selection of the physics papers that will be produced. Some items represent a whole program of new results. More detail is given for the near future. Only a few topics are considered in the longer run, since much of the physics program then depends on results to come in the next few years. All of the "possible discoveries" listed are of the scale that would change the direction of particle physics. Obviously, if any of them were realized, they would change the direction of the program dramatically.

Prospective physics highlights at a range of luminosities

At 0.1 fb-1:

Even with a data sample of this size, there will be many new physics results. New detectors have increased capability and the collider energy has changed from 1.80 to 1.96 TeV, significantly increasing cross sections for high-mass states. We can anticipate measurements of the cross-sections for the top, bottom, and charm quarks, W and Z, and jets. This range would mark the start of a broad program of measurements on particles containing the bottom quark, including spectroscopy, lifetimes, and mixing

At 0.3 fb-1:

At this point, major new results will appear in every area of research at the Tevatron, including the first opportunity to identify signals of new physics. We can anticipate measurements of the top quark mass with twice the present precision, and measurements of Bs mixing, which are critical for CP violation tests. In areas of new physics, we might discover extra dimensions with a scale of 1.6 TeV; and we can expect to confirm or eliminate new physics indicated by Run I observations of rare events. In QCD, we can expect measurements of the jet spectrum at highest transverse energy, probing for a substructure of quarks

At 1 fb-1:

In electroweak physics, we can expect measurements of W magnetic moment; signals for production of 2W's and W+Z events; and measurements of top quark properties with 1,000 top events per experiment. In supersymmetry, we might discover supersymmetric particles and possibly one of the five supersymmetric Higgs bosons. The possible discovery of technicolor would highlight other new physics. We can explore CP violation with measurements of the CP angle γ to 9^{o} using B and B_s decays.

At 2 fb-1;

At this point the full discovery potential of the Main Injector/Recycler upgrade is realized. In the electroweak sector, we anticipate precise tests of the Standard Model and prediction of the Higgs mass. We can measure W boson mass to greater precision than the LEP experiments achieved. We can make precise measurements of top quark properties of mass and decay modes. We can achieve a 95% exclusion of a Higgs boson with mass of 115 GeV. We would observe supersymmetric squarks and gluinos, if gluino masses are below 400 GeV. We would observe supersymmetric neutralinos, if their mass is below 180 GeV. In CP violation and the Bottom quark sector, we can achieve measurements of the decay mode
$B_d \rightarrow K^*\mu^+ \mu^-$, a mode sensitive to many modifications of the Standard Model.

At 4 fb-1:

Here, we can achieve a 95% exclusion of a standard Higgs boson up to 125 GeV. We see the possibility of discovering supersymmetry in a large fraction of parameter space for minimal supersymmetry, along with the possible discovery of a supersymmetric Higgs signal for a mass of 150 GeV. At this level, a series of very precise measurements of fundamental parameters is needed to test the hypothesis that CP violation comes from a single source: γ, sin(2 β), and V(ts).

At 8 fb-1:

Here, we can expect **3σ** evidence for a standard Higgs with a mass less than 122 GeV, and 95% exclusion of a standard Higgs for masses below 135 GeV, or from 150GeV to 180 GeV. We see the possible discovery of supersymmetric particles in a larger range of supersymmetric models, with a 95% exclusion of the minimal supersymmetric Higgs in the maximal mixing model.

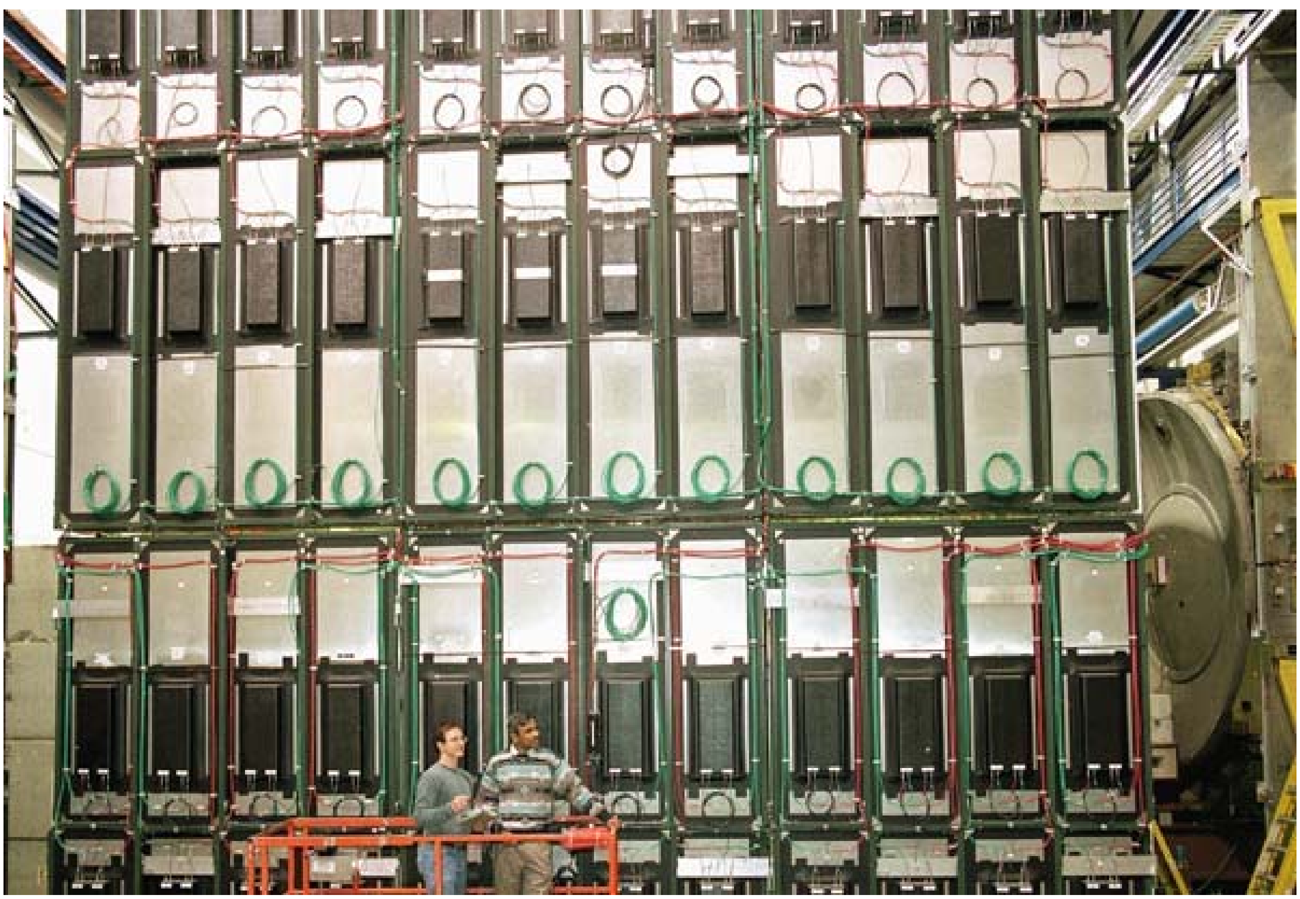
At 15 fb-1:

At this pinnacle of luminosity, we anticipate **4-5σ** evidence for a standard Higgs with a mass of 115 GeV, with 95% exclusion of a standard Higgs for all masses below 185 GeV. We can see the possible discovery of supersymmetric particles for gluino masses up to 600 GeV, and the possible discovery of a supersymmetric Higgs boson *A* with mass up to 200 GeV. In the electroweak sector, we can achieve top quark mass measurements with an error of 1.3 GeV (compared to 5 GeV today), and W mass measurements with a error of 15 MeV (compared to 40 MeV today).

Conclusions

The questions addressed at the Tevatron include most of the central questions in particle physics. The Tevatron is the only collider able to address the central problems in the field from 2002 to 2007. The Tevatron program has the potential for a discovery that would change the direction of particle physics.

But the FY 2004 budget request represents a challenge for high-energy physics, and a special challenge for Fermilab. In December 2002, we estimated it would take approximately $306 million in FY ’04 to sustain the full Run II plan, ongoing projects, and minimal preparation for the future. By contrast, the Fermilab budget is $288.5 million, a figure representing a 7% decrease relative to inflation since FY2002.

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III. Neutrinos: Great surprises, great opportunities

The identification of neutrino oscillations represents the greatest experimental surprise of the last decade. The demonstration of large mixing among the three neutrino flavors raises the possibility of observing an important new instance of CP violation, with a possible connection through the see-saw mechanism to a very high mass scale.

As home to the U.S. accelerator-based neutrion program, Fermilab is exploring neutrino anomalies and the question of neutrino mass, through two experiments: MiniBooNE, the short-baseline experiment using beam from the Booster accelerator; and MINOS, the long-baseline experiment that will draw beam from Fermilab's Main Injector accelerator, then send a beam of neutrinos through the earth to an underground detector in Minnesota, some 450 miles away.

MiniBooNE already piling up data

MiniBooNE, which collected more than 100,000 neutrino candidates in its first nine months of running, is on the quest to repeat the landmark neutrino oscillation result of the Liquid Scintillating Neutrino Detector at Los Alamos National Laboratory. MiniBooNE's goals are to confirm (or refute) the LSND observation with much better statistical precision (thousands of events compared to tens of events in LSND), and accurately determine the oscillation parameters ($\sin^2(2\theta)$, Δm^2) of the oscillations.

MiniBooNE expects to surpass the 5-million neutrino events milestone in 2004, halfway to the experiment's goal. Also, MiniBooNE expects to have non-oscillation physics results available on charge current quasi-elastic scattering, neutral current pi0 production, and neutral current elastic scattering in 2004, and is especting oscillation physics results to be ready in the summer of 2005.

LSND was the first accelerator-based experiment to produce evidence of neutrino oscillations. Confirming that result—accelerator-produced neutrinos that change from one flavor to another—would also indicate the existence of an additional flavor or type of neutrino, beyond the three now known. A fourth neutrino would represent another crack in the Standard Model of particle physics, and both a milestone and a challenge for particle physicists.

In one year, MiniBooNE transports more beam than in all 17 years of the Fixed-Target Program at Fermilab. To control the beam, External Beams has built two concepts into the MiniBooNE operation. The first is "auto-tune," an automated tuning program to keep the beam properly positioned inside the beam pipe. The second is "e-berm," an electronic monitoring system intended to help minimize beam loss. Earthen berms are built over accelerators to absorb particles from beam loss; "e-berm" aims at limiting the need for an earthen berm by limiting losses.

The concept has been used before at the lab, but this system is an entirely new one developed by the Accelerator Division. The system uses toroid detectors for measurements, one at the beginning of the beam line and one at the end. If the measurements are the same at both ends, the beam is intact; if not, beam losses are immediately tracked down and corrected. The program to decrease losses in the Booster have made it possible to increase the flux of the neutrino beam.

MiniBooNE's next step is to present the first physics results on muon neutrino disappearance and cross-sections. The experiment will also demonstrate updated sensitivities for muon neutrno to electron neutrino oscillations, with results of this search expected in early 2005. The results will greatly influence the decisions on MiniBooNE's future course, including whether to increase the running time or to build a second detector.

Completed MINOS detector collects cosmic ray data

After four years of work in a former iron mine a half-mile underground, the Main Injector Neutrino Oscillation Search MINOS) collaboration celebrated a milestoneon June 5, 2003, when technicians erected the last of 485 house-high detector planes of steel and plastic in the Soudan Underground Laboratory in Soudan, Minnesota.

Overall, the four-year project finished on schedule and on budget. The faster-than-expected installation made up for time lost during the excavation of the cavern that hosts the experiment.

The whole detector is about 100 feet long and consists of massive planes that are lined up like the slices in a loaf of bread. Each plane consists of a sheet of steel, about 25 feet high and one inch thick, covered on one side with a half-inch layer of scintillating plastic. Because all material had to enter the cavern through an old narrow shaft, the 6,000-ton detector arrived in pieces not more than seven feet in width—not unlike building a ship in a bottle.

The project began in July 1999, with the groundbreaking for the cavern that now hosts the detector. The installation of the first plane occurred in August of 2001. Because of limited storage space in the underground area, the work crew relied on continuous delivery of steel sections through the shaft. The Soudan Mine is a Minnesota state park, with 30,000 visitors per year. The transportation cage was used during the day for tourists visiting the old iron mine, so detector components were lowered underground during the second shift at night. Over a two-year period, only three shifts were canceled due to weather.

During the installation, technicians worked in two ten-hour shifts and accounted for about 75 percent of the total manpower. A mix of graduate students, postdocs and senior scientists from many of the 32 MINOS institutions from six countries—Brazil, France, Greece, Russia, United Kingdom and the United States—significantly contributed to the work at Soudan as well, with a special emphasis on the installation of the electronics and the commissioning of detector planes within days of their installation.

Work on the detector, however, was not limited to the Soudan mine. A number of university and laboratory groups in the U.S., UK, and Greece worked at their home institutions on the production of detector components, representing more than half the cost of the detector. In a carefully coordinated effort, the groups built and tested the pieces of the plastic scintillator system and then shipped them to the Soudan mine for installation.

The completed detector is observing cosmic rays and atmospheric neutrinos, which easily penetrate the surface of the earth and reach the MINOS detector deep underground. Previously, scientists had already used half of the detector to record particle interactions. In April 2003, the MINOS collaboration reported its first scientific results, the identification of twelve atmospheric neutrino events.

In early 2004 the construction of the NuMI conventional facilities will be completed. Installation will continue in the three main areas at Fermilab: completion of work in the Main Injector Tunnels during the 2004 shutdown; installation of the NuMI target station at MI-65; installation of the MINOS detector and absorber. The MINOS far detector at Soudan will continue to collect atmospheric neutrino data while awaiting beam.

Over the next two years MINOS scientists will focus on the so-called CPT test of atmospheric neutrino interactions, looking for differences in the interactions of matter and antimatter. Unlike earlier neutrino experiments such as Super-Kamiokande, MACRO, and Soudan 2, the MINOS detector features a 1.5-Tesla magnet that allows scientists to distinguish between signals caused by neutrinos and antineutrinos.

MINOS will enter its next stage in 2005, when scientists will use the detector to “catch” neutrinos created 450 miles away at Fermilab in Batavia, Illinois. The beam line creating the neutrinos is under construction. When ready, about five trillion muon neutrinos per year will travel straight through rock and traverse the detector in Soudan, but only about 1,500 of the rarely-interacting particles are predicted to leave a trace inside the detector. Scientists will use the long-distance experiment to study the oscillation of muon neutrinos into electron neutrinos or tau neutrinos under laboratory conditions.

Questions for the future

Is a new source of CP violation in the neutrino sector accessible to our experiments? So far, the two neutrino mixing angles measured are very large, and CP violation may be observed if Θ_{13}, the third mixing angle, is not too small.

Some possible steps in an experimental program to explore the neutrino sector:

–Having MINOS provide good measurements of Δm_{atm}^2 and sin 2 (2 Θ_{atm}) well would extend the search for Θ_{13}.

--An Off-Axis NuMI experiment would offer great discovery potential with modest enhancements of the existing beam being sent to the Soudan Underground Laboratory.

--A Proton Driver would greatly increase the neutrino flux.

–A very large detector would further increase sensitivity.

The ‘why’ of neutrino physics

We are entering an era in experimental neutrino physics whose main thrust will likely be twofold:

better understanding of the nature of the neutrino, i.e., a study of the neutrino properties, and use of the neutrino in astrophysics and cosmology as an alternative window on the universe, to supplement investigations with electromagnetic radiation. The MINOS experiment, which addresses the subject of neutrino oscillations, will make important contributions to the first part of this program.

Neutrinos are among the fundamental constituents in nature. The space around us is permeated with neutrinos which are relics of the Big Bang, with about 110 ν's/cm^3 for every neutrino flavor. But our knowledge of the neutrino's properties lags far behind our knowledge of other elementary constituents, for example, the charged leptons. A few examples will illustrate this point, quoting lepton values from the Particle Data Group:

- We do not know the size of neutrino masses; our current information gives us only upper limits ranging from a few eV for ν_e to some 20 MeV for ν_τ. We can contrast that with a fractional mass error of about 3×10^{-7} for the electron and muon and about 2×10^{-4} for the tau.

- We do not know if neutrinos are stable or decay, either into neutrinos of other flavors or into some new, as yet undiscovered, particles. In contrast, we know that the electron is stable, and we know the muon lifetime with a fractional error of 2×10^{-5} and the tau lifetime at the level of 0.5%.

- Finally, we do not know if the neutrinos have electromagnetic structure, for example a magnetic moment. The electron magnetic moment is known with a precision of about one part in 10^{11}, and the magnetic moment of the muon to one part in 10^8.

These are only a few examples of our incomplete picture of the basic nature of neutrinos, but they are sufficient to demonstrate that almost half a century after their discovery, neutrinos are still poorly understood. Because of their fundamental nature, we cannot profess to understand our universe without understanding neutrinos.

The study of neutrino oscillations offers potentially the most sensitive means to search for and to measure neutrino masses (or, to be precise, neutrino mass-squared differences). Observation of a nonzero neutrino mass, which follows directly from the observation of neutrino oscillations, is a clear example of a breakdown of the Standard Model and thus an indication of physics beyond it. Many of the popular extensions of the Standard Model do indeed predict nonzero neutrino masses and the existence of neutrino oscillations.
Furthermore, neutrino oscillations are more than just an attractive theoretical concept; the existence of the phenomenon is strongly suggested by several experimental observations:

a) The need for dark (i.e., non-shining) matter is based mainly on three phenomena: the motion of galaxies within clusters of galaxies, the rotational curves for stars in spiral galaxies, and the successes of inflationary Big Bang cosmology which predicts that the density of the universe equals the so-called critical density. Neutrinos, since they are present in abundance everywhere, account for at least a part of the dark matter.

b) The solar neutrino deficit, i.e., the observation of fewer sun-originated neutrinos on earth than is expected from the known solar luminosity.

c) The atmospheric neutrino anomaly, i.e., a measured ν_μ / ν_e ratio for neutrinos from cosmic ray interactions in our atmosphere which is significantly smaller than predicted. The hypothesis that this anomaly is caused by neutrino oscillations is strongly supported by the observation of an up-down asymmetry in the atmospheric ν_μ flux by the Super-Kamiokande Collaboration, as well as by their studies of upward going muons.

d) The apparent observation of $\nu_{e(bar)}$ in an almost pure ν_μ beam in the Los Alamos LSND experiment.

The MINOS experiment can explore a large region in oscillation parameter space. Furthermore, it can confront directly and conclusively the atmospheric neutrino anomaly and should be able to check the validity of the oscillation interpretation for the LSND effect. The underlying principle behind neutrino oscillations is the fact that a generalized neutrino state can be expressed either as a superposition of different mass eigenstates or of different flavor eigenstates. This is mainly a restatement of a well-known quantum mechanics theorem that, in general, several different basis vector representations are possible, with the different representations being connected by a unitary transformation.

Other well-known examples of this principle in particle physics are the $K^o / K^{o(bar)}$ system (strong interaction and weak interaction eigenstates) and the quark system (weak interaction and flavor eigenstates connected by the CKM matrix). From the study of e^+e^- annihilations at the Z^o peak, we know that there are only three light neutrino flavor eigenstates. Accordingly, the most likely situation is that we have three mass eigenstates and that the connecting unitary matrix is a 3x3 matrix. This is not rigorously required since we could have states with $m_\nu > m_Z/2$ or flavor states that do not couple to the Z^o. There has recently been significant theoretical effort to see whether such mechanisms could explain some of the anomalous effects seen in neutrino experiments.

