4.a Science Approach *(L.4.a, M.4.a)*

FRA's science approach provides world-class scientific and engineering talent needed to maintain and extend US leadership in particle physics research; it includes innovative solutions and initiatives to maximize the scientific impacts from user facilities and the output of FNAL's R&D programs focused on attracting the ILC.

FNAL is the only US laboratory devoted solely to particle physics research, providing DOE and the US scientific community with leadership in this field. The approach to achieve DOE's mission must ensure that FNAL possesses:

- World-class scientific and technical personnel, both now and in the future
- Cutting-edge research facilities and equipment, and outstanding user support
- Focused and prioritized science and technology R&D programs that maximize output at the lowest possible cost

FRA brings a new style of leadership to FNAL that will provide stronger management of scientific research. ***Figure 4.a–1*** lists the features and benefits of this new approach which focuses resources on the ILC while delivering on the current science program ***(Section 3.a)***. Specifically, we will instill a continuous improvement management culture at FNAL on the principles of DOE O 414.1C (discussed in more detail in ***Section 4.b***), introduce institutionalized strategic planning and workforce planning, and carefully prioritize our resources to maximize the value of each taxpayer dollar invested in FNAL.

FRA's approach provides DOE with the strongest assurance that the US will remain a leader in particle physics, fully prepared to attract the ILC to the US—i.e., ensure that the best scientific and technical talent come to where the best machines and user support enable scientific discovery.

Features of FRA's Science Approach	Benefits to DOE
Overall Science Approach	
Manage by Principles of DOE Order 414.1C	Sound management practices for maximum performance and introduction of continuous improvement culture
Institutionalize Strategic Planning Process	Improved resource planning to ensure lowest-cost approach to achieve DOE's strategic goals for FNAL
Approach to Attract, Develop, and Retain World-Class Scientific Personnel	
Institutionalize Organization and Human Asset Planning	Matching workforce skill sets and size to FNAL mission; agility and scalability to transition to LHC and ILC support
Attract Talent Through Stakeholders (Universities, Users)	Ability to attract leading talent through university joint appointments and programs and develop talent pipeline through users
Expand Reach of K-12 Science Education Programs	Significant increase in number of teachers and students exposed to science research; enhanced US competitiveness
Approach to Maximize Scientific Impacts From User Facilities	
Upgrade Performance of Research Facilities	Prioritized upgrades to achieve scientific discovery mission; improved ability to attract the best scientific talent
Instill Best Practices in User Support	Efficient and cost-effective support for users, allowing them to focus more time and resources on research
Approach to Maximize the Output of FNAL's R&D Programs	
Collaborate with ANL and Leading Universities	Prioritized technology R&D collaborations with ANL and leading universities to increase productivity, reduce cost
Build Center of Excellence for ILC Accelerator R&D	Strengthened technology base in Illinois for ILC development and construction in support of US bid to host

Figure 4.a–1. FRA Science Approach. FRA brings a fresh approach that will achieve DOE's mission of US preeminence in particle physics.

Overall Science Approach. FRA's top-level approach to managing science at FNAL instills a continuous improvement management culture based on the principles of DOE O 414.1C: management, performance, and assessment. This approach, based on quality assurance principles, integrates management and operation of FNAL, generates efficiencies and cost savings, and provides the framework for a set of new FRA management initiatives. These initiatives are a result of Director Oddone's 2005 Director's Management Review, his initial exercise to instill a new style of leadership that will yield stronger management of scientific research at FNAL. Initiatives at the strategic level, such as institutionalized strategic planning and human asset planning, are discussed in this section. Initiatives related to enhanced performance-based management of FNAL are discussed in ***Section 4.b***.

FRA's first strategic-level initiative implements an FNAL strategic planning process to elaborate on the Laboratory Director's 10-year vision for FNAL and provide an execution roadmap to achieve the vision. The new FNAL Strategic Plan serves as a guide for establishing budgets and work plans, and will be timed to coincide with, and to contribute to, DOE's annual planning process. It provides the top-level guidance that integrates FNAL's current planning processes, including the Budget Plan, Business Plan, Facility and Property Plan, and planning processes of the Physics Advisory Committee and Accelerator Advisory Committee. The Strategic Plan will also guide FRA's proposed Organization and Human Asset Plan (OHAP), discussed in ***Section 4.a.1***, and will serve as a communications tool to inform DOE, the particle physics community, the FNAL staff, and other customers and stakeholders of the laboratory's plan for achieving its mission and vision.

Under Director Oddone's leadership, Deputy Director Young-Kee Kim will apply her skills in managing large-scale scientific collaborations to define, direct, and coordinate the planning process. Dr. Kim will marshal subject matter expertise 1) within the laboratory (e.g., the COO, CFO, Office of Quality and Best Practices (OQBP, which is a new initiative discussed in ***Section 4.b***)), ES&H, and the line organizations; and 2) outside the laboratory (e.g., DOE, the NSF, the international particle physics community, and the FRA Board of Directors). To execute FRA's enhanced strategic planning process, illustrated in ***Figure 4.a–2***, Dr. Kim will form a Strategic Planning Advisory Panel made up of preeminent scientists from the laboratory and the international science community to review and adapt the Laboratory Director's strategic vision for FNAL. By the end of the first six months of contract execu-