IV. Fermilab and the Large Hadron Collider: A major stakeholder in the physics to come

The US has a $531 million commitment to provide accelerator and detector components for the Large Hadron Collider, which is under construction at CERN, the European Particle Physics Laboratory in Geneva, Switzerland, and which will begin operations later this decade.

The LHC is projected to achieve a center-of-mass energy of 14 TeV, some seven times the center-of-mass energy at the Tevatron, and about 10 times the effective constituent energy of the machine it replaces at CERN, the Large Electron-Positron Collider. In mounting proton-proton collisions, LHC will have beam crossings every 25 nanoseconds (compared to 396 nanoseconds now at the Tevatron), anticipating 20 to 30 collisions at every beam crossing. The luminosity, a measure of the collision rate, will reach 10^{34} cm^{-2} sec^{-1}, about 100 times that of the Tevatron.

When operational, the LHC will probe deeper into matter than ever before to explore a new energy region and search for new phenomena. The 27-kilometre rings of the LHC will circulate two counter-rotating beams of protons at nearly the speed of light (300,000 kilometers or 186,000 miles per second) while maintaining the protons precisely at the center of the beam pipe containing them.

With a major role in construction of LHC accelerator and detector components, Fermilab will be positioned for a major role in the emerging physics of the LHC.

Accelerator efforts

The US LHC Accelerator Project is led by Fermilab and carried out by three US national laboratories: Fermilab, Brookhaven National Laboratory (BNL) and Lawrence Berkeley National Laboratory (LBNL). The project focuses on the four Interaction Regions (IRs) and the radio-frequency straight section of the LHC Accelerator, testing of superconducting cable for the main LHC magnets, and accelerator physics calculations.

Fermilab, in collaboration with LBNL and BNL, is responsible for providing CERN with integrated inner triplet magnet systems for the IRs, which focus and bring the two proton beams into collision at the interaction points. The inner triplet systems consist of high-gradient quadrupoles provided both by Fermilab and the KEK laboratory in Japan, correction coils provided by CERN, dipole magnets provided by BNL, cryogenic feedboxes provided by LBNL, and absorbers provided by LBNL to protect the superconducting magnets from the collision debris. In addition to building half of the quadrupoles, Fermilab is responsible for the integration of the Fermilab, KEK and CERN provided magnets into three different types of quadrupole-corrector assemblies, insertion of these into cryostats, and the final measurements and tests of these assemblies.

The superconducting quadrupole magnets, which provide final focusing of the LHC beams at the interaction points, are some of the most challenging components of the machine. They must provide a field gradient of up to 215 Tesla/meter over a 70 mm aperture. They operate at 1.9 K, under heavy heat load due to secondary particles from beam-beam collisions. The LHC performance depends critically on their field quality. Following an intensive R&D program, in which nine model magnets and one full-scale prototype were built and tested, the inner triplet quadrupoles for the LHC are now in production at Fermilab. Four of the 18 quadrupoles that Fermilab will build are complete and two more are in production.

The first KEK and CERN provided magnets have arrived at Fermilab. The first quadrupole-corrector assembly, consisting of two Fermilab quadrupoles with a CERN correction coil, is being readied for insertion into its cryostat and is being tested. Production and testing of the quadrupoles will continue for the next two and one-half years, and all inner triplet quadrupoles will be delivered to CERN for installation in LHC by the end of 2004. The US LHC Accelerator Project is more than 75 percent complete, and is proceeding on schedule.

The development, construction and testing of these very challenging magnets for LHC helps to ensure that Fermilab and the US High Energy Physics program remain at the cutting edge of superconducting magnet technology. The lab's work with CERN (and KEK) on the construction of the LHC accelerator is an important step forward in international collaboration in large science projects, which will be crucial for the construction of future large accelerator facilities.

Fermilab is now preparing to extend this collaboration into the commissioning and operational periods of the LHC, and the lab is working with CERN to increase the luminosity of the LHC in order to extend its scientific reach. The US LHC Accelerator Research Program, which will be carried out by the same three US national laboratories under Fermilab's leadership, will focus on the commissioning of the LHC, accelerator physics experiments and calculations, R&D for quadrupoles of even higher performance than those now under construction for the inner triplet systems, and the development of advanced beam instrumentation and diagnostics.

This program will further develop the US laboratories' capabilities, so that the US can be the leader in the next generation of hadron colliders; it will serve as a vehicle for US accelerator specialists to pursue their research; and it will train future generations of physicists on some of the most advanced problems in accelerator physics.

The Compact Muon Solenoid detector, and US CMS

The Compact Muon Solenoid detector uses a large superconducting solenoid, with a length of about 12m and an inner diameter of about 6m—the largest magnet of its type ever constructed. The field strength will be 4 Tesla—about 100,000 times that of the earth's magnetic field. The conductor itself is made of so-called Rutherford Cable—Niobium-Titanium (NbTi) strands coated with a copper stabilizer. This cable is surrounded by an ultra-pure aluminium stabilizer, which is then surrounded by an aluminium alloy for strengthening purposes. The complete CMS detector stands 15 meters high and almost 22 meters long, and weighs about 12,500 tons.

The design of CMS allows all tracking devices and calorimetry to be placed inside the coil of the solenoid—resulting in a compact overall detector. Outside the coil will be a steel return yoke, built in layers, interspersed with muon detectors. The configuration of the magnetic field means that the momentum of muons will be measured both inside the coil (by the tracking devices) and outside the coil (by the muon chambers). Muons are extremely important in particle physics; they signify that "something interesting has happened," and thus can be used to help find a figurative "needle in a haystack."

At the same time, the Compact Muon Solenoid is a general-purpose detector designed to run at the highest luminosity at the LHC. It is also adapted for studies at the initial lower luminosities. The main design goals of CMS have been to achieve the highest performance muon system, electromagnetic calorimeter and central tracking system, and a hermetic hadron calorimeter.

Fermilab is involved in US-CMS as both the host laboratory and collaborating institution. The US-CMS project is proceeding on schedule. Fermilab and project management have been planning the transition to the CMS research program for two years, and the effort was baselined by a review in April 2002. Fermilab is working to integrate the CMS research program into the laboratory, and the first Ph.D. from US-CMS has been awarded for work on the alignment of the endcap muon chambers.

Fermilab has been responsible for construction of the Hadron Calorimeter for CMS. The completed CMS HCAL barrel and endcap weigh about 1600 tons, and most of the component weight is copper. It represents the heaviest copper alloy structure ever built. HCAL is similar in design to the end-plug calorimeter at Fermilab's CDF detector, and the proposed SDC calorimeter at the SSC. The magnetic field inside CMS will be 4 Tesla, double the strength of Fermilab's DZero detector (2T) and nearly three times that of CDF (1.4T). The higher magnetic field produces more bending, and thus higher differentiation, in particle tracks.

Fermilab's Silicon Detector Facility, already setting new standards with Run II detectors at Fermilab, has played a critical production role for the CMS all-silicon tracker. The unique facility produces silicon strip modules for the CMS tracker outer barrel, and will produce silicon pixel disks for the CMS forward tracking system.

The end-cap muon chambers, or cathode strip chamber (CSC) system, machined and assembled at Fermilab's Lab 8 and MP9, comprise the largest system of its kind anywhere, by a factor of 10. There are nearly 500 chambers with six layers in each chamber.

A revised design for the forward tracker has three disks at each end, for a total of 43 million pixels. Arranged like turbine blades on the disk, each individual detector is 8 mm x 10.45 mm, with a 52x53 pixel array, and is equivalent to 380K transistors. The pixel array will produce a resolution up to 15 microns (millionths of a meter). Among these detectors' responsibilities: putting a time stamp on the bunch crossings, which will be 25 nanoseconds (billionths of a second) apart.

Fermilab's microelectronics group has developed two radiation-hard chips for HCAL, one (QIE) based on earlier chips for CDF and KTeV and the other (CCA) an entirely new design. QIE takes signals from photomultiplier tubes and digitizes them over a wide dynamic range at high frequency. CCA takes output data from QIE chips and provides phase adjustment for data, and interfaces to the DAQ system.

Fermilab also will serve as the regional computing center for US CMS, which includes nearly 400 scientists from 37 institutions across the country (the worldwide CMS collaboration numbers approximately 1,800 scientists in 144 institutions). Fully functional prototypes of the software are already in use, and Fermilab has simulated more than four million Monte Carlo events for US CMS.

CMS is well-positioned for possible discoveries in the areas of Supersymmetry and Higgs physics.

The overall CMS detector experiment is one of the largest international scientific collaborations in history. As of February 2003, there were 2,300 people working for CMS, of whom 1,940 are scientists and engineers. Collaborators come from 159 institutes in 36 countries, spanning Europe, Asia, the Americas and Australasia.

V. Particle Astrophysics : Mapping the skies, tracking down the highest-energy cosmic rays, hunting for dark matter

Fermilab has special capabilities to mine the growing convergence between particle physics and astrophysics. The Laboratory already has a track record of making a big impact with modest resources. The current experiment effort is focused on three projects: the Sloan Digital Sky Survey, the Pierre Auger Observatory and the Cryogenic Dark Matter Search.

SDSS: Mapping the sky

Fermilab is responsible for project management and for data handling of the Sloan Digital Sky Survey, the most ambitious astronomical survey ever undertaken. During its five-year mission, the survey will create a detailed map of one-quarter of the entire sky, determining the positions and absolute brightnesses of more than 100 million celestial objects. It will also measure the distances to more than a million galaxies and quasars.

The SDSS with its Apache Point Observatory in New Mexico addresses fascinating, fundamental questions about the universe. With the survey, astrophysicists are mapping the large-scale patterns of galactic sheets, clusters, and voids in the universe. Different patterns of large-scale structure point to different ways the universe might have evolved.

In July 2003, SDSS scientists announced the discovery of independent physical evidence for the existence of dark energy. The researchers found an imprint of dark energy by correlating millions of galaxies in the Sloan Digital Sky Surve and cosmic microwave background temperature maps from NASA's Wilkinson Microwave Anisotropy Probe (WMAP). The researchers found dark energy's "shadow" on the ancient cosmic radiation, a relic of cooled radiation from the Big Bang.

With the combination of results from these two large sky surveys, this discovery provides physical evidence for the existence of dark energy; a result that complements earlier work on the acceleration of the universe as measured from distant supernovae. Measurements of the Cosmic Microwave Background (CMB) by the Balloon Observations of Millimetric Extragalactic Radiation and Geophysics (BOOMERANG) were also part of the earlier findings.

Dark energy, a major component of the universe and one of the greatest conundrums in science, is gravitationally repulsive rather than attractive. This causes the universe's expansion to accelerate, in contrast to the attraction of ordinary (and dark) matter, which would make the expansion decelerate. In a flat universe, the observed effect only occurs with the presence of dark energy. As photons from the cosmic microwave background travel to us from 380,000 years after the Big Bang, they can experience a number of physical processes, including the Integrated Sachs-Wolfe effect. This effect is an imprint or shadow of dark energy on microwaves. The effect also measures the changes in temperature of cosmic microwave background due to the effects of gravity on the energy of photons.

Photons streaming from the cosmic microwave background pass through many concentrations of galaxies and dark matter. As they fall into a gravitational well they gain energy (just like a ball rolling down a hill). As they come out they lose energy (again like a ball rolling up a hill). Photographic images of the microwaves become more blue (i.e. more energetic) as they fall in toward these supercluster concentrations and then become more red (i.e. less energetic) as they climb away from them. In a universe consisting mostly of normal matter, the net effect of the red and blue shifts would be expected to cancel. However in recent years, findings indicate that most of the content in our universe is abnormal in that it is gravitationally repulsive rather than gravitationally attractive. This abnormal content is called dark energy.

The net energy change expected from a single concentration of mass is less than one part in a million and researchers had to look at a large number of galaxies before they could expect to see the effect. Results confirm that dark energy exists in relatively small mass concentrations: only 100 million light years across. The previously observed effects of dark energy were on a scale of 10 billion light years across. A unique aspect of the SDSS data is its ability to accurately measure the distances to all galaxies from photographic analysis of their photometric redshifts, thus watching the imprint of the Sachs-Wolfe effect on the CMB grow as a function of the age of the universe.

The discoveries were made in surveys of 3,400 square degrees of the sky.

The Sloan Digital Sky Survey also has discovered the most distant quasars ever recorded. Studies of the image distortion due to the gravitational bending of light show that the unseen dark matter "halos" surrounding galaxies are about twice as large as previously believed. And still other data suggest that our Milky Way galaxy has cannibalized other galaxies: our galaxy's halo contains huge clumps of stars that appear to be the remains of smaller galaxies assimilated by the Milky Way more than a billion years ago.

Tens of thousands of asteroids have been detected in the database, providing the statistical power to chart the distribution of asteroid families according to chemical composition and orbital types. Asteroid families are presumed to have originated in the same parent object, which allows evolutionary processes in the solar system to be investigated.

Thus far, SDSS has generated 173 publications (103 in refereed journals), and 28 Ph.D. theses. The second public data release (DR2) will be made late in March 2004, comprising 3300 square degrees of imaging data and 360,000 object spectra. SDSS plans a major presence at the American Astronomical Society meeting in Dallas in June 2004, including a presentation on multi-wavelength studies of galaxies.

Pierre Auger Observatory: World's largest cosmic air-shower array

With some 200 surface detectors near the town of Malargue, Argentina, the Pierre Auger Observatory is the largest cosmic-ray air shower array in the world. Managed by Fermilab, the Pierre Auger project already encompasses a 70-square-mile array of detectors tracking the most violent processes in the entire universe—and perhaps the most puzzling.

Cosmic rays are extraterrestrial particles, usually protons or heavier ions-that hit the Earth's atmosphere and create cascades of secondary particles. While cosmic rays approach the earth at a range of energies, scientists long believed that their energy could not exceed 10^{20} electron volts, about 100 million times the proton energy achievable in Fermilab's Tevatron, the most powerful particle accelerator in the world. But recent experiments in Japan and Utah have detected a few such ultrahigh energy cosmic rays, raising questions about what extraordinary events in the universe could have produced them. The Pierre Auger collaboration of 250 scientists from 14 countries aims at tracking these ultrahigh-energy particles back to their sources, to answer the question of how nature accelerates a tiny particle to such an extraordinary energy.

Scientific theory can account for the sources of low- and medium-energy cosmic rays, but the origin of these rare high-energy cosmic rays remains a mystery. To identify the cosmic mechanisms that produce microscopic particles at macroscopic energy, the Pierre Auger collaboration is installing an array that will ultimately comprise 1,600 surface detectors in an area of the Argentine Pampa Amarilla the size of Rhode Island, near the town of Malargüe, about 600 miles west of Buenos Aires.

The highest-energy cosmic rays are extremely rare, hitting the Earth's atmosphere about once per year per square mile. When complete in 2005, the Pierre Auger observatory will cover approximately 1,200 square miles (3,000 square kilometers), allowing scientists to catch many of these events. The project will pick up from the point where the Akeno Giant Air Shower Array (AGASA) experiment in Japan has left off, attempting to resolve the conflict between AGASA and the HiRes experiment in Utah. AGASA sees more events than HiRes, but the statistics of both experiments are limited.

The Pierre Auger project, named after the pioneering French physicist who first observed extended air showers in 1938, combines the detection methods used in the Japanese and Utah experiments. Surface detectors are spaced one mile apart. Each surface unit consists of a four-foot-high cylindrical tank filled with 3,000 gallons of pure water, a solar panel, and an antenna for wireless transmission of data. Sensors inside the tanks register the debris of the invisible particle avalanches, triggered at an altitude of six to twelve miles just microseconds earlier, as it reaches the ground. The particle showers strike several tanks almost simultaneously.

In addition to the tanks, the new observatory will feature 24 HiRes-type fluorescence telescopes that can pick up the faint ultraviolet glow emitted by air showers in mid-air. The fluorescence telescopes, which can only be operated during dark, moonless nights, are sensitive enough to pick up the light emitted by a four-watt lamp traveling six miles away at almost the speed of light. By examining the air showers in two ways, the project can measure the shower energy in two independent ways, allowing cross-calibration.

The Auger Observatory has deployed more than 200 surface detector stations and hopes to have nearly half of the full array (800) by the end of 2004. By June of 2004, the collaboration will will have half of the observatory's 24 fluorescence telescopes operational. By the end of 2004 the Observatory hopes to have a data set which will allow a meaningful comparison of results with those of the AGASA array in Japan.

The Auger collaboration is also in the process of preparing a proposal for a second site of its observatory, to be located in the United States. Featuring the same design as the Argentinean site, the second detector array would scan the northern sky for sources of the most powerful cosmic rays.

Funding for the Pierre Auger Observatory in Argentina has come from the 14 member nations: Argentina, Australia, Brazil, Czech Republic, France, Germany, Italy, Mexico, Poland, Slovenia, Spain, United Kingdom and the United States (two associate members, Bolivia and VietNam, participate through Brazil and France, respectively) . The U.S. contributes 20 percent of the total cost, with support provided by the Office of Science of the Department of Energy and by the National Science Foundation.

CDMS: Combined effort in searching for dark matter

Using detectors chilled to near absolute zero, from a vantage point half a mile below ground, physicists of the Cryogenic Dark Matter Search announced on November 12, 2003 the launch of a quest that could lead to solving two mysteries that may turn out to be one and the same: the identity of the dark matter that pervades the universe, and the existence of supersymmetric particles predicted by particle physics theory. Scientists of CDMS II, an experiment managed by Fermilab, hope to discover WIMPs, or weakly interacting massive particles, the leading candidates for the constituents of dark matter—which may be identical to neutralinos, undiscovered particles predicted by the theory of supersymmetry.

The CDMS II experiment, a collaboration of scientists from 12 institutions with support from DOE's Office of Science and the National Science Foundation, uses a detector located deep underground in the historic Soudan Iron Mine in northeastern Minnesota. Experimenters seek signals of WIMPs, particles much more massive than a proton but interacting so weakly with other particles that thousands would pass through a human body each second without leaving a trace. Remarkably, in the kind of convergence that gets physicists' attention, the characteristics of this cosmic missing matter particle now appear to match those of the supersymmetric neutralino.