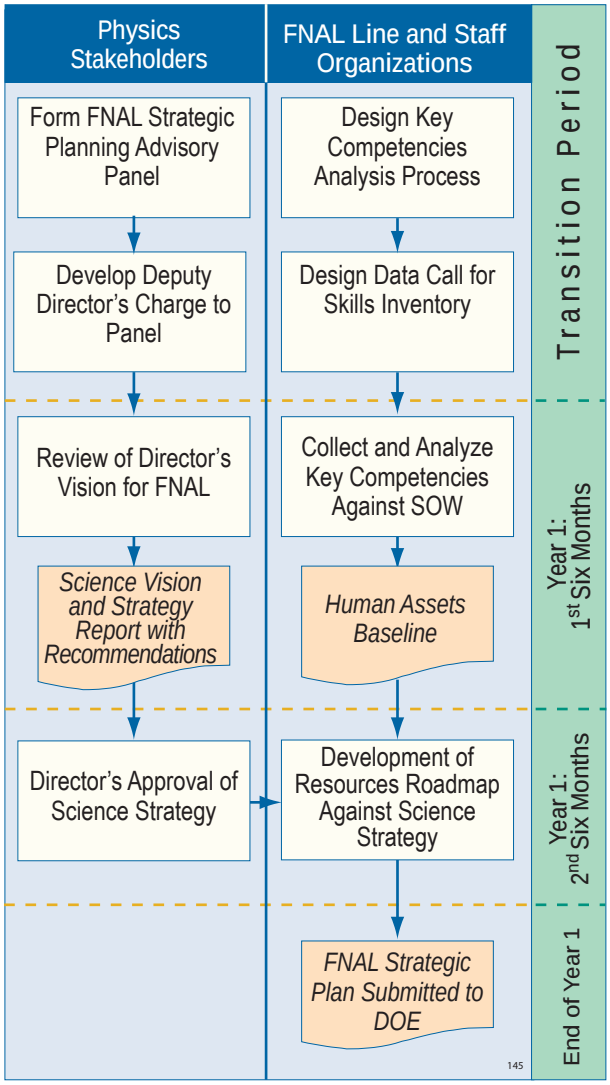


Figure 4.a–2. Enhanced Strategic-Planning Process—Transition Period and Year 1. Building on URA processes and procedures, FRA offers a disciplined approach to plan for FNAL's evolving mission that engages all internal and external stakeholders.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

tion, the Panel will produce a report with recommendations to the Laboratory Director on the relative priorities for scientific programs at the laboratory, and skills and expertise needed to achieve the scientific goals over a 10-year period. Dr. Kim will review the Panel's report and make recommendations to the Director for a revised Science Strategy for FNAL.

Once the Laboratory Director approves the revised FNAL Science Strategy at the beginning of the second six months of contract execution, the Deputy Director will task the line and staff organizations to develop a roadmap for execution of the FNAL Science Strategy. The roadmap will provide milestones along the 10-year timeline of the FNAL Science Strategy and develop resource requirements to achieve the milestones.

Beginning during the transition period, the Deputy Director will also direct a key competencies analysis to baseline the Laboratory's current human resources competencies against the SOW of the new FNAL contract. The Deputy Director will task the Human Resources Manager and the Head of the Office of Quality and Best Practices to design the analytical process and documentation approach—relying on input from designated subcontractor EG&G/URS and other sources. The Office of Project Management Oversight will provide input into process and documentation development to ensure that the output is standardization of skill sets throughout the Laboratory to generate future efficiencies in project planning.

The Laboratory Director, as President of FRA, LLC, will issue, during transition, the data call request for the key competencies analysis together with the employment letters to former URA employees. During the first six months of contract execution, the Human Resources Manager will execute the key competencies analysis. The deliverable will be a human assets baseline report that shows key competency gaps and redundancies against FNAL's current mission that will serve as a key element of strategic planning. The next step is to combine the human assets baseline with the FNAL science strategy to yield a fully resource-loaded science plan for the laboratory. The resulting Organization and Human Asset Plan (OHAP—see ***Section 4.a.1***) will identify financial or human resource gaps and establish key milestones and deliverables.

The deliverable to DOE at the end of the first year of contract execution—prior to the start of DOE's annual planning process—is a baseline FNAL Strategic Plan and resource-loaded schedule that articulates the scientific vision, along with the strategy and resource requirements to achieve the vision. During years 2-5 of the contract, the Deputy Director will obtain advice from the Physics Advisory Committee (PAC, discussed in ***Section 4.a.3.1***) and Accelerator Advisory Committee (AAC, discussed in ***Section 4.a.3.3***) for modifications to the Strategic Plan; FRA will monitor progress against established technical and financial milestones. The line and staff organizations will update annually the resource-loaded schedule prior to the start of DOE's annual planning process. The Deputy Director will reconvene the Strategic Planning Advisory Panel in the event of major developments in the international physics community's priorities and/or funding to make recommendations for major changes to the FNAL Strategic Plan.

The primary benefit to DOE of our strategic planning process is a formal, disciplined approach to planning for the transition of the laboratory's mission that engages all internal and external stakeholders and laboratory management. This process is particularly important over the next five years because of the uncertainties and variables that lie ahead concerning the future of the Tevatron, LHC, and ILC. The strategic planning process creates the structure for the laboratory to adapt to a changing mission as well as new discoveries that affect the direction of research programs. The FNAL Strategic Plan also serves as a single source document that integrates all laboratory planning and budget processes, resulting in enhanced efficiency in utilization of resources. Finally, DOE can rely on it as a communications document to inform stakeholders about the vision and direction of FNAL.

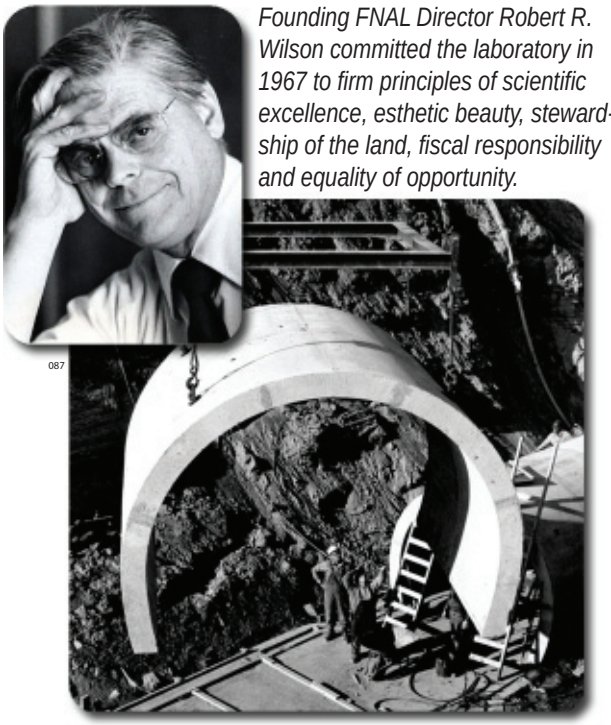
4.a.1 Attracting, Developing, and Retaining World-Class Scientific Personnel

(*L.4.a.1, M.4.a.1)*

The most valuable asset in an R&D organization is its staff. Our approach provides a working environment that attracts the best and brightest, providing training, benefits and incentives to retain them at FNAL. The next five years will be extremely dynamic and challenging as the Tevatron program ramps down, the LHC begins operations, and planning for the ILC accelerates. During this period, FRA will continue to focus on the founding principles of FNAL (***Figure 4.a–3***) to provide a world-class scientific environment that attracts the best talent and fosters scientific discovery. We will provide leadership by facilitating research collaborations and joint appointments that make possible a robust and ambitious scientific agenda. FRA will provide the leadership needed for FNAL to react quickly to rapidly emerging national and international developments that will shape the laboratory's future—in close partnership with DOE and its many stakeholders.

To ensure that FNAL has in place the right scientific and technical personnel to achieve its changing mission, FRA will implement a comprehensive Organization and Human Asset Plan (OHAP) process, which will be tied specifically to the FRA Strategic Plan. The OHAP will identify strategies and specific action plans related to organization structure and people that enable FRA to achieve its scientific mission. The OHAP process will be conducted at the organization as well as departmental level, and will include review of individual leaders, scientists and professionals. This crucial process will create and drive plans for:

- ***People resource planning and allocation***, including how many staff members, with what skills, at which locations and when; how FRA will acquire and retain the appropriate skill mix in view of changing priorities and initiatives identified and driven by the Strategic Plan; given the strategic goals of FRA, what is the most efficient and most cost effective organization structure possible; and how should roles and responsibilities be redefined/realigned to achieve this
- ***Recruitment planning*** for skill sets and experience not available internally
- ***Succession planning***, including specific development plans for key staff, where requisite skills may already exist in the organization
- ***Training and development priorities*** for the entire organization, and in particular, for key leaders and high potential laboratory employees; how FRA will rapidly accelerate development in areas where there are skill shortages or gaps, including science/technology, business operations and general management, and leadership
- ***Ongoing performance management,*** including regular reviews to hold leaders accountable for performance management of individual staff members



Founding FNAL Director Robert R. Wilson committed the laboratory in 1967 to firm principles of scientific excellence, esthetic beauty, stewardship of the land, fiscal responsibility and equality of opportunity.

Figure 4.a–3. FNAL Founding Principles. FRA will continue FNAL's focus on its founding principles, which are key to attracting, developing, and retaining world-class talent.

FRA will benchmark profitable commercial organizations that use best-in-class processes for organization and human resource planning—in particular, where organizations have demonstrated a direct link from their human

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

resource strategic planning to attainment of strategic business goals and/or improved profitability. In addition to EG&G/URS, potential benchmark companies include General Electric, Cisco, Bank of America and Proctor & Gamble. Business schools of UChicago and the Illinois universities serving on the FRA Board as well as the Center for Effective Organizations (CEO), Marshall School of Business at the University of Southern California will also be consulted for advice and guidance in developing the specific OHAP process for FRA.

Each year, an OHAP will be developed for the Laboratory Director's approval and submission to the Fermi Site Office Manager. A six-month update and review of action items will also be presented to DOE. Also annually and with a six-month update and review, division/section level plans will be prepared by each division/section head and presented to the Laboratory Director for approval. The OHAP process includes the following elements:

- Review the most critical scientific and resource shifts that will comprise FNAL's mission over the next several years (as detailed in strategic plan)
- Review critical strategies which must be effectively implemented to address those shifts (as detailed in strategic plan)
- Develop plans in the format of strategy/issue, background, current status, planned action, and measures of success
- Analyze key competencies required to deliver strategy (both organizational and individual)
- Analyze "build/buy" options for necessary talent and develop a plan to acquire required competencies, and/or analyze staff reduction options such as attrition and Reduction in Force
- Review current organization structure ("as is") and propose future organization structure ("should be") to best address strategy/issues
- Review positions, people and performance
- For critical positions, identify "ready now" and "ready soon" successors, and define development plans to accelerate readiness

As in DOE's desired outcomes for strategic planning, the OHAP will be used to build consensus around goals, provide a basis for resource allocation, control outcomes, and help evaluate performance. Senior staff and their direct reports will be held accountable to think beyond the current situation and today's priorities, beyond "the way we've always managed", and beyond leaders' perceived desires. Regular and ongoing review with the DOE Fermi Site Office Manager—as well as the FRA Board of Directors—will facilitate accountability for the strategic human asset plans and the desired positive impact on FRA's mission.

Attracting World-Class Scientific Personnel. FRA recognizes that the approach to attract world-class scientists is to offer unparalleled discovery-class research programs, facilities, and tools. The ground-breaking HEP work performed at FNAL attracts top-tier science and engineering talent from across the US and beyond. As the site mission adapts to the Tevatron's closing and other developments, however, FRA supervisors and managers will be especially challenged to maintain a highly effective scientific workforce to meet mission requirements. To help address this challenge, FRA will leverage the combined resources of URA and the major Illinois research universities, including UChicago, to broaden our reach among science and technical talent; to maintain and expand the site's disciplined processes and procedures to identify and attract the best qualified talent; and to engage, develop, and retain this talent over the long term. Features of our approach are illustrated in ***Figure 4.a–4***, below. This approach is fundamental to our success in achieving FNAL's plans for future scientific discovery. FRA parent organizations URA and UChicago bring significant capabilities and experience to this task, including:

- Nearly a century of combined experience and expertise in attracting many of the world's leading scientists at FNAL and ANL
- Forefront science programs at FNAL and ANL that attract thousands of scientists each year, some of whom are starting their careers and many who obtain doctorates on

their work—more than 100 scientists working at FNAL facilities obtained their doctorates in 2005 alone
- The top-tier scientific reputations of UChicago, the other Illinois universities, and URA's 90-member R&D university consortium—enabling our staff to "network" on a daily basis with both the nation's current and next generation of leading scientists, engineers, and computational specialists

Based on the key competencies analysis, and having instituted the OHAP in the first six months of contract performance, FRA will fill staffing gaps by expanding the current candidate resource base used to identify, attract, and hire well-qualified scientific talent. Our process is illustrated in ***Figure 4.a–5***. By leveraging URA and UChicago resources, established HR processes and systems, and combined reach into the national and international science community, FRA will maintain ample backup for every scientific, engineering, and information technology (IT) labor category to help fill vacancies as quickly as possible, including rapid ramp-up to support new programs such as the ILC. As shown in ***Figure 4.a–6***, the entire FRA organization supports and plays an active role in implementing the Laboratory's program to attract top-tier science and engineering talent to the laboratory.