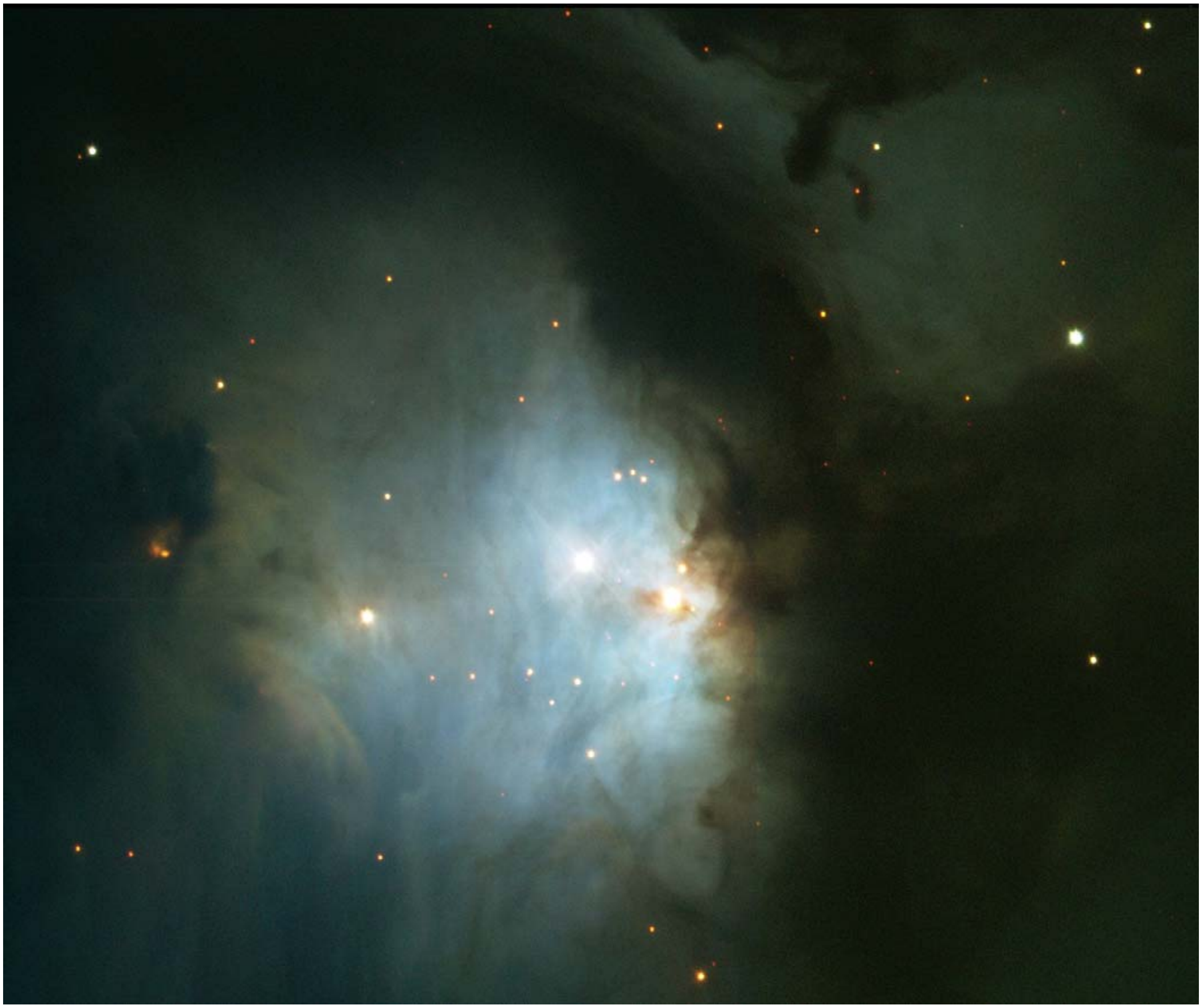
Raymond Orbach, Director of the Department of Energy's Office of science, has lauded CDMS a "a good example of cooperation between the DOE's Office of High Energy Physics and the National Science Foundation in helping scientists address the origin of the dark matter in the universe." Michael Turner, Assistant Director for Math and Physical Sciences at the Natinal Science Foundation, described CDMS II as "the kind of innovative and pathbreaking research NSF is proud to support."

By watching how galaxies spin—how gravity affects their contingent stars—astronomers have known for 70 years that the matter we see cannot constitute all the matter in the universe. If it did, galaxies would fly apart. Recent calculations indicate that ordinary matter containing atoms makes up only 4 percent of the energy-matter content of the universe. "Dark energy" makes up 73 percent, and an unknown form of dark matter makes up the last 23 percent.

Measurements of the cosmic microwave background, residual radiation left over from the Big Bang, have recently placed severe constraints on the nature and amount of dark matter. The lightweight neutrino can account for only a few percent of the missing mass. If neutrinos constituted the main component of dark matter, they would act on the cosmic microwave background of the universe in ways that the recent Wilkinson Microwave Anisotropy Probe should have observed—but did not.

Meanwhile, particle physicists have kept a lookout for particles that will extend the Standard Model, the theory of fundamental particles and forces. Supersymmetry, a theory that takes a big step toward the unification of all of the forces of nature, predicts that every matter particle has a massive supersymmetric counterpart. No one has yet seen one of these supersymmetric "superpartners." Theory specifies the neutralino as the lightest neutral superpartner, and the most stable, a necessary attribute for dark matter. The neutralino's predicted density and rate of interaction also make it a likely dark matter candidate.

Only occasionally would a WIMP hit the nucleus of a terrestrial atom, and the constant background “noise” from more mundane particle events—such as the common cosmic rays constantly showering the earth—would normally drown out these rare interactions. Placing the CDMS II detector beneath 740 meters of earth screens out most particle noise from cosmic rays. Chilling the detector to 50 thousandths of a degree above absolute zero reduces background thermal energy to allow detection of individual particle collisions. Fermilab’s Bauer estimates that with sufficiently low backgrounds, CDMS needs only a few interactions to make a strong claim for detection of WIMPs. While CDMS II watches for WIMPs, scientists at Fermilab’s Tevatron particle accelerator will try to create neutralinos by smashing protons and antiprotons together.



VI. Computing: The indispensable tool

Fermilab could not achieve the high-energy physics frontier without such cutting-edge computing capabilities. For example:

** The automated tape libraries in Fermilab's Feynman Computing Center achieved a milestone on August 20, 2003: accumulating one petabyte of data, an amount equal to one million gigabytes or one thousand terabytes.*

** Scientists from CDF, DZero and other experiments and projects rely upon robotic storage to archive raw data as it is acquired from the detectors. Capable of storing up to six petabytes of data, the robotic storage already holds approximately thirty times the amount of data that was recorded during Run I.*

** On an average day at Fermilab, approximately ten terabytes of data are transferred from experiments to robotic storage. To put this number into perspective, the entire Library of Congress, the largest library in the world, with approximately 530 miles of bookshelves, is also equivalent to ten terabytes. With this statistic in mind, on any given day at Fermilab, the robotic storage transfers an amount of data that is approximately equivalent to the Library of Congress if not more.*

** In Collider Run II of the Tevatron, Fermilab is meeting data acquisition and storage challenges that are unprecedented in high-energy physics. The tracking equipment housed in each of the 5,000-ton collider detectors, CDF and DZero, are delivering on the order of 250 kilobytes of data per collision event and 20 megabytes of data per second, storing more than 200 terabytes of raw data a year and producing more than 100 terabytes of data for a year's worth of final physics analysis. (By comparison, it would take more than 10,000 PC's, each with a 30-megabyte hard drive, to handle 300 terabytes of data.) The data accumulation rate is at least 20 times the data rate in Run I of the Tevatron, and thus, the total stored data will probably grow to at least 20 times the amount of Run I data.*

The data acquisition, storage, and processing challenges rely critically on robust and high bandwidth network infrastructures, both on the Fermilab site and linking to outside institutions.

Fermilab's Computing Division provides round-the-clock computing facilities for data processing and analysis for Run II, and also for MINOS, MiniBooNE, remaining fixed-target experiment analyses, and new physics computations (such as accelerator simulations) as they arise.

A major near-term focus for Computing will be to provide the data processing and analysis systems for Run II analysis. The many years of meeting Run II data taking and data processing needs will lead to increased reliance on all available collaboration computing – whether at Fermilab or the remote institutions – to achieve the physics results. Robust and high speed distribution of the data over the wide area networks has become an absolute necessity, given the numbers of scientists and institutions working all over the country and around the world.

Fermilab also is establishing a data sharing system with CERN for US CMS. Fermilab will become a Tier I Regional Center for storing and distributing data when the CMS experiment begins taking the data later this decade. The computing hub project has received both DOE and NSF support. Fermilab, the host laboratory for the U.S. collaboration building subassemblies of the CMS detector, is the collaboration's host laboratory for software, analysis and computing support. As host, Fermilab will have a continually updated copy of all the data used for analysis at CERN, and make it available to all scientists, at all universities and laboratories in the U.S. collaboration of 35 institutions in 19 states.

From the Scientific Discovery Through Advanced Computing (SciDAC) program in the DOE Office of Science, Fermilab physicists and computer scientists are receiving approximately $1.28 million a year for the next three years to participate in five nationwide collaborations: the Particle Physics DataGrid; Advanced Computing for 21st Century Accelerator Science and Technology; the National Computational Infrastructure for Lattice Gauge Theory, Storage Resource Management and Site Authentication and Authorization

These efforts share ambitious scientific goals: creating computer tools that will allow physicists to work at their home base with up-to-the-second experimental data from sources anywhere the world; and adapting those access tools to design the high-energy physics discovery machines of the future more efficiently and economically. As the major next step enabled by the SciDAC awards, the collaborations will help create a new generation of scientific simulation codes for "terascale" computers: computers capable of making trillions of operations per second ("teraflops"), while handling trillions of bytes of data ("terabytes").

Lattice Gauge/QCD: Power off the shelf

The theory of quantum chromodynamics describes the evolution and properties of all quark systems. Equations in the full QCD theory use a four-dimensional lattice. To approximate a volume as large as a proton, a typical calculation requires a grid of 24x24x24 points. The fourth dimension, which tracks the evolution in time, might be cut in 48 slices, resulting in a 660,000-point lattice.

Precise lattice calculations are essential for measurements of the mixing of strange B and Bbar mesons, to illuminate the tiny difference in the behavior of matter and antimatter. Since autumn of 2001, Fermilab has gained the financial means for increasing computing power for lattice QCD. As one of the first awards in the Scientific Discovery through Advanced Computing program, the Department of Energy committed almost $2 million over three years to Fermilab to develop a new supercomputer system. The SciDAC grant is part of a nation-wide effort to provide teraflop computing power for lattice theory projects in nuclear and high-energy physics, one of many SciDAC computing initiatives.

Collaborating with scientists from universities and national laboratories, Fermilab theorists are building a computer cluster consisting of 512 PCs, all off-the-shelf components. Each node will have a processor capable of more than one gigaflop, and all nodes will be able to communicate with each other. Creating a teraflop machine (one million million floating point operations per second) for lattice theory requires both high-speed processors and high-speed communication.

In lattice QCD computations, communication among different nodes is a crucial element of the calculation, since all nodes need to share data on the quark fields. Each node is responsible for a subset of lattice points, and each node constantly exchanges information with neighbors. Superfast communication hardware is the key to creating the best lattice supercomputers.

Advanced Computing for 21st Century Accelerators

The SciDAC accelerator modeling project is a national research and development effort whose primary objective is to establish a comprehensive terascale simulation environment needed to solve the most challenging problems in 21st century accelerator science and technology.

In June 2002, a SciDAC team announced the development of a new code for modeling colliding beams, with a collective set of capabilities making it unique among beam-beam simulation codes: it is parallel; it uses a slice model; it can model offset beams; and it can model collisions with a finite crossing angle. As an initial test, a simulation was performed to study the coherent beam-beam dipole oscillation in the LHC. The code will now be applied to modeling the Fermilab accelerator complex.

The code includes a new algorithm for solving Poisson's equation that is very efficient for modeling the long-range offset colliding beam situation. The team showed that it is possible to use a Green’s function approach without gridding the full region. The ability to accurately model and predict the performance of colliders is important to many accelerator projects, including the Tevatron, the PEP-II B-factory at SLAC, the Relativistic Heavy Ion Collider (RHIC), and the LHC.

U.S. Physics Grid Projects

The Particle Physics Data Grid is integrating and developing Grid-enabled tools for the data-intensive requirements of particle and nuclear physics. The poject is in collaboration with leading computer scientists in the field. Their goal is to bring Grid-enabled data manipulation and analysis capabilities to the desk of every physicist.

The GriPhyN (Grid Physics Network) collaboration is funded by the NSF. This team of experimental physicists and information technology (IT) researchers is investigating computational environments called Petascale Virtual Data Grids (PVDGs) to meet the data-intensive computational needs of the participating experiments

The International Virtual Data Grid Laboratory is an NSF funded collaboration that will enable Fermilab to work with the distributed TeraGrid and other initiatives together with US, European and Asian colleagues to achieve the CMS and other experiment data analysis goals.The three US Physics Grid projects are working closely with CERN and the European Grid projects to provide seamless distributed computing environments for the LHC experiments.

Challenges in data acquisition

In yet another area of computing advances, Fermilab hopes to contribute understanding to the issue of why things don't work as well as we'd like. The BTeV (B Physics at the Tevatron) experiment trigger will be challenged to reconstruct 15 million particle events per second, and to use that reconstruction data in deciding which events to keep for further analysis, while concurrently findingand correcting errors. With an Informational Technology Research grant from NSF, BTeV is building an advanced, fault tolerant system into its trigger and data acquisition project. BTeV must assemble as many as 10,000 parallel computers and make them work together dependably and consistently in the triggering and DAQ systems, despite incorporating different kinds of computers with different tasks. This is another project which teams physicists and computer scientists to find solutions to particle physics experiment problems.

5

Operations and Infrastructure

I. Environment, Safety and Health

Fermilab's emphasis on integrating environment, safety and health into employee work tasks during the past several years has resulted in a remarkable reduction of employee injuries. The accelerator was shutdown for 8 weeks during FY03 to allow for upgrades and maintenance work in the tunnel. This significantly increased the opportunity for injury as a number of employees and subcontractors faced higher than normal occupational hazards. Due to the extensive work planning that was conducted prior to the shutdown, however, injury rates have actually been lowered. In fact, the number of Total Recordable Cases and DART (Days Away, Restricted or Transferred) Cases for FY03 was the lowest in Fermilab's entire history.

Holding subcontractors to Fermilab's high expectations is always a challenge. In 2003, the Laboratory Director established a safety panel to examine the problems that gave rise to unacceptably high construction subcontractor injury rates the previous year. The panel included members from Fermilab and subcontractor management, as well as outside experts from DuPont and ExxonMobil. The reviewers concluded that Fermilab has a sound construction safety program that is continuing to mature. There was ample evidence of ownership and safety leadership on the part of most Fermilab employees. There was also a demonstrated desire on the part of subcontractors and their employees to work safely. The panel also identified several other positive aspects of the program, including the use of an integrated project team to manage activities from the very beginning, as well as the observation that subcontractor personnel indicate that Fermilab is a safe place to work.

The NuMI construction project has presented a formidable safety challenge over the last couple of years. This $30 million tunneling project required significant daily attention to be certain that the plethora of environmental and safety hazards were being adequately mitigated. As the civil construction of this project moved from the tunneling phase into the more conventional surface buildings and outfitting phase, and as safety expectations are continually reinforced with the subcontractor, injury rates have been quite low. The next safety challenge is to install the experimental components with the same degree of planning and care that has been exhibited during recent laboratory shutdowns.

With an eye toward reducing its environmental liabilities, Fermilab continues to invest a significant portion of its operating funds toward the cleanup and conversion of its onsite facilities. In FY02-03, the laboratory continued its Restoration and Renovation Program with the cleanout and materials recovery activities at a former target hall. A large amount of the removed materials were either earmarked for reuse or recycled. Only a small amount of material required disposal as low-level radioactive waste. In addition, a new compressed natural gas vehicle refueling system was added at the lab's refueling station. This will service the twenty-six bi-fuel vehicles at Fermilab. Other projects included the reuse of water from the NuMI project tunnel to supplement cooling water; process improvements to reduce waste and effluent discharges from magnet flushing; and refurbishment and distribution of abandoned bicycles to reduce vehicle use.

Security Issues

Fermilab conducts no classified research. In response to the terrorist attacks of September 11, 2001, the lab took several precautionary measures to control access to its facilities. An additional six security personnel began patrolling the lab regularly. Laboratory employees were required to wear badges for the first time. Visitors were required to obtain passes when entering on laboratory business. Recreational use of the site was prohibited.

In attempting to balance the need for security with the laboratory's heritage of openness to the public, Fermilab continued to hold public events such as the Enrico Fermi Centennial Celebration and the Fermilab Arts and Lecture Series, and to allow access to the Leon Lederman Science Education Center. Additional restrictions were placed on parking locations for those attending the Arts Series events. In the ensuing months, Fermilab permitted access to walkers, joggers and bikers without requiring visitors' passes. In May 2002, the special Buffalo Viewing Pass was introduced, allowing visitors to drive areas adjacent to the buffalo pasture for viewing the herd that has stood at Fermilab since introduced by founding director Robert Rathbun Wilson in 1968. In June 2002, the lab introduced proximity card access to buildings regarded as sensitive areas not open to the public. Only employees and users with properly coded identification cards were able to enter these buildings.

With due diligence to security requirements, Fermilab maintains its commitment to welcoming the public to a 6,800-acre site offering many opportunities for recreation and the appreciation of nature.

ISSM

Fermilab embraces the principles of Integrated Safeguards and Safety Management (ISSM), in the same way it embraces Integrated Safety Management (ISM). By integration, we mean that security, like safety, is not treated separately, but is considered as we plan our work, conduct our work and check our work after it is finished. Fermilab has used the same infrastructure for instituting ISSM as that used for carrying out ISM. Line management is responsible for security, just as it is for safety, and uses the existing safety or security support services for assistance in carrying out these responsibilities. The lab has integrated all ISSM steps requiring new action and is now in the maintenance stage, looking for new ways to strengthen security. DOE classifies Fermilab as a "Property Protection Site." The lab has no classified material, no attractive nuclear material, and no proprietary data. Thus, our security responsibilities are much less intensive than those of other DOE sites.

Kerberos

To enhance computer security, Fermilab has adopted Kerberos, a system of "strong authentication" for computer users invented at the Massachusetts Institute of Technology, is already operating at many universities and several Department of Energy national laboratories. Fermilab introduced Kerberos for the CDF and DZero experiment collaboration computers during 2000, with a goal of extending the protection to the entire site.

Kerberos strives for the best balance between security and freedom by addressing the question of identity, and attempting to prevent identity theft. Kerberos establishes proof of identity ("user authentication") through cryptographic calculations at local computers, with a central server validating the proof. Kerberos aims to keep passwords from being transferred over networks, where they are vulnerable to "sniffers:" programs that watch for passwords going by, and harvest them for identity theft. Unfortunately, sniffers are everywhere.

Kerberos acts as a gatekeeper for access to certain high-priority services, while leaving lower priority services alone. There will be two access routes, via software or cryptocard. The first route involves installing software on a desktop computer so a user can prove a Kerberos identity locally. The desktop will exchange information with the Key Distribution Center, which issues a key or ticket good for a computer anywhere in the lab. The alternate route involves a cryptocard, which produces a one-time password. A user without a Kerberos identity will be given a cryptocard challenge, which, if passed, issues a one-time, one-use password.

The lab also has a "volunteer fire department," the Fermilab Computer Incident Response Team. Volunteers from many areas of the lab take turns being on call to "put out fires," providing the first line of defense against unauthorized access. Crawford admitted that Kerberos won't plug every hole, but pointed to its widespread acceptance through its adoption by vendors including Microsoft, Sun, Cisco, IBM and many others. In addition, the goal for the security system is to maintain openness and minimize disruptions in communicating scientific information.

II. Office of Public Affairs: Reaching neighbors, local and world-wide

Fermilab has always been a good place to visit, and it always will be. The Arts and Lectures Series annually draws about 11,000 patrons; the Education Office annually works with nearly 7,000 teachers, and with more than 1,000 adults in tour groups. The annual Tornado Seminar in April draws an audience of about 2,500. Before the events of Sept. 11, 2001 led to restricted access, Public Affairs was the unofficial greeter for more than 30,000 visitors annually for self-guided tours and recreational purposes around the site. As a gauge of the level of interest in the lab and its environs, the last site-wide open house drew 15,000 visitors in 1997.