FRA will fill significant science and management vacancies through search committees and teams composed of members with prestigious credentials, which helps to attract a diverse pool of top candidates—as we proactively invite applications from individuals identified as highly qualified. Other specialized approaches and techniques will be deployed as well. Our approach will be similar to the search process used in hiring Director Oddone:
- Appoint a distinguished Chair of the search committee
- Post an informational website to capture a broad set of recommendations and inputs
- Invite senior members of the scientific community to nominate candidates
- Authorize the committee to screen and interview qualified candidates
- Present candidates to FRA Board for review and final approval

Through UChicago and the other Illinois universities, FRA will expand the number of joint appointments (discussed in ***Section 8***) provided to leading scientists conducting research at FNAL. We understand that bright, young sci-

FRA New Initiative 6

Features
- Expand Joint Appointments with UChicago and other Illinois universities
- Provide exciting, program-based research opportunities and the resources and leading-edge infrastructure to support staff in pursuit of these opportunities
- Expand visiting researchers programs with URA's 90 research university members
- Work with UChicago, other Illinois universities, and URA-member schools to increase the supply of science and engineering students
- Cultivate students participating in the FNAL research program
- Feature the Chicago area's quality of life based on its leading cultural, educational, medical, recreational, and affordable housing offerings
- Identify qualified candidates via the "Dual Career Network"
- Maintain FNAL's 8 major fellowships, including the newly-established International Fellows at Fermilab Program
- Continue use of Internet-based recruiting systems and tools to process qualified science, engineering, and computational talent
- Offer attractive, market-competitive compensation and benefits

Benefits
- New resources from alliances with Illinois research universities
- Scalability to meet any new FNAL challenge
- Highest-quality science and engineering talent, both in the US and internationally
- Continued high rate of employee retention
- Well-managed fellowship programs that provide additional sources of qualified candidates

191

Figure 4.a–4. Features and Benefits of FRA's Approach to Attract World-Class Talent. FRA's approach assures that the best science and engineering talent is available to conduct forefront science.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

entists are often drawn to academic life as a job choice: for this reason, UChicago is committed to creating joint appointments within the University's Department of Physics and Department of Astronomy and Astrophysics. In addition, the other Illinois universities represented on the FRA Board commit to providing at least one joint appointment each. The Director identifies the need for a scientific position which is an opportunity for a joint appointment. A FNAL-university committee makes joint appointment recommendations, and the Laboratory Director negotiates candidates with the University. The joint appointee becomes a member of the university faculty and a staff member at FNAL as the home for his or her research. Salaries will be shared by the respective university and FRA, providing DOE an efficient and mutually beneficial arrangement. Our joint appointments initiative will strengthen the intellectual talent base in physics in Illinois that is tied to FNAL, which will help to maintain US competitiveness in particle physics research and to support the US bid to host the ILC.

1 Sources/Methods to Identify Outstanding and Diverse Scientific Personnel

- Scientific networking through URA, UChicago, and other university connections, conferences, links with university collaborations
- Networking through professional associations
- Search committees with prestigious members for top management positions
- International outreach through collaborations and conferences
- Attendance at job fairs and annual conferences of the Black and Hispanic Physicists, and Societies for Women, African American and Hispanic Engineers
- Board membership with HBCU/minority institutions—e.g., Prairie View A&M University, Prairie View, Texas
- Web advertising on several job website and niche job websites (e.g., monster.com, careerbuilder.com, AID.org, CERNCourier.com, SPIRES, and HACE)
- Intern and co-op programs that encourage future hires —e.g., Graduate Minority Engineers (GEM) program
- Continuation of recently launched FNAL committee to research and recommend new methods for identifying and hiring minority and women candidates

2 Hiring Process

- Line managers identify staffing needs, participate in the search process, and make final hiring decision
- Search committees and interview teams evaluate and interview candidates
- Human Resources screens and interfaces with candidates
- Behavioral interviewing process—managers are trained to use the system

3 Results

- Top-tier scientific talent for FNAL
- Highly-motivated employees interested in long-term science opportunities
- Low-cost process due to high acceptance rate
- Increased diversity and lessons learned for Diversity Council's consideration

004

Figure 4.a–5. Rigorous Identification, Screening, and Hiring Process. Our approach greatly reduces short- and long-term FNAL staffing risks.

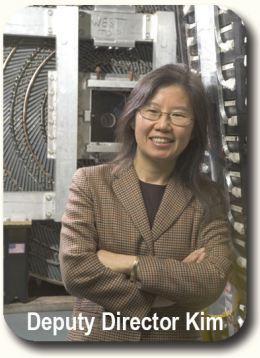
In addition to joint appointments, FRA will provide eight fellowship programs—seven well-established, the eighth new to FNAL. These established fellowships, which have succeeded in bringing dozens of top-tier scientists and engineers to the lab over the years, include:

- Robert W. Wilson Fellowship Program: Experimental Physics—tenure track
- Leon M. Lederman Fellowship Program: Experimental Physics—early postdoctoral
- John Peoples Fellowship Program: Accelerator Science—tenure track
- Gary Brinson Fellowship Program: Particle Astrophysics—Ph.D Students
- John Bardeen Fellowship Program: Engineering—entry-level M.S. or Ph.D
- David N. Schramm Fellowship: Theoretical Astrophysics—postdoctoral research
- FNAL Computing Fellowship: young researchers in high-performance scientific computing/ networking

The new fellowship is FRA's proposed International Fellows Program, described in ***Figure 4.a–7***. FRA developed this program to ensure that FNAL continues to capture international talent, since much of FNAL's science talent originates (and will continue to originate) overseas. This program will provide an opportunity for

FRA New Initiative 7

research and training in experimental physics for the most promising early career physicists worldwide and will benefit FNAL by focusing international attention on the current Tevatron program and US advances in development of the ILC. Scientists will gain experience by participating in research at FNAL, and by working with outstanding scientists at the forefront of particle, astroparticle and accelerator physics. In addition, this program involves scientists and engineers in current FNAL experiments and development of the ILC.