Maintaining access

While increased security concerns have led to curtailments of the lab's historically open nature, Fermilab and the Department of Energy have worked closely together to find ways of maintaining public access without compromising safety. The Arts and Lectures Series has remained open, offering a major demonstration that visitors could be admitted under precise stipulations. With due diligence for the Secon alert levels posted by the Department of Energy, Fermilab has again been able to welcome visitors to the Lederman Science Education Center, visitors with passes, visitors for recreational use who walked or biked onto the site, and visitors with special buffalo passes, who are allowed to drive on the site to view the herd of American bison that has symbolized Fermilab's presence on the frontier of high-energy physics since 1969.

In planning for a future reinforcing its heritage of openness, the Office of Public Affairs formed a Design Task Force with representation from various areas of the lab. The task force has worked to formulate an overall plan to provide a coherent framework for the visitor experience throughout the site, and its pilot project is a new exhibit for the 15^{th} floor of Wilson Hall. The key messages, slated to begin appearing in January 2004, highlight science as a pathway of discovery, scientists as real people, physics without borders, the advance of technology, and accessibility of a national science laboratory to the nation's citizens—and to other nations' citizens.

It's also important for Public Affairs to visit the laboratory's neighbors and maintain contact in all possible ways. Representatives attend community meetings and offer presentations where and when appropriate—for example, at the DuKane Valley Council, the East-West Corporate Corridor Association, Chicago Wilderness, and various homeowners' associations. The Speakers' Bureau turns down no requests, annually averaging appearances with 20 adult groups and 20 school groups separately from the many school visits of the Education Office. Public Affairs has a policy of never missing a phone call, viewing each call as an opportunity to make a friend for the lab. The Fermilab Web site, administered by Public Affairs, includes a community forum (www.fnal.gov/pub/about/community) featuring questions from neighbors and responses, and links to areas of concern such as safety and the environment.

Community Advisory Group: Consulting and connecting with neighbors

The Fermilab Office of Public Affairs, with the support of Northern Illinois University and funding from the Northern Illinois Center for Accelerator and Detector Development (NICADD), is working to form a task force to develop an understanding between the lab and the community (i.e., state and local governments, community groups and invididuals) on how the laboratory will consult with its neighbors on decisions affecting both the local community and Fermilab's nationally and internationally critical science missions.

The task force will aim at making recommendations for how the lab should consult with state and local governments, groups and individuals, addressing such topics as:

- on what kinds of issues should the community be consulted?
- who in the community should be conslted?
- when in the decision-making process should this consultation take place?
- what consultation mechanisms should be used?

The task force will be asked to answer these questions based on two specific examples: 1) future land use on the Fermilab site; and 2) Fermilab's future science missio. These two cases illustrate, respectively, decisions of significant concern to the local community, with major implications for Fermilab's science mission; and decisions heavily involving the national and international science communities, with potentially signficant local impacts.

The task force will address Fermilab's methods of consultation on these two issues, chosen because they present significant concerns both for the local community and for Fermilab's mission. The task force membership will represent key interests with a stake in Fermilab decisions, including representatives of local and state governments, nearby residents, public interest groups, lab managers and scientists, and the U.S. Department of Energy.

In consultation with DOE, Fermilab plans to use the conclusions reached by the task force as the basis for extending the lab's community outreach approach. The task force is expected to meet approximately six times over a five-month period, with recommendations presented in mid-2004.

Also in consultation with DOE, Fermilab has developed a prelimiary list of groups, organizations and entities from who the Task Force will be chosen. A steering committee representing Fermilab, DOE and community leaders will determine the Task Force membership, comprising about 20 invited members. Fermilab will then issue the invitations.

The steering group will be formed to oversee the operations of the task force, making decisions about the scheduling of meetings, the use of briefing materials, the participation of consultants, and other issues arising from the work of the group. The steering group will consiste of three or four represntatives of Fermilab and DOE, and the same number of community leaders. Fermilab will also provide logistical support for the task force, either with Fermilab staff or by contracts.

Suggested meeting topics:

Meeting 1: Fermilab's mission, and the methods of decision-making on national science projects.

Meeting 2: Major planning issues in the surrounding community.

Meeting 3: Community involvement at other sites; e.g., European laboratories and other high-impact U.S. facilities.

Meeting 4: Options for consultation; e.g., community boards, task forces, workshops, hearings, etc.

Meetings 5-6: Developing recommendations.

Possible entities, organizationa and individuals for selection to the task force:

1. City of Batavia
2. City of St. Charles
3. City of Aurora
4. City of Warrenville
5. City of West Chicago
6. City of Geneva
7. Congressional representatives
8. Du Page County
9. Kane County
10. State of Illinois
11. DOE-CH and Fermi Group
12. DOE-CH Program staff
13. Fermilab scientists and administrators
14. Users (UEC)
15. URA, Inc.
16. Northwest Illinois Planning Commission
17. CATCH (Citizens Against The Collider Here)
18. Local media
19. Business community
20. Homeowners' associations
21. Educational community
22. Environmental groups
23. Taxpayer associations

There are compelling reasons to establish a task force, whose goal will be consensus.

Decisions about land use on the Fermilab site hold significant potential for concerns in the surrounding communities. Fermilab's 6,800-acre site remains one of the largest open spaces in the west suburban Chicago area, inviting increasing pressures on its property to meet community needs. Establishing a standing procedure for working with the community on these issues can mitigate a possible adversarial relationship.

The community may hold the key to Fermilab's ability to consider future projects. Several proposals for future facilities would require off-site construction. An established community outreach and dialogue process is essential in any attempt to build the level of trust, respect and open communication necessary to gain community support for future accelerator development.

The goal of the task force will be to reach an understanding among all the parties. Toward this end, decision-making within the task force will be oriented toward reaching consensus agreements, rather than taking votes. Minority reports will be permitted, but every effort will be made to reach agreements by consensus.

Design Task Force: Crafting a coherent visitor experience at Fermilab

New security regulations and limitations on visitors have served as an added incentive for creating new ways to make visitors feel welcome at the lab and to enhance the accessibility of "science in the neighborhood." The Office of Public Affairs, in collaboration with Fermilab Visual Media Services and outside resources, has contracted to work with the design firm of Aldrich Pears of Vancouver, British Columbia, to formulate a "Visitor Experience Master Plan," a long-term strategy for the development of the optimum visitor experience at Fermilab. A preliminary version of the draft master plan was presented to Fermilab Director Michael Witherell and the Associate Directors on September 24, 2003.

The overriding interpretive goals for a new visitor experience:

- create a powerful base of support for Fermilab and for Particle Physics;
- build a strong relationship with the lab's local community;
- educate and inspire visitors about basic science and about discoveries at Fermilab.

To reach these goals, the plan has formulated both experimental and cognitive objectives. The experiential objectives include seeing real science in action; meeting a real scientist; visiting a Fermilab experiment; touching real apparatus; enjoying hands-on, minds-on interaction with exhibits; viewing video presentations to experience "the big picture." Cognitive objectives include: increasing the understanding and curiosity of visitors; answering specific questions; providing intellectual stimulation, in addition to inspiring enthusiasm and creating positive connections with the public.

The Master Plan has identified six key messages to stress to all the lab's visitors, who include representative from all levels of government and from foreign countries, as well as scientists, school groups and the general public. The messages:

1. ***Discovery:*** Fermilab is a place of discovery;
2. ***Physics Without Borders:*** Fermilab has a long and honored history of world science, emphasizing international collaboration and the free exchange of ideas;
3. ***You Are Welcome at America's Science Lab:*** As a U.S. Department of Energy/Office of Science National Laboratory, operating on public funds, Fermilab wants visitors to see the workings of the world's leading research institution in high-energy physics, and its function as an educational resource;
4. ***Technology:*** Fermilab is a center for putting technology to work in ways that may generate applications in many other areas;
5. ***Real People:*** Scientists are real people, with real stories;
6. ***Fermilab is Safe and Green:*** Fermilab is a safe place to be and to work, and in fact serves as a de facto nature reserve with a diversity of plant and animal species on its 6,800-acre site, which includes some 1,100 acres of restored prairie and wetlands.

In identifying the limited number of onsite facilities suitable for standardized tours, the Master Plan also identified an important missing element—the lack of an area for general site orientation, visitor gathering, or for orientation before a tour. The Master Plan also points out that secure access control is important for science facilities, but not for the entire site; that control of access to the site needs to be flexible; that visitors must be registered and badged; and that visitor access cannot interfere with the daily operation of the laboratory. In addition, planning for a coherent visitor experience runs up against the limitations of resources and funding, as well as takes the lab to a place where few other labs have gone before.

The vision for an optimum visitor experience is one that provides one-on-one, custom interactions; for example, providing unique, behind-the-scenes tours for prominent visitors from government, science and other fields. It offers access to real science, and the chance to meet with the real people who are conducting the science and to hear their stories. It offers the opportunity to see what happens in science and to see how it happens, but using different media to bring the hidden into view. And it offers a connection to the public, to extend the experience of the lab to the surrounding communities—communities that adjoin the site, or communities extending to different parts of the world.

The major theme of the renewed Fermilab visitor experience would be, “Quarks to the Cosmos: A Journey of Discovery.” Scientists at Fermilab are studying the unimaginably small and the incredibly large. By probing the inner space of protons and their subatomic constituents, scientists are opening new windows on the nature of matter, energy, space and time—the makings of our universe.

Carrying through the major theme is the job of the subthemes to be developed in the visitor experience. Examples:

- ***“Eureka! Fermilab is a place of discovery”***--the top quark, the bottom quark, and other breakthroughs at a lab that unravels the mysteries of the universe and serves as a microcosm of the larger, international scientific community;
- ***Particle Physics 101***—introducing the basics of particle physics and the process of science;
- ***Tools at the Frontier***—advances on the frontiers of technology, for example the superconducting wire industry, medical applications, the world wide web;
- ***Science in America***—the Department of Energy and the federal government support research at Fermilab and other institutions, where scientists develop knowledge that changes the world;
- ***Where the Buffalo Roam***—how the lab supports a restored prairie ecosystem.

The Master Plan identifies four major science facilities that are readily adaptable for a new and coherent visitor experience: Wilson Hall, the Linac area, and the CDF and DZero collider detector buildings. Wilson Hall symbolizes Fermilab, its scientists and its artistic and scientific culture, and affords the opportunity to meet (or at lease see and hear) scientists. The Linac area is highly visible with real and distinctive technology, showing science in action, and the space may be available to allow for presentations and interpretation. CDF and DZero show scientists at work on Fermilab experiments in large, dramatic settings, with designated areas for artifact display and interpretation, and provide strong visual cues about the collaborative and international nature of particle physics.

The key features of the proposal presented to the Fermilab Directorate:

1. Build a new visitor center outside the area of the laboratory that must be secured.
2. Link the new visitor center to the Lederman Science Education Center.
3. Zone the site into controlled and non-controlled areas.
4. Develop a suitable security approach for the Village.
5. Ensure that exhibits on the 15th floor of Wilson Hall relate to the site areas or to the buildings that can be seen.
6. Allow visitors to take guided tours to secure areas of the site.
7. Improve visitor services at recommended science facilities.

A coherent visitor experience encompasses everything that visitors see, hear, touch, feel and do while they are at Fermilab. It includes their intellectual and emotional interactions with exhibits and guides. The planning process for crafting a coherent visitor experience encompasses creating the vision, identifying obstructions, comparing strategic directions, and putting plans into action.

FERMILAB TODAY

At approximately 9 a.m. on Monday, July 21, the first issue of *FERMILAB TODAY* was distributed electronically throughout the laboratory. This electronic news service arrives every morning in employees’ emailboxes, bringing a calendar, photos and stories, employee milestones and achievements, accelerator updates, and pointers to Fermilab stories in the news. *TODAY* is a primary communication channel for information about safety, benefits, policy changes, power outages, and anything affecting daily life at Fermilab.

Earlier in the year, people from every part of Fermilab participated in focus groups on communication within the laboratory. Uniformly, employees from all divisions and sections, with every kind of job, said they wanted more information and a stronger sense of community. FERMILAB TODAY was instituted to respond to those needs. For each Tuesday’s edition, Director Michael Witherell writes a "Director's Corner" message. Each Thursday’s edition carries a “Result of the Week” from the CDF and DZero collider detector experiments as they begin physics analysis from Run II data.

Everyone at Fermilab is encouraged to write to today@fnal.gov to offer their comments, suggestions, questions and ideas, and to serve as active collaborators in this effort for better communication at Fermilab.

FERMINEWS

Fermilab's distinctive physics newsmagazine, with a circulation of nearly 15,000 monthly, aims to support the lab's science mission, carry messages to DOE, offer a credible response to bad news, build morale within the lab, reinforce national and international connections, and direct the message of the importance of basic science research repeatedly toward readers who are prepared to hear that message.

FermiNews regularly includes policy stories, enterprise science stories of lab developments, targeted stories for issues of morale and support, explanations of scientific principles ("Physics Made Painless"), coverage of the lab's environmental and educational efforts, and portraits of scientists as people. The publication has always enjoyed the strong backing of lab management, and of the scientists themeslves, who appreciate the opportunity to talk about their work. FermiNews delivers the message of HEP with credibility, and is highly regarded throughout the field. FermiNews also won a 2002 Gold Trumpet Award, for "distinguished achievement in planning, creativity and execution of a public relations effort," by the Publicity Club of Chicago, the nation's largest independent public relations membership organization.

As a strategic audience, FERMINEWS identifies state and local officials, DOE, OMB, OSTP, NSF, Members of Congress, Congressional staffers, science journalists worldwide and URA university presidents. As an informational audience, FERMINEWS identifies employees, retirees, users, vendors, physicists worldwide; university physics departments, libraries and labs worldwide, physics buffs, students and teachers, and neighbors.

With a shift to monthly publication, FERMINEWS continues its evolution as a voice of US HEP, not just of Fermilab. Stanford Linear Accelerator Center has become a regular contributor to the publication, and Fermilab Public Affairs is actively seeking the cooperation of other labs in communicating the message of high-energy physics. The recommendations of an April 2002 DOE Peer Review of the Office of Public Affairs included the establishment of national newsmagazine for US HEP, in conjunction with SLAC and with the cooperation of other national labs conducting HEP research.

Some of the most prominent voices in national science policy have stressed the importance of science communication.

Vern Ehlers, in the 1998 report "Unlocking Our Future: Toward a New National Science Policy," wrote: "Research sponsored by the Federal government should be more readily available to the general public, both to inform them and to demonstrate that they are getting value for the money the government spends on research. Agencies that support scientific research have an obligation to explain that research to the public in a clear and concise way."

John Marburger, Director of OSTP and Science Advisor to the President, declared at the AAAS Symposium on Science and Technology Policy (April 11, 2002): "We cannot fund all the sciences, all the time, to the full extend that we'd like. Choices need to be made. We need to advise the government on how to evaluate and make those choices wisely, and not leave them to random decisions of the public finance process."

FERMINEWS accepts that responsibility.

Interactions.org

On August 12, 2003 during the Lepton-Photon Symposium at Fermilab, the InterAction collaboration of communicators from the world's particle physics labs launched Interactions.org, a new global, Web-based resource developed to provide news, high-quality imagery, video and other tools for communicating the science of particle physics.

The Web site, found at www.interactions.org, provides a newswire with the latest developments in particle physics and related fields, as well as links to current particle physics news from the world's press. It offers high-resolution photos and graphics from the world's particle physics laboratories and links to education and outreach programs.

The site also presents timely information about science policy and funding; links to universities; a glossary and a conference calendar.

Interactions.org was developed and is jointly maintained by the InterAction collaboration, representing the communication staffs of all the world's particle physics laboratories. The new site responds to the growing demand for information and images from particle physics laboratories in Europe, North America and Asia. The group pooled experience and resources to create a centralized Web site, already visited regularly by journalists, researchers and policy-makers on a daily basis.

Interactions.org will give the media, the science community, policy makers, funding agencies, students, and teachers the tools to better understand and communicate the nature and value of particle physics research and its connections to other fields of science. Users of interactions.org will find current information about the status of initiatives, people and facilities involved not only in particle physics but also in other related fields, and not only in one country but across the globe.

Global collaboration is the foundation of success in this era of particle physics research, and Interactions.org will help facilitate that teamwork.

Contributing Members of Interactions.org

- The American Physical Society (APS)
- Brookhaven National Laboratory (BNL)
- European Organization for Nuclear Research (CERN)
- Deutsches Elektronen-Synchrotron (DESY)
- Fermi National Accelerator Laboratory (FNAL)
- High Energy Accelerator Research Organization (KEK)
- INFN: Laboratori Nazionali del Gran Sasso (LNGS)
- INFN: Laboratori Nazionali di Frascati (LNF)
- Institut National de Physique Nucleaire et de Physique des Particules (IN2P3)
- Institute for High-Energy Physics, Protvino (IHEP)
- Istituto Nazionale di Fisica Nucleare (INFN)
- Thomas Jefferson National Accelerator Facility (TJNAF)
- Joint Institute for Nuclear Research, Dubna (JINR)
- Laboratory for Elementary-Particle Physics at Cornell University (LEPP)
- Lawrence Berkeley National Laboratory (LBL)
- Saclay Physics Institute
- Stanford Linear Accelerator Center (SLAC)

III. Education: Teaching teachers and reaching young minds

Fermilab's Education Office is a local, regional and national resource for teachers seeking to improve science education. The staff of Fermilab's Education Office (established in 1989) and the Leon Lederman Science Education Center (celebrating its 10th anniversary) train and work with six to seven thousand teachers every year, as part of the mission to improve the way science is taught in surrounding communities and across the nation.

At least 150 high schools across the country, including the nearby Illinois Math and Science Academy, have begun teaching secondary-school science in a sequence that begins with physics then moves to chemistry and biology, an idea strongly endorsed by Leon Lederman, Nobel Laureate and Fermilab Director Emeritus. Physics is the conceptual underpinning to the study of systems in many other fields. Starting with classes in physics exposes students early on to concepts such as atoms and electricity, which are, for example, necessary to explain chemical reactions and the communication among cells in biology. Through its many programs, the Education Office extends the reach of the idea of science education as an interactive process.

QuarkNet brings high school students and teachers to the frontier of 21st century research that seeks to resolve mysteries about the structure of matter and the fundamental forces of nature. QuarkNet centers are connected to HEP experiments at Fermilab, SLAC and CERN. There are 44 QuarkNet centers already operational, with a goal of 60. Physicists mentor and collaborate with high school teachers, giving students the opportunity to learn fundamental physics by analyzing live on-line data and participating in inquiry-oriented investigations; and giving teachers the opportunity to join research teams with physicists at a local university or laboratory.

The Teacher Resource Center provides a preview collection of K-12 instructional materials and acts as a resource and clearinghouse of science, mathematics and technology education ideas. Educators have access to curriculum materials, books, multimedia, educational supply catalogs, periodicals and newsletters. The collection also includes reports on science and mathematics education, standards, assessment, equity and other topics. TRC services include outreach resource and Internet awareness workshops, consultation assistance (available on request), a periodical holding list, bibliographies and telephone reference. A US Department of Education Eisenhower National Clearinghouse Demonstration Site for the North Central Region is located in the TRC.