"If we are going to bring the International Linear Collider to Fermilab, we need to provide leadership internationally and embrace FNAL's qualities of openness and collaboration."
FRA Deputy Director,
Dr. Young-Kee Kim

International Fellows Program Goals

- Bring best of international student, post-doctoral, and scientist candidates to FNAL for up to 3 years
- Use international talent and ties to maximize results of current Tevatron and LHC program
- Enhance international collaboration with FNAL on ILC

Figure 4.a–7. International Fellows Program. FRA will attract promising international talent to FNAL, which will benefit DOE by focusing international attention on the current Tevatron program and US advances in development of the ILC.

Initially, fellowships under the International Fellows Program will be available to physicists interested in working on the Tevatron collider experiments, and scientists and engineers interested in developing accelerator and detector technology and test facilities for the International Linear Collider. Our approach

FRA Board of Directors

- Provide insight and guidance
- Leverage URA-member institutions, UChicago, and other Illinois universities as resources for recruiting scientific and engineering talent for FNAL
- Maintain ties with URA research universities and industry
- Establish search committee for Laboratory Director position
- Broaden staffing pipeline through networking
- Approve key personnel
- Approve compensation plan for submittal to DOE
- Approve joint appointments

FRA Line Managers

- Participating actively in HEP community
- Contribute to workforce-planning and succession-planning processes
- Evaluate FNAL staffing needs
- Work with HR to identify top candidates
- Interview and select candidates
- Present key position and joint appointment recommendations to Director for submission to Board
- Feed staffing pipeline for future openings
- Assess hiring program success, including number of diversity candidate hires
- Attend job fairs and professional association meetings as FRA representatives; attend client engagement meetings with recruiters

FRA Workforce

- Identify staffing needs
- Provide HR with qualified candidates
- Support and mentor new hires
- Provide feedback to HR on effectiveness of staffing initiatives and procedures

FRA HR Specialists

- Execute FRA's Organization and Human Asset Plan (OHAP) process
- Maintain pipeline in a manner that attracts the best scientists and engineers to FNAL
- Identify staffing needs with line managers and supervisors—provide them with lists of qualified candidates
- Assess candidates for position openings
- Conduct searches as necessary
- Keep candidates apprised of hiring status
- Process all hiring forms
- Maintain HR-related metrics to measure program success and areas for improvement

Figure 4.a–6. FRA Approach to Attracting Scientific Personnel. We will involve the entire FRA organization—and will provide an expert HR staff—to ensure that FNAL continues to attract and hire the best science and engineering talent.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

includes categories for student, post-doctoral, and scientist candidates. In future years, FRA plans to extend the program to other areas of activity at the laboratory. ***Figure 4.a–8*** provides an overview of this new program.
FRA will continue to support the activities of the Awards Committee, which was formed four years ago by URA. This committee systematically searches for award opportunities available in the US and abroad, identifies qualified FNAL candidate scientists and engineers, and prepares and submits the appropriate nomination packages. A number of FNAL scientists and engineers have received awards as a result of the work of this committee—many of whom are included in the awards tables provided in ***Section 2.a***. FRA will also continue to offer the annual *Alvin Tollestrup Award* to a postdoctoral researcher for outstanding research, and the *Thesis Award* to a graduate student for an outstanding doctoral thesis based on FNAL research.

FRA will also maintain the successful FNAL Accelerator Ph.D program, which operates in similar fashion to the fellowship programs discussed above. This program, initiated in 1984 has:

- Accepted students from 26 universities
- Graduated 30 Ph.Ds, many who have already achieved distinguished physics careers
- Supports 8 current students

Finally, FRA will also link FNAL to the Dual Career Network, a program designed to assist permanent new faculty and staff spouses/partners in their job search. Here, our HR specialists will facilitate the finding of positions for partners of faculty and staff that the participating FRA institutions are trying to attract or retain (i.e., FNAL, ANL, UChicago, and the other Illinois universities).

Developing World-Class Scientific Personnel. FRA will enrich the professional experi-

International Student Fellows	
Duration	❖ Up to 3 years
Financial Support	❖ $25,000 per year ❖ Additional financial support will be provided for presentation of a paper at one conference per year
Requirements	❖ Candidates must be enrolled in a Ph.D program at a non-US institution ❖ The student's institution agrees that research at FNAL, if successfully carried out, will be in partial fulfillment of the student's Ph.D thesis ❖ An FNAL scientist or faculty member from a collaborating institution will be assigned as a co-advisor to supervise each student
International Post-Doctoral Fellows	
Duration	❖ Up to 3 years
Financial Support	❖ Up to $25,000 per year supplement, in the form of a stipend ❖ Additional financial support will be provided for presentation of a paper at one conference per year
Requirements	❖ Candidates must be employed by, and receive salary support from, a non-US institution, to which they will normally be expected to return following the term of the Fellowship
International Scientist Fellows	
Duration	❖ 1 year base period, but renewable annually up to total 3 years
Financial Support	❖ $40,000 per year supplement ❖ Additional financial support will be provided for presentation of a paper at one conference per year
Requirements	❖ Candidates must be employed by a non-US institution, to which they will normally be expected to return following the term of the Fellowship ❖ They must also have a salary paid by the non-US institution ❖ Financial support provided by FRA is meant to be used for extra costs necessitated by the temporary relocation at FNAL

Figure 4.a–8. Proposed International Fellows Program. FRA will work to ensure that FNAL continues to attract top international science talent.

ence of FNAL scientists and engineers by facilitating breakthrough research opportunities, providing strong links to the worldwide physics community, and providing a positive, team-based work environment. Both URA and UChicago have enhanced personnel development by creating a dynamic environment where scientists are challenged to push traditional boundaries in the pursuit of science discovery. URA has developed and nurtured such an environment at FNAL over four decades; synergistically, UChicago has been at the forefront of scientific breakthroughs in astrophysics and other fields relevant to FNAL, made possible in large part by UChicago programs to develop and retain our scientists, engineers, and other technical staff.

While creating the right environment for scientific discovery is the critical component to employee development and retention, it must be coupled with a comprehensive program that focuses on career development and nurtures our science and engineering talent. A well-qualified scientific hire will enter the FRA employee-development program under an assigned mentor. Our approach to professional development is described in ***Figure 4.a–9***.