Fermilab LInC Online is creating a cadre of educational leaders who effectively use technology to support K-12 engaged learning. Teams of classroom teachers, technology coordinators and library media specialists create engaged learning projects that incorporate the best uses of technology. The projects are structured so that students are responsible for their own learning. The projects are collaborative, student-driven and technologically dependent. When skillfully applied, technology can enhance learning in new and powerful ways. The LInC course prepares participants to develop these types of projects for and with their students. Course topics include: investigating engaged learning; exploring effective strategies for using technology in education; finding information on the Internet; creating and publishing web pages and graphics; planning staff development. All LInC materials are available on-line. A facilitators' academy is available for educators who wish to offer a LInC course in their region. Participants can receive an optional six graduate credits in education from Aurora University.

The Education Office offers Science Adventure classes for K-12 students, and programs for technical students, undergraduates and graduate students. Web-based instructional materials are available for educators and students. The Fermilabyrinth is a collection of Web-based games developed from selected hands-on exhibits at the Lederman Science Education Center, for students in grades 6-12 through classroom or home use. Three on-line projects bring the prairie to life for students. The Fermilab Life Sciences Data Web site offers databases in flora and fauna, images of the prairie, "Particles and Prairies" videodisc slides, an index to student prairie plant population data, and prairie research topics using plant population data.

The Education Office could not operate without the help of the Fermilab Friends for Science Education, which seeks to create and support innovative science education programs. FFSE fulfills its mission by enhancing the quality of precollege science education in public and private schools; encouraging young people to pursue careers in science and engineering; and promoting a broader public awareness and understanding of science.

IV. Management Practices

Excellence in science is achieved by creating and maintaining an environment that enables all employees to contribute their full potential toward the Laboratory's mission, values and goals. We continue striving to increase and enhance our diversity representation through hiring, development and retention efforts.

The Laboratory promotes career opportunities and enriches the diversity of its applicant pool by attending job fairs and career days at colleges and universities serving populations historically underrepresented in the sciences. The summary below represents specific activities that we have attended and will continue to support as financial and human resources permit.

Recruiting

Fermilab has participated in both graduating student on-campus recruiting as well as Cooperative Student Job Fairs. For example, Fermilab representes have gone to the University of Illinois Urbana-Champaign and University of Michigan, for engineering recruitment, to Northern Illinois University for a Cooperative Student Job Fair, and an array of job fairs including Brass Ring Chicago, the MLK Classic Diversity Fair at Illinois Institute of Technology; and Shomex Co., co-sponsored with the NAACP.

The Laboratory has also advertised employment opportunities in the following:

- HACE – Hispanic Alliance for Career Enhancement
- *Diversity Careers*
- *Workforce Diversity*
- *Minority Engineer*
- *Woman Engineer*
- *SWE – Society of Women Engineers Journal* (Magazine and Conference Guide)
- Equal Opportunity Publications
- National Society of Black Engineers
- SHPE – Society of Hispanic Professional Engineers
- *Winds of Change*
- IEEE Spectrum – Institute of Electrical and Electronics Engineers
- *Graduating Engineer*
- *Careers and the Disabled*
- *Chicago Tribune*
- Local area Newspapers
- ChiefMonster.com
- *Chronicle of Higher Education*
- *Physics Today*
- *CERN Courier*
- SHRM – Society of Human Resource Management
- IT Careers
- Cass Communications (variety of college town daily papers)
- *Nature*

The Laboratory continues its membership in the Prairie View A&M University cluster. This initiative will increase our visibility at this campus, a URA associate member, and will provide us with enhanced opportunities to recruit for interns and regular full time employees. The Laboratory is also represented on the Minority Engineering Advisory Board, College of Engineering, University of Illinois at Chicago. The Laboratory will continue its collaboration with the Illinois Department of Rehabilitation (DORS) to identify FNAL positions where persons with disabilities may be bridged into employment.

The Laboratory provides pre-college, college, and graduate opportunities to increase the numbers of historically underrepresented minority students selecting science and engineering as careers.

TARGET is a program for academically talented minority high school students. Annually since 1980, the Laboratory offers a 6-week combined work and enriched classroom experience to 25 participants, chosen from Chicago area schools and programs.

The Laboratory is a prime sponsor of the program "Tomorrows Scientists, Technicians, and Managers" organized through the Urban League affiliate in our area. Students from this program are also recruited for TARGET.

The Laboratory is a member of the "Youth Motivation Program" through the Chicago Area Chamber of Commerce. To support this initiative, Laboratory employees volunteer their time to speak at Career Day at local high schools.

Each year, since 1970, the Laboratory has invited approximately 20 college minority students to the Laboratory to participate in a 12-week program, Summer Internships in Science and Technology (SIST). Students must be matriculating in Computer Science, Electrical or Mechanical Engineering, and Physics. They are recruited nationally and from Puerto Rico.

Graduate Degrees for Minorities in Engineering (GEM). This program provides tuition. Since 1978, the Laboratory has been a member of the National Consortium for and stipends for students seeking advanced degrees in engineering and the sciences. The Laboratory is currently supporting 5 fellows.

The Lab provides mentoring and financial support for minority students working toward a Ph.D. in Physics at an URA University. The program currently has 2 fellows (1 Hispanic female and 1 African-American female). The program has had 6 graduates.

The Equal Opportunity Manager serves on the Minority Engineering Advisory Board at the University of Illinois at Chicago. This group works to develop strategies to assist African-American and Hispanic engineering undergraduates in their preparation for professional placement upon graduation. Each year Fermilab provides speakers for two courses, Engineering 189 and 190, and Engineering Corporate Day at UIC; for the past three years we have participated in "Shadow as Engineer Day", designed to help freshmen students strengthen their commitment to Engineering as a career.

The Laboratory has a Co-operative Education Program (CO-OP) that provides students with a combination of work and school experience. In FY 2001, we participated with seven universities and provided employment and training opportunities for 15 students.

Development

The Laboratory continuously updates its training modules addressing diversity awareness. A discussion and video on managing diversity is incorporated in the 12-week Supervisory Development series. Additional training is provided throughout the Laboratory on sexual harassment prevention and disability awareness.

The Laboratory has initiated three training programs to further develop the skills of its supervisory personnel. The first of these is "Accelerating Leadership in the new Millennium", designed for upper management. "The Effective Manager" is designed for middle managers. "Positive Employee Relations" focused on recognizing factors contributing to a negative work environment and pro-active measures to minimize these obstacles. Since 2002, single classes have been offered to help supervisors and employees enhance their skills in a particular area, for example, conflict resolution, team management, time management. The Laboratory is also exploring the use of computer-based training.

The Laboratory has a tuition reimbursement program, which is available to all full time employees. In order to be eligible for Fermilab's tuition reimbursement, the course work or degree program must be job-related to the person's current job or one to which he/she can reasonably aspire. The Laboratory has a very unique aspect to this program called tuition advancement. The Laboratory will advance the cost of the course(s) for employees not on probation (the advance must be repaid if the person does not satisfactorily complete the course). This aspect of the program has proven to be a real assistance to those employees who would like to upgrade their present job skills without having the financial burden of paying for the course upon enrollment.

For FY 2001, a total of 111 employees participated. Of this number there were 16 minorities (4.4% of the Laboratory's minority population) and 33 females (7.1% of the Laboratory's female population). These employees attended 28 universities and colleges.

Retention

The Laboratory offers programs that are family-friendly, and has won recognition in the form of the Golden Family Award from the Chicago regional chapter of the Society of Women Engineers, citing the lab for "outstanding support of family issues." The award has also been won by such noted companies as Motorola and Lucent Technologies.

The Laboratory has had on-site day care, The Children's Center, since 1980, and is fully staffed to handle children age's 6 weeks through 6 years. A family leave policy and flexible spending tax-exempt accounts for dependent care have been established. The Laboratory offers Day Camp in the summer for school age children, featuring swimming, crafts, day-trips, and other activities. Wellness Committee programs have been offered focusing on family issues such as elder care, financial management, gender specific health issues, and estate planning.

The Laboratory offers problem resolution programs. The Laboratory has continued Management Training designed to provide supervisors and managers with an updated skill set in leadership techniques and practices and in understanding the complexities of managing people, teams, and projects. The Laboratory has a well-established and promulgated Grievance Procedure to provide employees a formal process to discuss workplace problems and resolutions with management. Additionally the Equal Opportunity Office provides an avenue for internal complaint resolution. The Employee Assistance Program Counselor is also available to help arrive at resolutions to individual workplace and personal problems.

All Division and Section Heads are responsible for the implementation of the Affirmative Action Program within their specific areas. Additionally, semi-annually, the Director reviews our goal achievement and progress. Issues pertinent to our AAP goals and initiatives are presented at the Laboratory Administration Management meeting on a continuing basis throughout the year.

V. Site, Facilities and Infrastructure Management

Identifying infrastructure asset management requirements

The information contained in this section for Fermi Lab's site, facilities and infrastructure is derived from the DOE facilities information management systems (FIMs) and the Fermilab Strategic Facilities Plan (SFP). As part of the Institutional Plan this information is intended to identify infrastructure asset management requirements and actions necessary to ensure that Fermi National Accelerator Laboratory continues as an efficient and effective world-class scientific research facility well into the 21st Century. These include:

- Mission. Facilities will be right-sized to the type and quality of space and equipment needed to meet mission needs and includes co-location of activities, minimization of leased space and adaptability to changing research requirements.
- Working Environment. Creation of a "preferred" working environment to attract and retain high quality staff and users to include the latest advances in information technology.
- Environment, Safety, Health and Security. To satisfy all necessary ES&H and Security elements for workers, visitors and neighbors.
- Operations and Maintenance. Infrastructure including facilities and other systems such as roads, utilities and equipment will be funded, operated and maintained from a life-cycle asset management standpoint.

Description of Laboratory Site and Facilities

Site Characterization

The Fermilab site contains 6800 acres of land and has 338 buildings totaling 2,270,310 square feet of space. In addition to this space, Fermilab has 112 trailers that provide additional space of 92,186 square feet in support of laboratory operations

Utility systems. Fermilab utility systems include electrical, natural gas, pond water systems (industrial cooling water), potable water (domestic), and sanitary (wastewater).

Electrical.

- **Description.**

Electric power for the Fermilab Main Site is provided by Commonwealth Edison Company from their 345 kV transmission lines and over 26000 MW of electrical generation and supply contracts for Northern Illinois. Transmission line 11120 is the preferred line between the Electric Junction and Lombard Substations with Line 14419 between the Electric Junction and Wayne Substations serving as the second source of transmission to the site. Between Fermilab owned and operated high voltage substations, Kautz Road and Master Substation, the 345 KV bus is transformed through seven (7) 40 MVA and one (1) 60 MVA transformers to 13.8 KV for underground distribution through 22 feeder breakers. Fermilab secondary distribution consists of approximately 280 substations with from 15 miles of overhead conductors and 100 miles of underground cable. In addition, 34.5 KV lines from Electric Junction serve the Village 12.4 KV overhead distribution system and provide emergency 13.8 KV from the Village and Giese Road.

- **Current Condition (reliability)**

The current condition of Fermilab electrical power system is adequate. The new components installed under the main injector project and selected feeders upgraded within the last few years are rated as good. Other secondary systems including transformers and conductors, as well as some primary 13.8kv feeders have elements that are rated as poor based on their current condition. As critical systems are identified as vulnerable or as failures have occurred, those sections have been replaced. There is a Line Item project to replace the 345 kV wood structures and selected 13.8kV feeders in the planning for FY06/07 funding.

Pond Water Systems.

- **Description**

Fermilab provides its own Industrial Cooling Water (ICW) from site sources and when needed is able to draw make-up water from the Fox River under a State of Illinois permit. The Industrial Cooling Water system at Fermilab has a dual purpose. It is used to supply water to the various fire hydrants and fire protection sprinkler systems located in buildings across the site. In addition, ICW is utilized in many of the experimental areas as a source for conventional magnet cooling. The distribution system for ICW extends from the main pumping station at Casey's Pond to the Support Area, Wilson Hall and Footprint Area, and most of the Experimental Areas located on the Fermilab site. The main storage reservoir for the ICW system is Casey's Pond which is located in the northern portion of the Fermilab site. A secondary storage facility was recently dedicated in honor of Andy Mravca, and is called Andy's Pond.

There are two sources that provide water to the reservoir. A site-wide network of lakes and ditches is used to collect runoff water, as well as heat exchanger and sump discharge water, and return it to the main reservoir at Casey's Pond. Water is also collected in the Main Ring Lake, located within the main accelerator ring, and Lake Law, located in the southeast portion of the site. The water from these lakes is then transferred to the main reservoir by means of a pumping station located at the Main Ring Lake. It is important to note that the entire Fermilab 6,800 acre site provides runoff to this network of ditches and lakes and thus even open areas of the site contribute to the experimental effort of the Laboratory. There is a second source used to supply water to the main reservoir. The State of Illinois allows Fermilab, when water levels are sufficient, to pump water from the nearby DOE owned Fox River pumping station to supplement and maintain capacity at the main reservoir. A third source of water will soon come from the deep tunnel for the NuMI project/MINOS experiment.

- **Current Condition (reliability)**

The current condition of the Fermilab Industrial Cooling Water (Pond water) system is adequate. The main reservoir has been expanded in the last few years for increased capacity and gas-fired turbines (while near the end of life) provide a dual fuel source for a pumping system that is rated as good. Additionally, completion of a new utility corridor allows more effective transfer of water across the site and allows for further redundancy of supply for this critical Fermilab system.

The adequacy of the DOE owned Fox River pumping station is under review based on removal of a downstream dam that will permanently lower the water level of the river. Discussions are underway with the dam owner, Kane County Forest Preserve District, in order to preserve the lab's pumping capability.

The site has about 105,000 linear feet of piping for this non-potable water distribution system some of which is nearing the end of its useful life. The most critical sections with the highest vulnerability to fail have been identified and have either been replaced or are planned for replacement. The ditch return systems and pond water control systems are in need of repair more from a water conservation standpoint but are satisfying the current capacity needs.

Natural Gas.

- **Description**

From two separate metered source points, gas is delivered to Fermilab by NICOR and purchased under a supply contract with the Defense Energy Supply Center. The primary gas supply is an 8-inch line metered at the Wilson Road boundary. Two branch lines extend south. One serves the Village while the other terminates at the Central Utility Building. A second 4-inch back-up supply line has been recently completed which supplies gas through a meter station at the west boundary of the site, adjacent to Giese Road. This line is connected to the Central Utility Building gas supply. Through a system of sectioning valves, limited gas supply can be maintained to the site in the event of an interruption of the 8-inch primary supply. The pressure site-wide is regulated to maintain 100 psi. The Village and Site 38 are regulated to maintain 60 psi. Natural gas is primarily used for heating; however, it is also used to drive turbine engines for generating emergency electricity at Casey's Pond, Well #3, the Master Substation, and Wilson Hall. The site has approximately 65,000 lineal feet of underground natural gas piping owned by the federal government and maintained by Fermilab. Fermilab currently consumes around 100,000 Deka-therms (MMBTU) per year which equates to one hundred million cubic feet of gas supply

- **Current Condition (reliability)**

The current condition of the Fermilab gas system is good.

Potable Water.

- **Description**

There are two main and five minor domestic water supplies that provide domestic water to the various areas of the Fermilab site. The Main Site system supplies domestic water through a piping network to the majority of the facilities on site. The primary water source for this system is Well No. 3, located north of Road B near the Receiving Road. Water is pumped from the well into a 50,000 gallon reservoir adjacent to the plant. There it is chlorinated and then pumped through the site-wide distribution system. The secondary source for this system is Well No. 1, located near the Central Utility Building. When Well No. 3 is not in use, water is pumped from Well No. 1 into a 50,000 gallon reservoir at that well site. The main site water system is owned and operated by Fermilab and continues to provide adequate supply. Well capacities are under review to determine if a third main site well, or other source, may be necessary to supply future needs.

Domestic water is supplied to the Village Residential Area and the Village Technical Area by a direct metered connection to the community water supply of the neighboring Village of Warrenville. This system, also Fermilab owned and operated, is a separate distribution system independent of the main site distribution. In addition to potable water, this system provides the source of water for the fire protection systems located in the Village Areas.

Three additional shallow water wells serve individual buildings at outlying sites. These are wells associated with the farm sites that existed when the land was originally acquired by the Atomic Energy Commission. They are kept in service to supply water to the adjacent, former farm residences and storage buildings which are still utilized for various laboratory requirements.

- **Current Condition (reliability)**

The current condition of the Fermilab potable water system is adequate. The water wells are well maintained and in good condition. A majority of the village distribution system has been replaced and the main site distribution systems are in need of repair as they have reached their end of life.

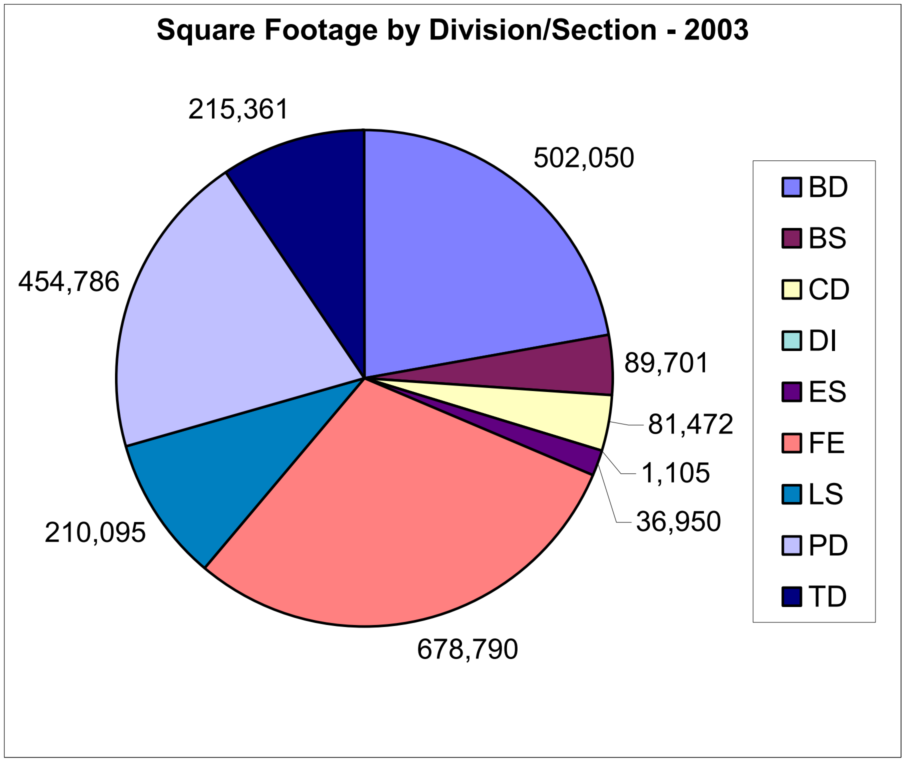
Sanitary Sewer.