FRA will continue the formal FNAL mentoring program for the experiment research associates at the Laboratory, organized through the individual experiments where the research associates do their research, but coordinated by the Environmental Physics Projects (EPP) Department of the Particle Physics Division (PPD). The FNAL Committee on Scientific Appointments (FCSA) and the Engineering Policy Committee regularly review scientific and engineering staff for career advancement.

Providing a comprehensive, current, and compelling training program, described in ***Figure 4.a–10***, is also key to developing our scientific personnel as part of the broader initiative under DOE O 414.1C. The primary goal of our training and development function is to increase the knowledge and skill base of FNAL employees. Training is designed to enhance current job performance and to prepare employees for future job responsibilities. We will identify performance-improvement requirements via a needs-assessment process and/or direct manager/employee requests—then implement training solutions tailored to meet those needs. Our training system uses participant workbooks, instructor guides, videos, and job aids. Instruction is followed by Level I and II evaluations.

FRA Professional Development Program Elements

- "Career pathways" support and mentoring to help employees reach their full potential
- Tuition-reimbursement provided for degree programs and individual courses at local universities related to the individual's current position or another that an employee might fill
- Web-based refresher training modules (e.g., ES&H, laboratory services) and access to publications and videos of conferences and symposia
- Commercial best-practices training offered by team subcontractor EG&G/URS including project management delivery and IT systems and software
- Support for employees' certifications
- Support for employees' membership and participation in professional associations and conferences to keep their knowledge and skills current
- Performance appraisals containing a section focused on professional development
- Professional Organization courses in computer skills, interpersonal skills, safety, and technical training
- Management development in collaboration with UChicago, IIT, and Northwestern business schools

193

Figure 4.a–9. Developing Our Scientific Talent. The FRA approach improves performance over the short term and prepares staff for higher levels of responsibility.

Retention of World-Class Scientific Personnel. Our approach to retention parallels our approach to attracting personnel. We offer the world's best research programs, facilities, and tools in the field of HEP. One risk for retention in the coming years, however, is the shutdown of the Tevatron as we enter the transition period to future programs. Features and benefits of our approach to mitigate this risk are described in ***Figure 4.a–11***. Leading scientists and engineers will always seek opportunities first where breakthrough science is possible. Over the long term, the greatest breakthrough science will be performed at the ILC. At the strategic level, our

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

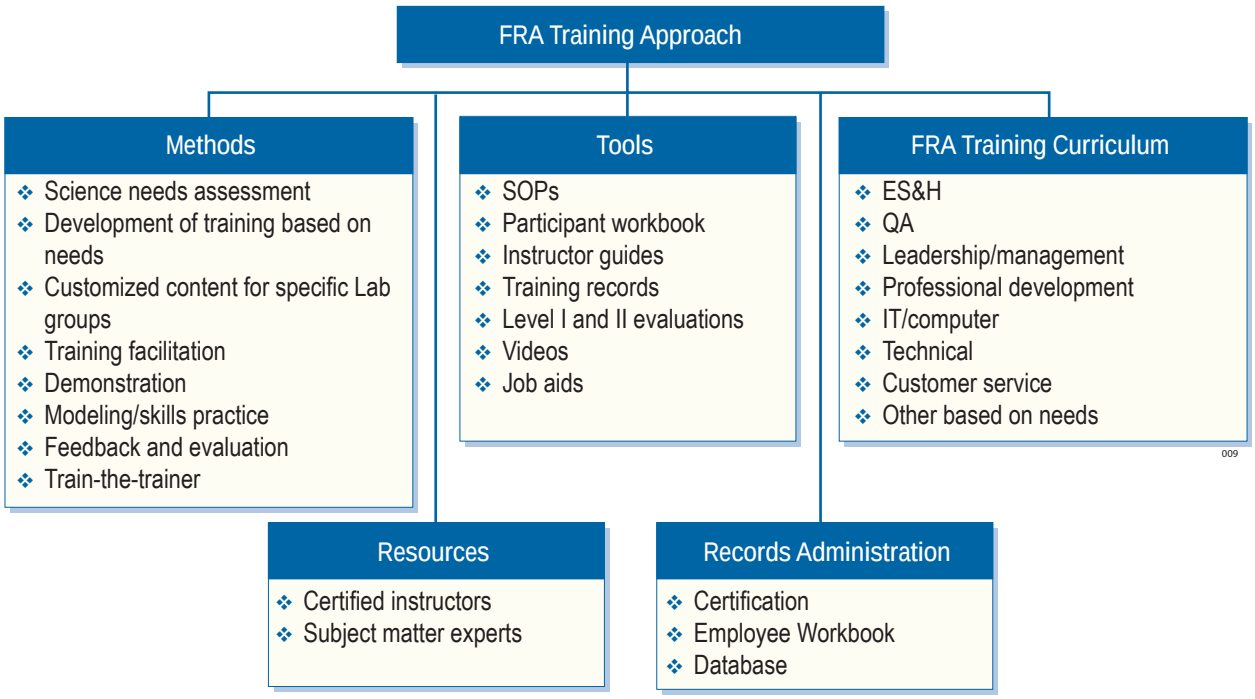


Figure 4.a–10. FRA Training Program. Effective training is a key component to developing our science and engineering talent.

primary mitigation of the retention risk is our strategy to focus significant resources on attracting the ILC to FNAL. To execute this strategy, the Laboratory Director will involve FNAL scientists and engineers in our ILC capture plan so they are invested in the success of the bid to host and build the ILC.

To support this strategy, the Deputy Director has appointed and will convene an ILC Task Force consisting of 9 FNAL and 11 non-FNAL particle physicists, and an ILC Particle Physics Team consisting of over 30 FNAL particle physicists. The ILC will involve particle physicists in accelerator as well as detector

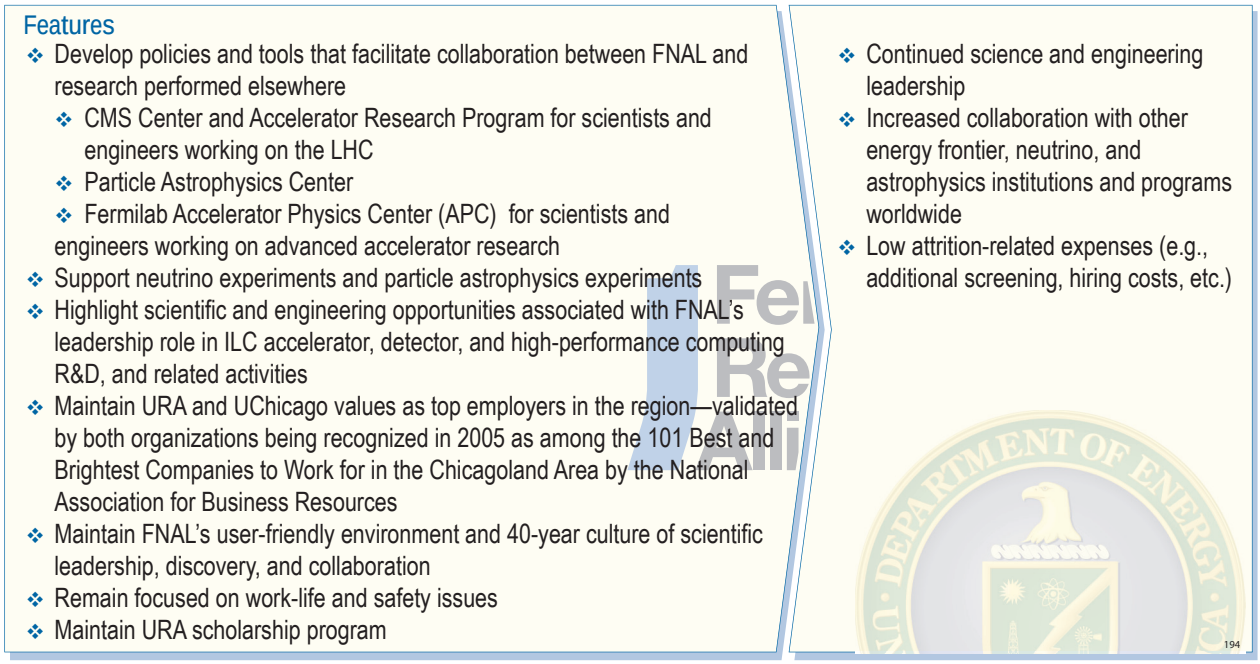


Figure 4.a–11. Mitigation of Major FNAL Retention Risks. Our approach helps to ensure that we maintain the best scientific and technical personnel to achieve maximum results in the Tevatron program, support the LHC, and attract the ILC.

development, giving FNAL physicists broader involvement and helping to retain the best physicists at FNAL. The ILC Task Force and the ILC Particle Physics Team will construct a strategic plan to increase laboratory particle physicists' involvement in the ILC and to identify areas appropriate for collaboration between FNAL and the high-energy physics community. FRA's mandate to the task force is to recommend well-defined projects where the laboratory particle and accelerator physicists can work side-by-side with university groups to enhance the US bid to host the ILC. The Deputy Director will evaluate recommendations from the task force and present her project to the Director for approval and implementation.

In addition, to focus on the ILC, FRA will continue to maintain at FNAL a safe, secure, and employee-focused working environment for which it has received numerous awards (***Figure 4.a–12***).

Developing and Educating the Next Generation of Scientists and Engineers. FRA recognizes that there is a growing concern in the US regarding the state of science and engineering education at both the university and K-12 levels. We share this concern and have developed a strategy to do our part to meet this challenge (***Figure 4.a–13***). As Norman Augustine noted in his May 31, 2006 public lecture at FNAL covering the findings of a National Academies' October 2005 report, *Rising Above The Gathering Storm: Energizing and Employing America for a Brighter Economic Future*, "the existence of quality jobs in the decades ahead is very likely to depend on new developments in science and engineering."

We define "next generation", in descending order, from young FNAL scientists and engineers to graduate-level, undergraduate, and K-12 students across the country and abroad. As described earlier in this section, FRA will extend FNAL's eight fellowship programs to develop tenure track personnel, research associates, and Ph.D, and M.S. students, and will maintain FNAL's Internships for Physics Majors program, which has brought undergraduate summer interns to FNAL for 26 years,

*Figure 4.a–12. Employee Focus. The regional office of the Society of Women Engineers recently awarded the **Golden Family Award** to URA in recognition of the employee- and family-friendly policies at FNAL. In 2005, the National Association for Business Resources selected both FNAL and ANL to its list of the **"101 Best and Brightest Companies to Work for in the Chicagoland Area."***

introducing them to current methods and challenges in high energy physics research. UChicago adds synergy to these efforts:

- Helping develop promising young scientists through the use of joint appointments
- Providing the UChicago Department of Physics' Summer Undergraduate Research Opportunities for Minorities and Women program (10 to 15 internships for 10 weeks; $4,300 stipend)
- Providing representative research grants for interdisciplinary or multi-institutional activities
- Maintaining the SciTech Chicago Outreach Pilot Exploration (SCOPE) program, a pilot project with the SciTech Hands-on Museum in Aurora, Illinois that teaches graduate students about the presentation of science to children and the general public

FRA will continue to support the key role that FNAL managers play in the governance of the academic aspects of U.S. Particle Accelerator School operations; they are also essential fiduciaries of the school's business operations. FRA is convinced of the essential role of USPAS in educating the next generation of accelerator scientists and engineers, for the benefit of both FNAL and the broader US community, and is committed to the robust support of the school.

FRA will continue and improve the current laboratory education program serving students from pre-K to graduate research scientists-in-

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

Features

- Leverage the expertise and network of UChicago to optimize current FNAL programs
- Integrate best practices from ANL, which, like FNAL, has one of the best education programs among the national laboratories
- Expand the reach of the Lederman Science Center program for K-12 students
- Maintain 7 established Fellowship Programs and develop a new program for international scientists and students
- Serve as US Particle Accelerator School (USPAS) host
- Provide joint engineering programs and engineering co-op programs
- Sponsor scientist and engineer degree programs
- Continue FNAL outreach programs aimed at the general public to help expose all segments of society to science issues and opportunities
- Provide attractive compensation package, "career pathways" support, skills-development, and personal mentoring
- "Market" HEP opportunities to middle and high school students across the US, including ILC-specific opportunities
- Model approach on successful QuarkNet project
- Provide outstanding training and advanced degree opportunities

195

Benefits

- Long-term source of world-leading science and engineering talent
- Key support for continued US leadership in energy frontier, neutrino, and astrophysics discovery
- Continued source for US economic growth and innovation

Figure 4.a–13. FRA Approach for Developing Next-Generation Science Talent. Our approach ensures that FNAL does its part to maintain US scientific competitiveness by developing future US scientists and engineers.

training, while focusing on historically under-represented groups.