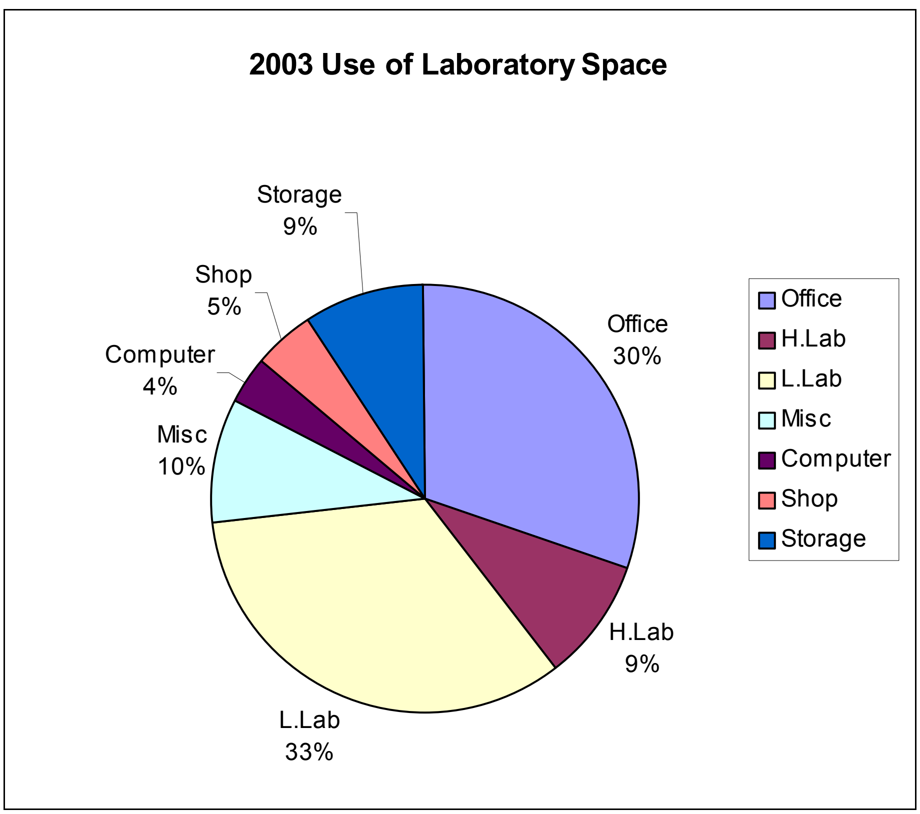
- **Description**

There are two (2) underground sewage collection systems at the Laboratory. One serves the main site, and the other serves the Village area. The main site collection system has six (6) lift stations; the Village system has one. No sewage is treated on site. Sewage from the main site is delivered and treated on a fee basis by the City of Batavia. Sewage from the Village is handled by the City of Warrenville under a similar arrangement. Fermilab owns and operates the sanitary collection system. The sewage system at the site contains 38,000 linear feet of gravity feed sewage line, 14,000 feet of pressure fed sewage line, and septic tanks with a capacity of 14,000 gal.

- **Current Condition (reliability)**

The collection system serving the main site facilities is in good working condition. A recent inflow and infiltration study has been completed that identified necessary repairs and improvements to this system to increase operating efficiencies and improve the capacity of the collection system. Off site collection of Fermilab's wastewater by the City of Batavia in adequate.


Square Footage by Division/Section - 2003
215,361
502,050
454,786
89,701
81,472
1,105
36,950
210,095
678,790
BD
BS
CD
DI
ES
FE
LS
PD
TD


2003 Use of Laboratory Space
Storage 9%
Shop 5%
Computer 4%
Misc 10%
Office 30%
H.Lab 9%
L.Lab 33%
Office
H.Lab
L.Lab
Misc
Computer
Shop
Storage

Replacement Plant Value (RPV)

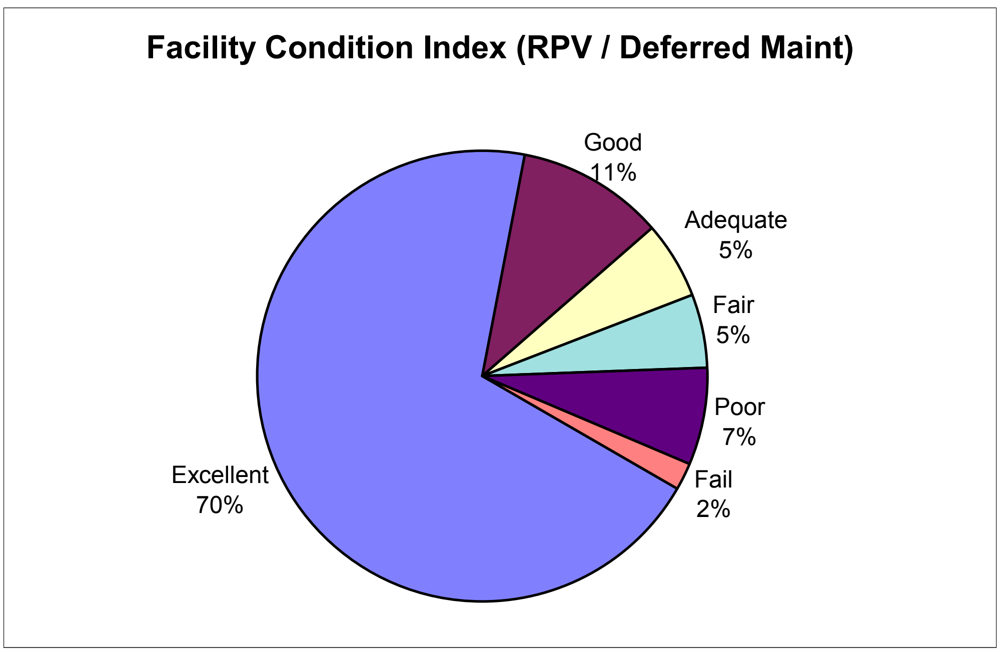
The RPV for Fermilab infrastructure is listed at $1.219B and is subdivided into Buildings at $383M and Other Structures and Facilities (OSFs) at $836M. Fermilab further subdivides the OSFs into Accelerators at $741M and Other OSFs at $95M which includes primarily the utility systems described. The breaking out of Accelerators is necessary since these figures should not be figured into the recapitalization period (time necessary to rebuild the lab with current annual investment of GPP and line item funding). The justification for this is that Accelerators including tunnels and equipment would not likely be recapitalized but rather replaced by other more state of the art machines.

Buildings	**$383 Million**
Accelerators	**$741 Million**
Other Structures and Facilities (OSFs)	**$ 95 Million**
Total	**$1.219 Billion**

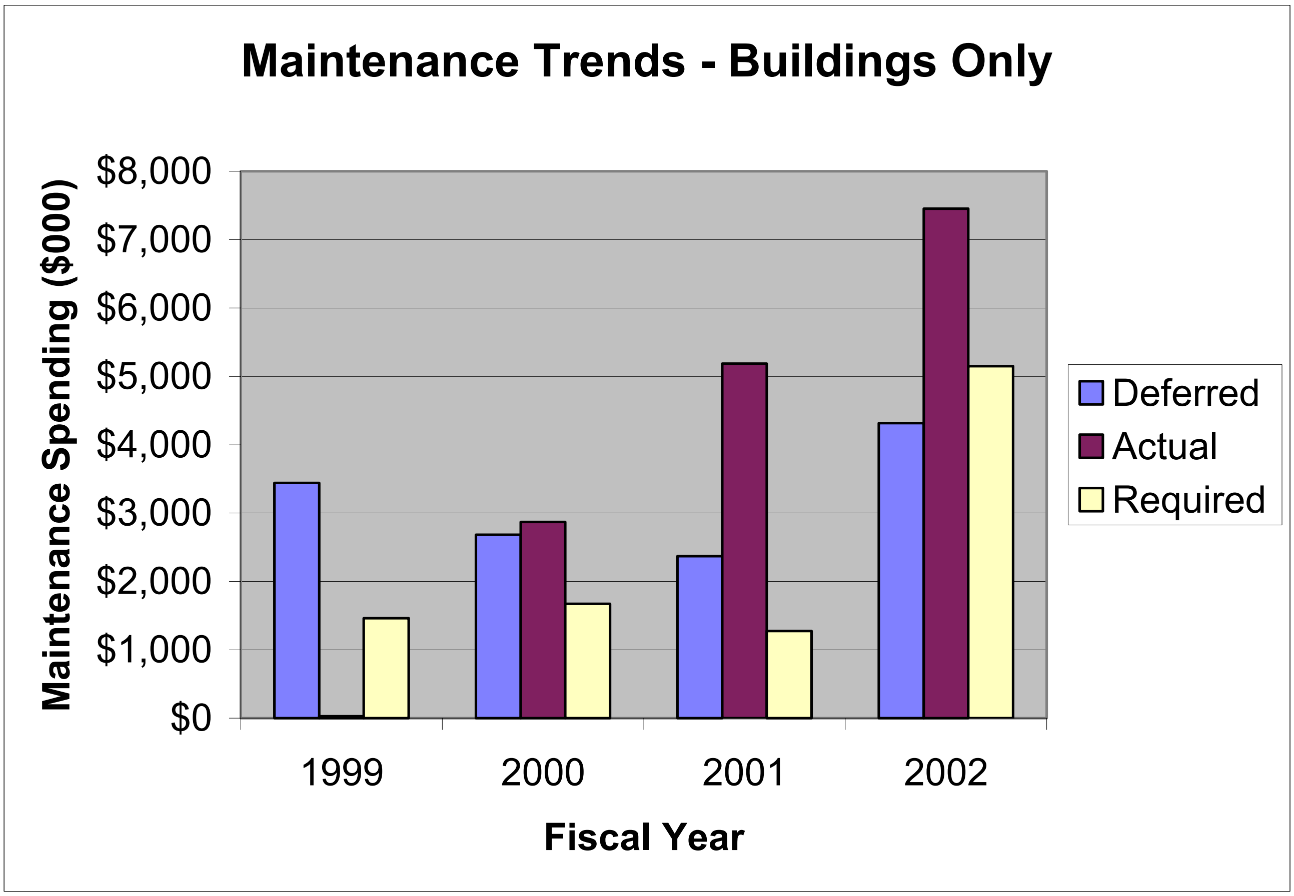
Condition Assessment Surveys

Condition Assessment Surveys (CAS) are basically building and utility system deficiency inspections to assess the condition of the facilities. This is an important piece of Infrastructure management in order to identify funding needs and ties directly into the lab's maintenance planning and budget forecasting. DOE order 430.1B of September 2003 provides new guidance on CAS and Fermilab is preparing to meet the requirements through development of processes and procedures and the recent hiring of an engineer to fill a newly created position titled "infrastructure condition assessment administrator." Recent purchase of the Whitestone Sustainability Forecasting System will assist in CAS requirements and maintenance planning.

- **Facility Condition Index (FCI) –** reflects the maintenance backlog. It is calculated as Total Deferred Maintenance as a percentage of Replacement Plant Value (RPV) where Deferred Maintenance is maintenance that was planned but not performed. The FCI underestimates true condition because it does not include major rehabilitation/renovations and improvements needed to better accommodate mission activities (e.g. improvements in vibration, air quality, temperature, access to power, etc.). Deferred maintenance/ replacement value is the FCI and is used as an indicator of facility condition. The failed buildings and a majority of those falling into the poor category are buildings acquired as part of the land acquisition for the laboratory. Many are unheated farm facilities used for covered storage that are servings their intended purpose. Others have low RPV's based on initial accounting records established at acquisition that will be updated.

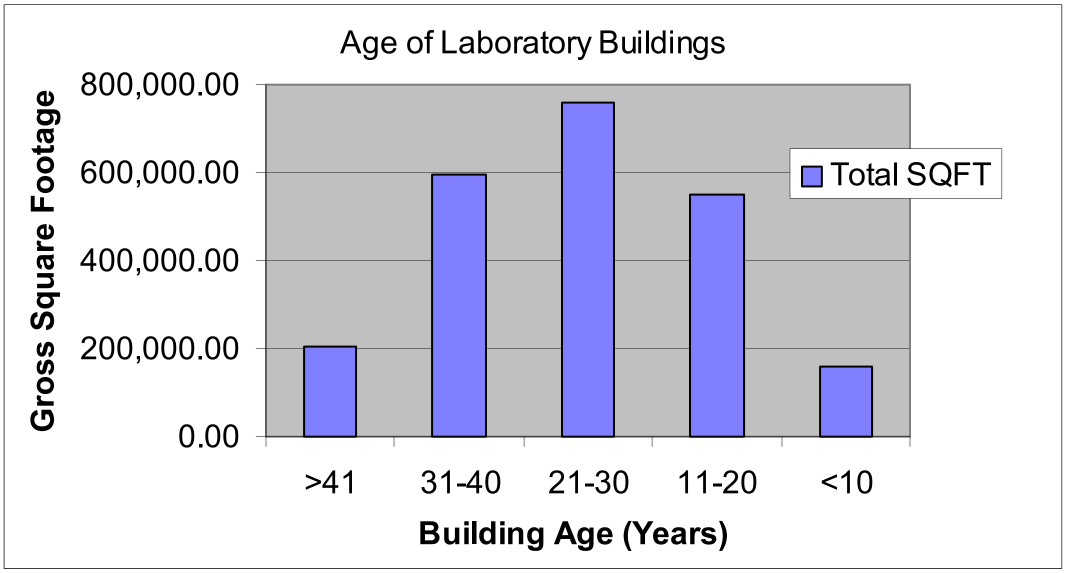


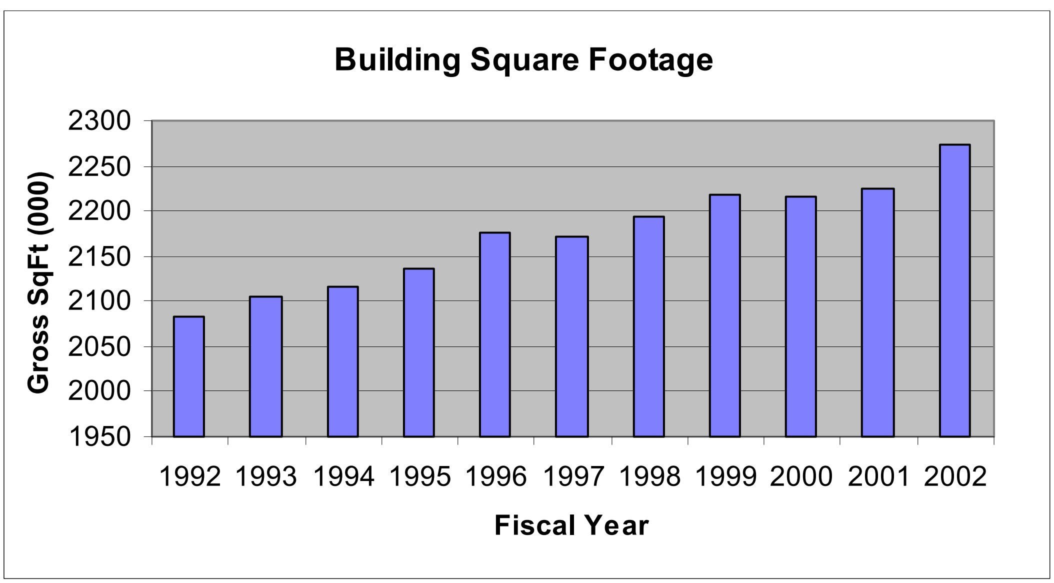
Real Property Maintenance*–Actual maintenance is the actual cost of all real property maintenance activities in the current fiscal year. Required maintenance is the estimate of all costs to perform maintenance activities deemed necessary by engineering and life-cycle studies. Deferred maintenance is maintenance that was planned but was postponed to a future period due to lack of funds.*



Age of Facilities

The distribution of age for the buildings is shown in the following graph. The buildings less than 30 years old were constructed specifically for laboratory operations while the buildings over 30 years old were predominantly part of the original land acquisition for the site and included a residential village complete with utility systems.





Laboratory Site and Facilities Trends

Resource Needs Summary

To satisfy the requirements identified in Section VI, Plan for Modernization (including Collaborative Research projects, Integrated Workplace projects) and existing and projected Infrastructure projects, Fermilab has identified the funding requirements over the 10 year period of this plan (2004-2013) in the areas of GPP and operating funds as described and included in the spreadsheet included herein.

A. Line item funding

In support of the Office of Science Modernization program, several Science Laboratory Infrastructure (SLI) line item projects are planned for development as listed below. Also included are two infrastructure upgrade projects for critical utility systems.

B. General Plant Projects (GPP)

With the exception of some of the projects under $100,000 that will be funded from Real Property Maintenance funds, all projects requirements are proposed for GPP funding. Through GPP funding and continued third party investment, all requirements can potentially be satisfied.

Master Planning potential (Line item)	Cost ($Millions)
Computing Division	5
Technical Division AMF	15
High Voltage Distribution Upgrades	11
Underground Piping Upgrades	7
Total	38

Integrated Workplace potential	Cost ($Millions)
Smart Laboratory	1

Utility Category	Cost ($Millions)
High voltage feeders (13.8 kV)	6.1
Safety related (2.0)	
Cooling water upgrades	3.6
Village domestic water upgrades	0.6
Sanitary sewer upgrades	1.2
Master substation upgrades	3.2
Main site domestic water wells	2.7
ICW water and distribution	1.5
Natural gas system upgrades	0 .5
CUB system upgrades	1.5
Pond water system upgrades	3.6
Total	24.5

Other Categories	Cost ($Millions)
Building roofing systems	4.4
Roads and trails	2.9
Building improvements	18.8
Total	26.1

Grand Total	89.6

C. Real Property Maintenance

Funding for this infrastructure element includes annual real property maintenance and repairs including structures and utilities, roofing, chiller/boiler replacement, and other mechanical, electrical and lighting, including preventative maintenance, cyclical maintenance, and service calls. DOE 430.1B suggest certain funding levels for sustainability and recapitalization. Funding levels tied to performance measurements such as the Maintenance Investment Index (MII) will require further discussion to better define direct and indirect maintenance as well as how to calculate the Replacement Plant Value based on conventional or programmatic facilities.

The third party alternative financing program of Utility Energy Services Contracts (UESC – formerly known as UIP) has achieved a high level of recapitalization of Fermilab assets over the past five years, but recent legal decisions appear to significantly reduce the viability of this program.

Eliminating excess buildings

Fermilab's excess facility program continues to be in development as part of the sitewide master planning initiative thatincludes space banking. The program has enjoyed early success with receipt of SC funding for removal and demolition of four excess facilities. Fermilab initiated this effort through submission of projects in support of the Particle Physics Divisions Master Planning. It should be noted that of the near two million dollars in project requests, a majority of this request was to remove obsolete beamline enclosures. This request when funded will remove 19,605 SF from the Fermilab inventory. As part of the lab's Master Planning process, Fermilab will be investigating space consolidation and additional excessing actions to support the newly established requirement commencing in FY03 for offsetting demolition square footage for each new construction project that adds building space. The Fermilab excess facility project demolition submittals are shown below:

Project title	**FIMS number**	**Demolition costs**
Neon Compressor building - funded	625	$ 44,000 (FY02)
Muon Beam enclosures (22)	701030125	$ 1,151,000
Muon Beam enclosures (pilot-3)	701030125	$ 178,000
Lab G trailer	T-060	$ 31,000
Bubble Chamber equip. removal	602 (equip.)	$ 233,000
PCenter trailer	T-009	$ 18,000
Laser Building	602 (annex)	$ 67,000
Lab G concrete slab	NA	$
Shed B Site 50	945	$ 24,000

Employing cost efficiencies

An Integrated Workplace (SMART Lab) feasibility study was recently completed under a DOE FEMP direct funded project that supports the SMART Lab master plan concept currently being developed at Fermilab. The foundation for this initiative is information sharing between existing control and communication systems and a plan to move towards the latest technology for systems integration. The initiative seeks to develop data highway infrastructures (fiber optic networks in most cases) to facilitate site services that are labor intensive and to support automatic process control of various electrical and mechanical systems. Immediate uses for Fermilab include:

- Building system automation
- Pond water system flood and drought control
- Electrical load management and utility metering
- Equipment control and predictive maintenance

Future uses could also include:

- Medical information
- Fire and emergency services
- Video conferencing
- Recreational programs

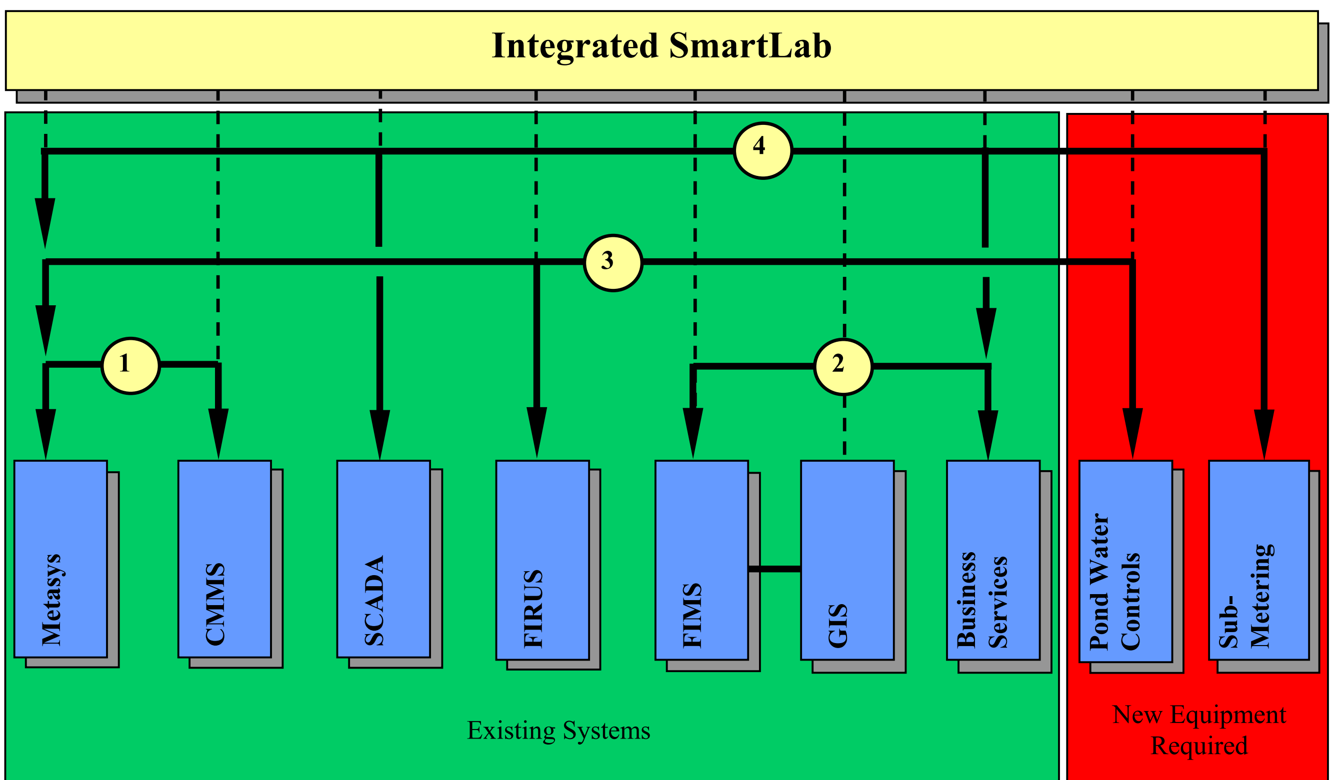


Figure 6.1 - Identified SmartLab Pilot Projects

1.Link Metasys and CMMS to facilitate predictive maintenance
2.Link FIMS to other programs to eliminate manual data entry
3.Install automated pond water level monitoring system
4.Implement electrical submetering and reporting

Risk Level To Safety Mission Environment	Low	Medium	High
1	C	B	A
2	D	C	B
3	E	D	C
4	E	E	D
5	E	E	E

Probability of Failure

Repair Code
- A - Immediately
- B - Within a Year
- C - As Soon As Possible
- D - Maybe Yes/No
- E - Never

Vetting process for 10-Year plan development (identifying and prioritizing)

The following offers a brief summary of the process used to develop the plan and establish priorities.

- The process started with interpretation of the guidelines based on Fermilab's mission as stated in the Fermilab Institutional Plan and known programmatic changes since the last plan update.

- A review of existing deficiencies from the building inspection program, latest infrastructure assessment and site wide utility energy/water audits (performed under the UIP initiative), was completed to identify new requirements necessary to meet the flexibility and versatility guidelines.

- Collaborative Research and Integrated Workplace requirements were identified that needed integration into the plan. Technology zoning and evolution were determined to be satisfied at the necessary level based on existing and projected mission requirements.

- Brief scope descriptions and order of magnitude cost estimates were developed for the identified requirements and updated for existing infrastructure requirements.

- Different approaches were then considered for funding including continuation of third party investment through the Utilities Incentive Program.
- Since Fermilab is basically one large machine and one large office building (Wilson Hall), and since Wilson Hall the multi-year modernization improvement project has completed, the majority of the projects listed in this plan were determined to fall within the utility system category with a focus on reliability. Projects developed from the master-planning efforts now underway will be included in future updates as applicable.

- Prioritization of these utility system projects was based on risk levels associated with safety, mission and environment and the probability of failure of a particular system. Projects were ranked and placed in a particular year for funding.

•Criteria
–Safety (is it a threat to personnel safety)
–Vulnerability (is it mission critical)
–Reliability (will its loss impact the mission)
–Redundancy (does the equipment have a back up)
•Ranking: level of risk and probability of failure

Assets Management

"The Laboratory maintains a DOE-approved Property Management System in order to provide acquisition, necessary and appropriate protection, control, use, and disposal of government property. A Balanced Scorecard self-assessment program is used to ensure effective service and partnership, effective life cycle management of assets to meet DOE missions, access to dynamic and strategic information and management systems, and optimum cost efficiency of Property Management Operations." Real Property management of land and improvements involves coordination with new and changing mission of experiments and integration with the Land use plan.

Energy Management and Sustainable Design

Energy management initiatives at Fermilab are in compliance with the recently issued DOE O 430.2A. More specifically
Energy Reduction Performance

1. **Standard Buildings:** FY2002 consumption was **48.63% lower** on a Btu/GSF basis than the FY1985 Baseline, which is **0.47% lower** than the previous year. Fermilab continues to exceed the goals of 30% improvement by 2005, and 35% by 2010 as in prior years.
2. **Industrial and Laboratory Facilities:** FY2002 consumption was **68.95% lower** on a Btu/Performance-unit basis than the FY1990 Baseline, which is **45.35% lower** than the previous year. This is reflects improved accelerator performance during the Run IIa colliding beam experiments and exceeds the goals of 20% improvement by 2005 and 25% by 2010. Efficiency will vary widely from year to year in these facilities depending upon the mode of operation (Collider, Fixed Target, or Non-Beam), and is expected to drop off after the current Collider mode at the end of Run II. In spite of this fact, a general efficiency trend should emerge over time reflecting performance in all three modes. The rate-based measure used is Btu/Baseline Collider Experiment Hour since colliding beam experiments are the predominant mode of Fermilab operations. Experimental results at the lab are derived by statistical analysis of large numbers of events created by particle interactions of the accelerator beam. The number of interactions produced per hour in experiments is affected by the beam strength, which in colliding beam mode is mainly limited by the antiproton PBar stacking rate. This rate is used to convert current Collider run hours into equivalent run hours required at the stacking rate of the baseline period. During the consecutive years 1989 to 1991 the lab ran in each of its three operating modes, making it possible to equate hours of operation in each of the other modes into equivalent colliding beam hours in terms of baseline energy consumption. This same correlation is carried forward into current year operations to calculate efficiency.
3. **Exempt Facilities:** Fermilab does not list any exempt facilities.

Awards:

a. In FY03 Fermilab received a DOE Federal Energy and Water Management Award for the Fermilab Building Controls Retrofit Group for innovative work accomplished in the Technical Division Industrial Center Building.

b. In FY2001 Fermilab made cash awards totaling $3K to two employees for their exceptional performance in the successful execution of the UESC project ECP-X under UIP Delivery Order ECM2000 – Phase N. This was a $1M retrofit that upgraded a main cryogenic compressor and cooling tower associated with the Central Helium Liquefier (CHL) facility.

c. The lab received a DOE 2001 Departmental Energy Management Award in Washington DC this year for innovative energy technology associated with its new CHL Liquid Nitrogen Recovery Retrofit. Three lab employees and two local DOE employees were allowed to attend the ceremonies honoring this accomplishment. The impact of this retrofit reflects on Metered Process energy efficiency.

d. The lab received a DOE 2001 Departmental Energy Management Award in Washington DC this year for alternative financing energy projects associated with its new ECM2001 – Phase C and Phase N Delivery Orders issued this year. Three lab employees and two local DOE employees were allowed to attend the ceremonies honoring this accomplishment.

e. Four awards were received this year from the Association of Energy Engineers (AEE). One was given to the Fermi Area Office of DOE for developing contractual methods for implementation of the Fermilab UIP program over consecutive years. The three other awards were given to Fermilab for issuing the second set of two UESC Delivery Orders in FY2001 totaling over $27M which continued energy Audit Master Plan (AMP) implementation, for energy retrofit upgrades to the Feynman Computing Center under ECM2001 – Phase C, and for CHL retrofit upgrades under ECM2000 - Phase N. One lab employee and one DOE employee were allowed to attend the ceremonies honoring this accomplishment.

Energy Star status

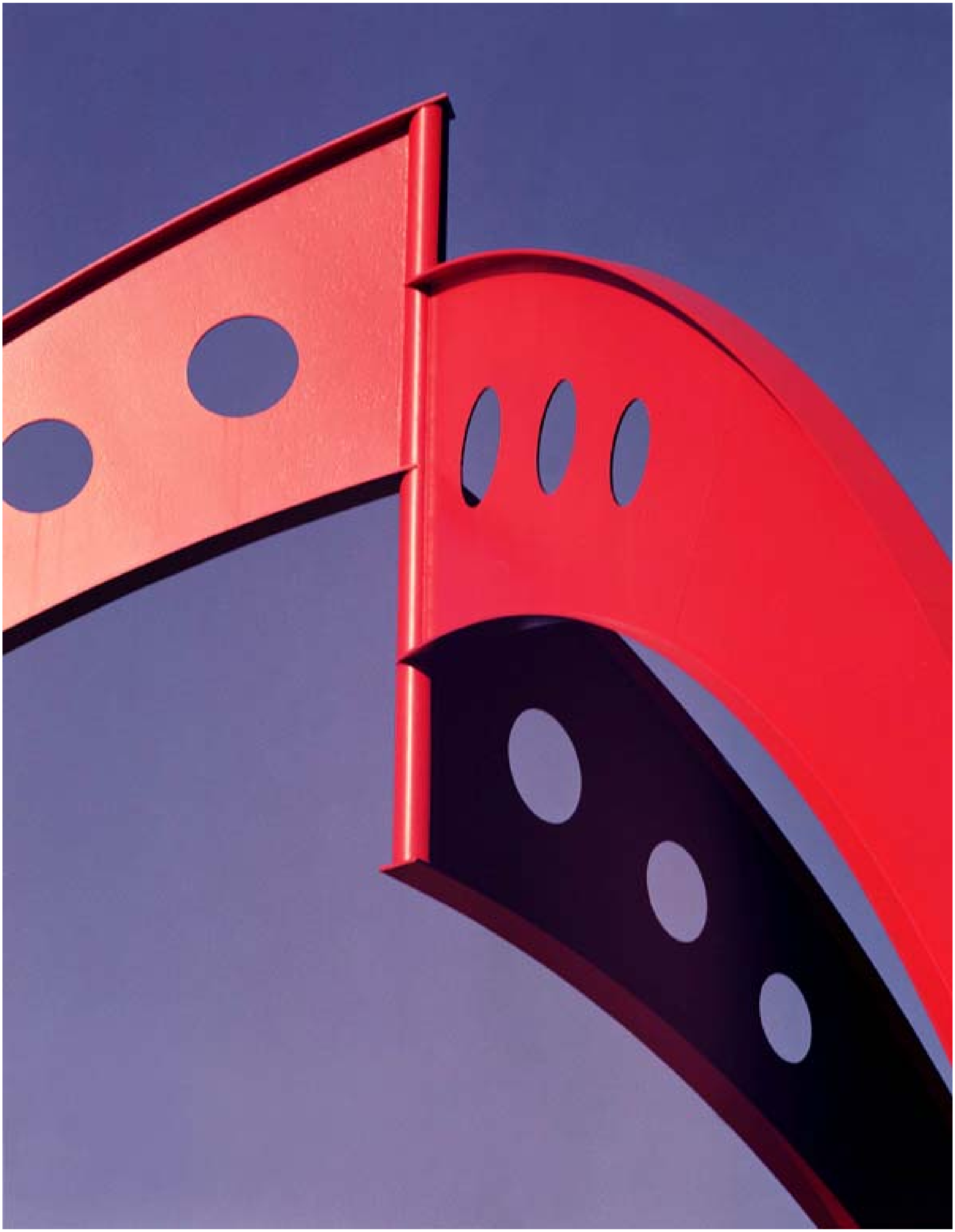
Although none of the buildings on site fit the Energy Star Building benchmark criteria, Fermilab continued to promote efficiency measures through its UIP program, and engineering design specifications. Fermilab has submitted a project to be constructed through its UIP program in ECM2001a – Phase C on Energy STAR building upgrades and certification in its Village area to DOE FEMP for funding under its FY2001 *Energy Retrofit Projects* initiative. It will also continue to monitor the Energy Star program for new developments. This addresses the goals of the *Fermilab Energy Management Plan* Section III paragraph 15 that pertains to Executive Order 13123 Section 403.c and d.

Summary

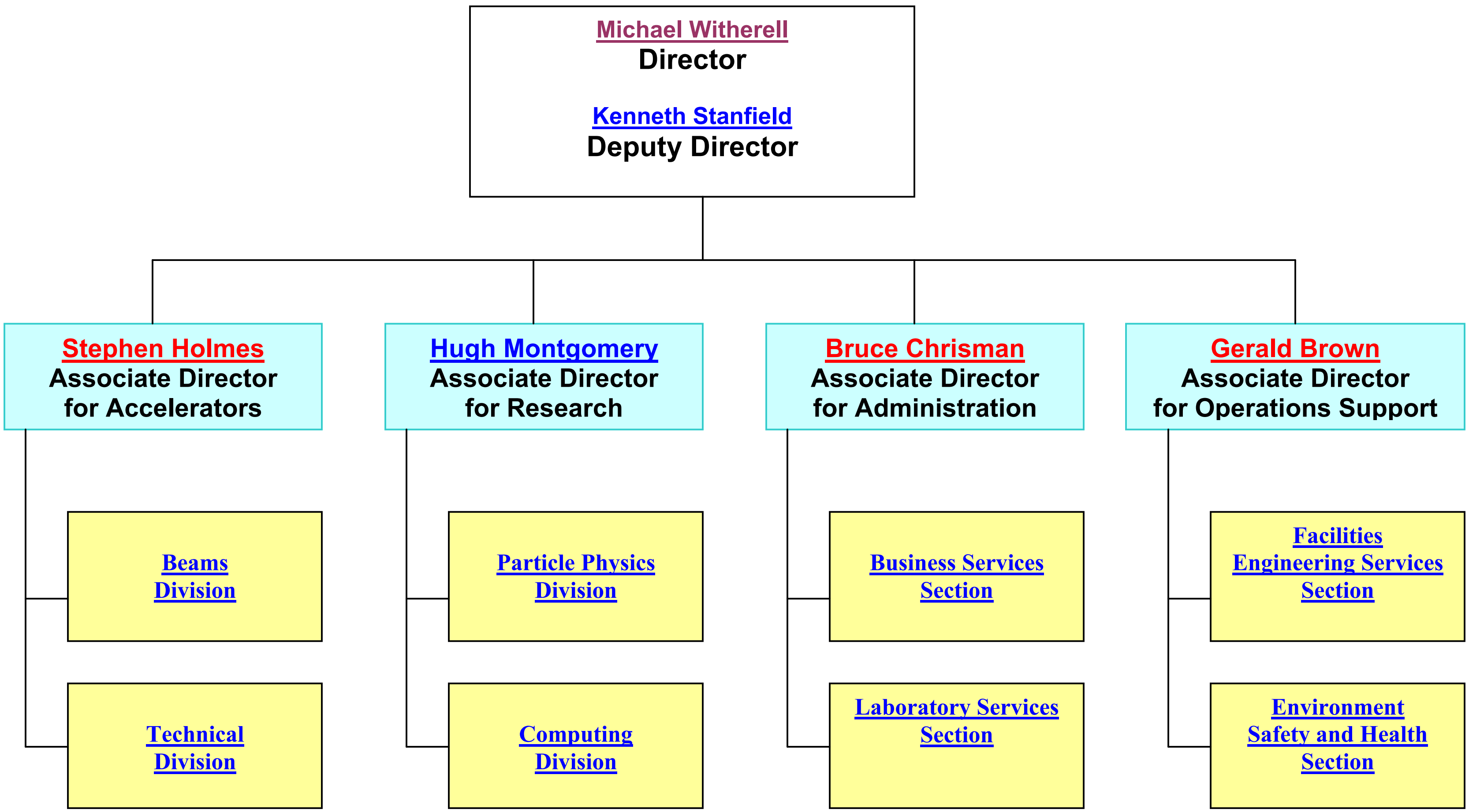
The Fermilab Strategic Facilities Plan brings together modernization guidelines and existing infrastructure requirements to identify in a comprehensive manner all known needs to continue towards achieving recognition as a "model" Office of Science laboratory for the 21st century. This Strategic Facilities Plan focuses on rebuilding Fermilab to best satisfy the current mission requirements while considering the various future activities that could be satisfied through infrastructure that has some of the highest utility reliability (and capacity) in the SC laboratory complex.

Most significant are the completion of the Utility Incentive program and master planning efforts underway to move towards SC modernization initiatives. Use of such programs has the potential to reduce overall revitalization costs by creating a platform for detailed infrastructure analysis in conjunction with utility company expertise, while creating real incentives to reduce costs and maximize return on investment. One of the advantages of using third party funding is that it allows immediate implementation of detailed infrastructure assessments and optimization planning together with initial renovation work at relatively low costs. This could allow more time for SC to develop direct funding sources without delaying critical infrastructure needs.

The identification and prioritization process that is described in this plan is one of several ongoing management initiatives used to develop this plan. These initiatives will continue to be critical management components for ensuring Fermilab continues to be operated and maintained with the focus of sustainability through flexibility and versatility thereby ensuring taxpayer investments continue to be used to create the highest value and associated contribution to science.



Fermilab Directorate Organization Chart



Resource Projections

and

Supplemental Information

Major Construction Projects ($ in Millions)

	TEC	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Funded Construction											
Program Line Item Projects											
NuMI Project	109.2	14.3	22.0	22.9	11.4						
General Plant Projects (KA)		3.9	2.8	3.0	1.4						
Accelerator Improvement Projects (KA)		3.5	4.4	4.9	3.8						
Total Funded		21.7	29.2	30.8	16.6	0.0	0.0	0.0	0.0	0.0	0.0
Budgeted Construction											
Program Line Items											
NuMI Project						20.1	12.5	0.5			
General Plant Projects (KA)											
Accelerator Improvement Projects (KA)											
Total Budgeted		0.0	0.0	0.0	0.0	20.1	12.5	0.5	0.0	0.0	0.0
Total Funded and Budgeted		21.7	29.2	30.8	16.6	20.1	12.5	0.5	0.0	0.0	0.0
Proposed Construction											
Program Line Items											
General Plant Projects (KA)						4.8	5.5	5.5	5.5	5.5	5.5
Accelerator Improvement Projects (KA)						8.5	8.6	12.8	10.6	9.4	9.5
Total Proposed		0.0	0.0	0.0	0.0	13.3	14.1	18.3	16.1	14.9	15.0
Total Funded, Budgeted, and Proposed		21.7	29.2	30.8	16.6	33.4	26.6	18.8	16.1	14.9	15.0

Funding by Activity

Millions of dollars, rounded to one decimal place

	FY 03	FY 04	FY 05	FY 06	FY 07	FY 08
R&D and Operations	226.7	230.5	246.5	258.5	273.9	280.8
Construction	33.4	26.6	18.8	16.1	14.9	15.0
Capital	40.9	45.2	45.2	44.0	37.4	38.2
Non-DOE Funds						
External Performers						
Total	301.0	302.3	310.5	318.6	326.2	334.0

Laboratory funding summary ($ in Millions)

($ in Millions-BA)	FY1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006
DOE Effort	180.7	177.2	199.1	211.4	224.3	249.4	215.4	222.1	236.0	248.3
LHC		4.1	14.9	11.7	8.3	8.7	11.1	8.2	10.3	10.0
Work for Others	0.2	0.2	0.2	0.2	0.0	0.0	0.2	0.2	0.2	0.2
TOTAL OPERATING	180.9	181.5	214.2	223.3	232.6	258.1	226.7	230.5	246.5	258.5
Program Capital Equipment	22.9	35.8	32.9	19.4	20.2	24.8	28.6	32.3	33.2	34.1
LHC Capital Equipment		11.6	28.1	21.8	21.7	20.4	12.3	12.9	12.0	9.9
Subtotal		47.4	61.0	41.2	41.9	45.2	40.9	45.2	45.2	44.0
Program Construction										
NuMI	- -	5.5	14.3	22.0	23.0	11.4	20.1	12.5	0.5	0.0
AIP/GPP	6.0	8.7	7.4	8.4	7.1	15.5	13.3	14.1	18.3	16.1
Subtotal	58.0	50.2	21.7	30.4	30.1	26.9	33.4	26.6	18.8	16.1
TOTAL LABORATORY FUNDING	261.8	279.1	296.9	294.9	304.6	330.2	301.0	302.3	310.5	318.6

Laboratory Funding Summary: Resources by Major DOE Programs
($ in millions)

Program	FY 1997	FY 1998	FY 1999	FY 2000	FY 2001	FY 2002	FY 2003	FY 2004	FY 2005	FY 2006	FY 2007	FY 2008
KA - High Energy Physics												
Operating (2)	####	181.3	214.0	223.1	232.6	258.1	223.2	226.8	242.7	254.6	269.9	276.7
Capital Equipment	22.9	47.4	61.0	41.2	41.9	45.2	40.9	45.2	45.2	44.0	37.4	38.2
Construction	58.0	50.2	21.7	30.4	30.1	26.9	33.4	26.6	18.8	16.1	14.9	15.0
Total KA	####	278.9	296.7	294.7	304.6	330.2	297.5	298.6	306.7	314.7	322.2	329.9
Program 60 - Work for Others												
Operating	0.2	0.2	0.2	0.2	0.0	0.0	0.2	0.2	0.2	0.2	0.2	0.2
Miscellaneous												
Operating	3.7	0.0	0.0	0.0	0.0	0.0	3.3	3.5	3.6	3.7	3.8	3.9
Capital Equipment	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Construction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total Misc.	3.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Personnel	**1,526**	**1,537**	**1,632**	**1,660**	**1,660**	**1,660**	**1,741**	**1,741**	**1,741**	**1,741**	**1,741**	**1,741**

Laboratory Funding Summary: Work for Others ($ in millions)

	FY03	FY04	FY05	FY06	FY07	FY08
Work for Others	0.2	0.2	0	0	0	0
Total	0.2	0.2	0	0	0	0

Laboratory Personnel Summary
Personnel Headcount at Fiscal Year End**

	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08
Direct	1,694.0	1,703.0	1,741.0	1,741.0	1,741.0	1,741.0	1,741.0	1,741.0
Indirect	495.0	496.0	507.0	507.0	507.0	507.0	507.0	507.0
TOTAL LABORATORY	2,189.0	2,199.0	2,248.0	2,248.0	2,248.0	2,248.0	2,248.0	2,248.0

*** Includes permanent and guest scientists, temporary and part time employees, and excludes employees on leave of absence**

Laboratory Staffing Summary

	2002	2001	2000	1999	1998	1997	1996	1995	1994	1993	Change 02-93
Engineers and Scientists	738	720	700	663	626	613	619	610	616	616	122
Technicians and Tech Support	623	634	650	659	663	681	711	740	792	819	-196
Computer Professionals	264	236	225	209	191	185	187	183	189	196	68
Other	561	560	576	563	547	572	611	618	674	685	-124
TOTAL LAB	2,186	2,150	2,151	2,094	2,027	2,051	2,128	2,151	2,271	2,316	-130

Years Since PhD—1997-2003

Yrs/Phd	1997	2002
0-5	60	75
6-10	72	71
11-15	72	79
16-20	53	71
21-25	34	53
26-30	48	36
31-35	21	46
36-40	11	16
41-45	0	6
45+	2	1

EEO Utilization Analysis Within Major Job Groups

	U.S. SOC Total	Male	Female	Male Black	Asian	Amer. Indian	Hisp. All Oth.	His/Lat White	Ha/Pac Islander	Female Black	Asian	Amer. Indian	Hisp. All Oth.	His/Lat White	Ha/Pac Islander	Total Minority	Total Female	Availability Minority	Percent Female	Under Minority	Utilization Female
Officials and Managers																					
Executives & Managers	145	117	28	0	2	0	0	1	1	3	2	0	1	0	0	10	28				
Percent			19.3	0.0	1.4	0.0	0.0	0.7	0.7	2.1	1.4	0.0	0.7	0.0	0.0	6.9	19.3	14.3	27.7	YES	YES
Unit Supervisors	91	82	9	4	1	0	1	0	0	1	0	0	1	0	0	8	9				
Percent			9.9	4.4	1.1	0.0	1.1	0.0	0.0	1.1	0.0	0.0	1.1	0.0	0.0	8.8	9.9	0.0	0.0	NO	NO
Skilled Supervisors	25	23	2	3	0	1	1	0	0	0	0	0	0	0	0	5	2				
Percent			8.0	12.0	0.0	4.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	8.0	0.0	0.0	NO	NO
Total Officials and Managers	261	222	39	7	3	1	2	1	1	4	2	0	2	0	0	23	39				
Percent			14.9	2.7	1.3	0.4	0.8	0.4	0.4	1.7	0.8	0.0	0.8	0.0	0.0	8.8	14.9				
Professionals																					
Administrative Support	123	39	84	3	1	0	1	0	0	6	6	0	3	3	0	23	84				
Percent			68.3	2.4	0.8	0.0	0.8	0.0	0.0	4.9	4.9	0.0	2.4	2.4	0.0	18.7	68.3	0.0	0.0	NO	NO
Engineering Physicists	67	60	7	3	3	0	0	0	0	0	0	0	0	0	0	6	7				
Percent			10.4	4.5	4.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NO	NO
Physicists	239	216	23	1	21	0	3	0	0	0	3	0	1	0	0	29	23				
Percent			9.6	0.4	8.8	0.0	1.3	0.0	0.0	0.0	1.3	0.0	0.4	0.0	0.0	12.1	9.6	19.4	16.4	YES	YES
Research Associates	204	165	39	0	33	0	2	5	0	0	9	0	1	1	0	74	39				
Percent			19.1	0.0	16.2	0.0	1.0	2.5	0.0	0.0	4.4	0.0	0.5	0.5	0.0	36.3	19.1	0.0	0.0	NO	NO
Engineering/Elec./Mech.	215	202	13	5	20	0	8	3	0	0	4	0	0	0	0	41	13				
Percent			6.0	2.3	9.3	0.0	3.7	1.4	0.0	0.0	1.9	0.0	0.0	0.0	0.0	19.1	6.0	0.0	10.3	NO	YES
Computing	187	141	46	5	18	0	2	0	0	1	6	0	3	0	0	35	46				
Percent			24.6	2.7	9.6	0.0	1.1	0.0	0.0	0.5	3.2	0.0	1.6	0.0	0.0	18.7	24.6	0.0	0.0	NO	NO
Technical Aides	140	128	12	10	1	0	2	0	0	1	0	0	2	0	0	16	12				
Percent			8.6	7.1	0.7	0.0	1.4	0.0	0.0	0.7	0.0	0.0	1.4	0.0	0.0	11.4	8.6	19.1	18.4	YES	YES
Total Professionals	1,175	951	224	27	97	0	18	8	0	8	28	0	10	4	0	224	224				
Percent			19.1	2.3	8.3	0.0	1.5	0.7	0.0	0.7	2.4	0.0	0.9	0.3	0.0	19.1	19.1				

	U.S. SOC Total	Male	Female	Black	Asian	Amer. Indian	Hisp. All Oth.	His/Lat White	Ha/Pac Islander	Black	Asian	Amer. Indian	Hisp. All Oth.	His/Lat White	Ha/Pac Islander	Total Minority	Total Female	Availability Minority	Percent Female	Under Minority	Utilization Female
Technicians																					
Drafting	39	32	7	3	1	0	1	0	0	0	0	0	0	0	0	5	7				
Percent			17.9	7.7	2.6	0.0	2.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.8	17.9	0.0	0.0	NO	NO
Technicians/Elec. Mech.	340	289	51	21	10	1	19	2	0	5	0	0	9	2	0	69	51				
Percent			15.0	6.2	2.9	0.3	5.6	0.6	0.0	1.5	0.0	0.0	2.6	0.6	0.0	20.3	15.0	0.0	0.0	NO	NO
Operations Support	42	31	11	1	1	0	0	0	1	1	0	0	2	1	0	8	11				
Percent			26.2	2.4	2.4	0.0	0.0	0.0	2.4	2.4	0.0	0.0	4.8	2.4	0.0	19.0	26.2	0.0	0.0	NO	NO
Total Technicians	421	352	69	25	12	1	20	2	1	6	0	0	11	3	0	82	69				
Percent			16.4	5.9	2.9	0.2	4.8	0.5	0.2	1.4	0.0	0.0	2.6	0.7	0.0	19.5	16.4				
Office and Clerical																					
Clerical	42	8	34	2	0	0	1	0	0	0	0	0	5	0	0	8	34				
Percent			81.0	4.8	0.0	0.0	2.4	0.0	0.0	0.0	0.0	0.0	11.9	0.0	0.0	19.0	81.0	0.0	0.0	NO	NO
Secretarial/Computg	67	3	64	0	0	0	0	0	0	8	0	0	6	1	0	16	64				
Percent			95.5	0.0	0.0	0.0	0.0	0.0	0.0	11.9	0.0	0.0	9.0	1.5	0.0	23.9	95.5	0.0	0.0	NO	NO
Total Office and Clerical	109	11	98	2	0	0	1	0	0	8	0	0	11	1	0	24	98				
Percent			89.9	1.8	0.0	0.0	0.9	0.0	0.0	7.3	0.0	0.0	10.1	0.9	0.0	22.0	89.9				
Craft Workers(skilled)																					
Misc. Crafts / Apprentices	97	92	5	7	2	0	11	1	0	1	0	0	0	0	0	23	5				
Percent			5.2	7.2	2.1	0.0	11.3	1.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	23.7	5.2	0.0	0.0	NO	NO
Machining	28	28	0	5	1	0	0	0	0	0	0	0	0	0	0	6	0				
Percent			0.0	17.9	3.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	21.4	0.0	0.0	0.0	NO	NO
Total Craft Workers (skilled)	125	120	5	12	3	0	11	1	0	1	0	0	0	0	0	29	5				
Percent			4.0	9.6	2.4	0.0	8.8	0.8	0.0	0.8	0.0	0.0	0.0	0.0	0.0	23.2	4.0				

	U.S. SOC Total	Male	Female	Black	Asian	Amer. Indian	Hisp. All Oth.	His/Lat White	Ha/Pac Islander	Black	Asian	Amer. Indian	Hisp. All Oth.	His/Lat White	Ha/Pac Islander	Total Minority	Total Female	Availability Minority	Percent Female	Under Minority	Utilization Female
Operatives (Semi-Skilled)																					
Assembly	4	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1				
Percent			25.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	25.0	0.0	0.0	N0	NO
Miscellaneous Operatives	35	31	4	6	0	0	3	1	0	1	0	0	0	0	0	11	4				
Percent			11.4	17.1	0.0	0.0	8.6	2.9	0.0	2.9	0.0	0.0	0.0	0.0	0.0	30.8	11.4	0.0	0.0	NO	NO
Total Operatives (Semi-Skilled)	39	34	5	6	0	0	3	1	0	1	0	0	0	0	0	11	5				
Percent			12.8	15.4	0.0	0.0	7.7	2.6	0.0	2.6	0.0	0.0	0.0	0.0	0.0	30.8	12.8				
Service Workers																					
Service Workers	16	0	16	0	0	0	0	0	0	0	0	0	2	0	0	2	16				
Percent			100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	12.5	100.0	20.5	0.0	YES	NO
Total Service Workers	16	0	16	0	0	0	0	0	0	0	0	0	2	0	0	2	16				
Percent			100.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.5	0.0	0.0	12.5	100.0				
Overall Total	2,146	1690	456	79	115	2	54	14	2	28	30	0	36	8	0	396	456				
Percent			21.2	3.7	5.4	0.1	2.5	0.7	0.1	1.3	1.4	0	1.7	0.4	0	18.5	21.2				

Fermilab Users—2003

US	Physicists	Students	Subtotal	Institutions
Universities	761	445	1203	93
National Laboratories	402	20	422	6
Subtotal	1163	465	1628	99
Non-US	**Physicists**	**Students**	**Subtotal**	**Institutions**
Universities	459	195	654	90
National Laboratories	294	39	333	23
Subtotal	753	234	987	114
Total	**1916**	**699**	**2615**	**213**

INTERNATIONAL USERS / TOP 10 Institutions

INSTITUTION	Phys.	Grad.	Total
1. IHEP - Protvino (Russia)	60	2	62
2. INFN – Pisa (Italy)	36	13	49
3. JINR – Dubna (Russia)	43	2	45
4. University of Tsukuba- Japan	14	24	38
5. INFN – Frascati (Italy)	22	3	25
6. ITEP – Moscow (Russia)	25	0	25
7. University of Padova - Italy	14	9	23
8. University of Oxford - England	13	9	22
9. University of Toronto - Canada	11	10	21
10. CEA-SACLAY - France	18	2	20
10. CBPF - Brazil	15	5	20

Fermilab Users—2003

BY COUNTRY OFHOME INSTITUTION

Italy, 203; Russia, 180; Japan, 98; United Kingdom, 83; France, 77; Germany, 53; South Korea, 43; Brazil, 39; Peoples Republic of China, 28; Canada, 26; India, 26; Mexico, 21; Switzerland, 13; Czech Republic, 12; The Netherlands, 12; Sweden, 11; Greece, 7; Colombia, 6; Spain, 6; Byelarus, 4; Finland, 4; Vietnam, 4; Israel, 3; Poland, 3; Argentina, 2; New Zealand, 2; Ecuador, 1; Ireland, 1; Slovakia, 1; Turkey, 1

U.S. USERS / TOP 10 (after FNAL, 295)

INSTITUTION	Phys.	Grad.	Total
1. Lawrence Berkeley National Lab	42	17	59
2. University of Michigan, Ann Arbor	28	23	51
3. University of Rochester	24	27	51
4. University of Chicago	19	16	35
5. SUNY at Stony Brook	18	17	35
6. Michigan State University	22	12	34
7. University of Illinois, Champaign	17	16	33
8. Harvard University	16	15	31
9. Argonne National Laboratory	29	1	30
10. University of Minnesota	18	12	30
10. Rutgers University	25	5	30

BY STATE OF HOME INSTITUTION

Illinois, 463; New York, 169; California, 162; Massachusetts,108; Michigan, 92; Texas, 72; Indiana, 70; Pennsylvania, 58; New Jersey, 39; Florida, 37; Maryland, 31; Minnesota, 31; Kansas, 29; North Carolina, 29; New Mexico, 27; Arizona, 23; Virginia, 19; Wisconsin, 18; Colorado, 17; Iowa, 17; Rhode Island, 17; Connecticut, 14; Oklahoma, 13; Ohio, 11; Louisiana, 10; South Carolina, 10; Tennessee, 10; Washington, 7; Hawaii, 6; Puerto Rico, 6; Alabama, 4; Nebraska, 4; Oregon, 4; Delaware, 1

Education Programs—Fermi National Accelerator Laboratory

Program	Part S	Part T	Hits	Wks	Year	Partners
Annenberg Leadership Academy		12		1.0	2	
Cryogenic Show	4,062			0.1	22	
Daughters and Sons to Work Day	250			0.2	9	
Fermilab Lecture Series		58			1	
Fermilab LInC Online		39		1.0	7	2 LInC teams
Fermilab Science Award	56				1	
Fermilab Teacher Fellowship		1		36.0	8	
Hands-on-Science	375			0.2	15	
Lederman Center	1,180	618		0.1	11	
Museum Partners		36		0.2	5	Chicago Museum Ptnrs
Phriendly Physics		28		0.4	6	
Physics Science Experience	2,853	17		1.0	19	
Prairie Science Experience	6,385	24		1.0	14	
Professional Networks		559		0.9	19	
QuarkNet Follow-on		398		1.0	2	24 QuarkNet Centers
QuarkNet Institutes		57		3.0	4	10 QuarkNet Centers
QuarkNet Research		20		9.0	5	10 QuarkNet Centers
Saturday Morning Physics	370			1.0	24	
Science Adventures	731			0.1	14	
Speaker's Bureau	594			0.1	4	
Target	20			6.0	24	
Teacher Resource Center		351		0.1	15	MSC
Tours	2,392	111		0.1	32	
TRAC				8.0	15	
Webserver			8,703,233		6	
Workshops/Presentations		774		0.2	19	
	19,268	3,103				

Education: Minority Programs

	FY2000:			FY2001:			FY2003:		
	Total	Minorities	Women	Total	Minorities	Women	Total	Minorities	Women
PRE-COLLEGE PROGRAMS									
Student Programs: TARGET	18	18	5	15	15	7	20	18	10
UNDERGRADUATE PROGRAMS									
Student Programs: Summer Internships in Science and Technology	18	18	7	17	15	5	14	14	3
GRADUATE PROGRAMS									
Student Programs: GEM PhD fellowships for minority students	5	5	1	3	3	2	3	3	2