FNAL will also continue the international science education program for students and teachers in Latin American countries. In addition to collaborating with, and receiving funding from, DOE, science and engineering educational programs are sponsored by the Fermilab Friends for Science Education and funded by NSF, the State of Illinois Department of Education, and private foundations and individuals.

FRA will fully support programs of the FNAL Education Office (***Figure 4.a–14***), which manages 40 programs and hosts a robust web site that provides information on educational opportunities and instructional materials to assist science teachers, students at all levels, and post-docs. The web site was selected by the DOE Web Council as a featured site for the December 2000 edition of www.energy.gov, and was awarded the Eisenhower National Clearing House's *Digital Dozen Award*.

From 2000 through 2005, over 30,000 teachers and 132,000 students have visited the Lederman Science Center or attended programs in their respective schools offered through the Center. Programs at the Lederman Science Center annually involve between 200 and 250 members of FNAL's technical staff on a volunteer basis and 50 educators as instructor staff. This will remain a critical component of FRA's approach.

Every year, 15-20 undergraduates from colleges across the country come to FNAL to participate in the Summer Internships in Science & Technology (SIST) for Minority Students program (***Figure 4.a–15***). This intensive 12-week program is a success year after year not only because of the highly motivated interns but also due to the proactive day-to-day involvement of FNAL mentors. FRA will continue this focus on minority students.

FRA will also continue the following successful URA K-12 programs:

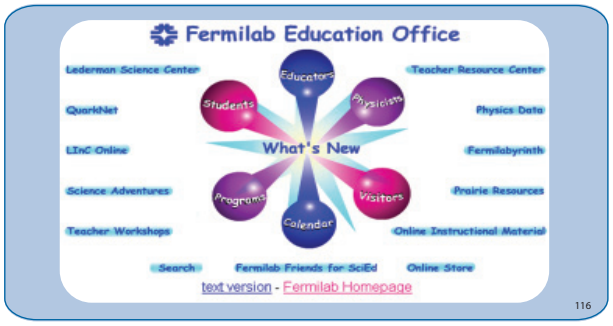


Figure 4.a–14. FNAL's Comprehensive Education Program. Our comprehensive, award-winning education program will continue to expand its reach to develop future scientists.

Figure 4.a–15. Summer Internship in Science & Technology (SIST) Program. 2003 SIST Student Angelica Perez adjusts the aperture of the neutron beam at the Neutron Therapy Facility. Hands-on summer internships are invaluable in developing science and engineering talent.

- ***Lederman Science Center***—the home of K-12 education programs; includes Quarks to Quasars, interactive exhibits that explain the science and technology of FNAL, and the Teacher Resource Center.
- ***Teacher Resource Center***—educators have access to a large preview collection of K-12 science, mathematics and technology materials and support for professional development and may ask for assistance in enhancing their classroom programs.
- ***Saturday Morning Physics***—this program furthers the understanding and appreciation for modern physics among high school seniors whether or not they are interested in pursuing science as a career.
- ***Science Adventures***—the Lederman Science Center offers a variety of informal classes for students and families throughout the year on the first and third Saturdays of the month and during summer vacation
- ***Beauty and Charm***—a teacher-developed unit of hands-on experiments enables mid-level students to explore ways scientists study the subatomic world. Classes completing the unit may visit FNAL.
- ***Fermilab LInC Online***—In this online course, participants develop online classroom units in which the Internet supports engaged learning.
- ***Fermilabyrinth***—Students explore the science and technology of FNAL by playing games that are online versions of the Quarks to Quasars exhibits.
- ***QuarkNet***—QuarkNet centers are connected to high-energy physics experiments operating at FNAL; 53 centers are associated with research groups at universities and laboratories across the US. QuarkNet enables physicists to mentor and collaborate with high school teachers. Through these collaborations, students learn fundamental physics as they analyze live online data and participate in inquiry-oriented investigations; teachers join research teams with physicists at local universities or laboratories.
- ***Topics in Modern Physics***—teacher-developed classroom materials introduce students to particle physics within the curriculum of a standard introductory high school or college physics course.

Building on this, one of the largest and most effective education programs among DOE Office of Science laboratories, FRA is committed to increasing the quality, diversity, and effectiveness of K-12 education programs in a continuing effort to educate the younger generation and develop a pipeline of bright young people to become the next generation of scientists. FRA plans to expand the Education Program's reach to teachers and students, which will develop increasing numbers of future scientists to maintain US preeminence in scientific research. As the program grows, we will increase staffing at the Lederman Science Center by seeking funding from grants, add outdoor facilities, and remodel space into dual-purpose classrooms. In 2005, over 25,000 young people participated in FNAL's education programs, which introduced many of them to the wonders of math and science for the first time. Building on initiatives begun by Leon Lederman in the late 1970s, FRA will work systematically to attract young students to FNAL towards developing the next generation of scientists and engineers who will maintain US competitiveness in science.

4.a.2 Maximizing Scientific Impacts from User Facilities *(L.4.a.2, M.4.a.2)*

FRA's approach to maximizing the scientific impact from user facilities is based on the principle that leading scientists and engineers will

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

always seek opportunities first where breakthrough science is possible. Breakthrough science in particle physics requires cutting-edge research facilities, and an efficient user support program that provides a safe, healthy, secure, and comfortable working environment, allowing researchers to focus on science. Our approach focuses on a rigorous process of prioritizing resource investments in research facility infrastructure and in the research programs themselves to ensure that we execute our science strategy (***Section 3.a***) with the most efficient use of scarce resources. It also ensures that we bring best practices to user support to maintain an environment conducive to scientific discovery. This approach, implemented by URA at the laboratory's inception, which balances openness to all qualified investigators with structured support, has attracted the current community of over 2000 users.

In this section, we discuss our approach and plans to maximize the technical capabilities of the user facilities and to provide efficient user support. (In ***Section 4.a.3***, we discuss our strategy and approach for maximizing output of research programs and technology R&D.) Our approach includes five overarching elements to maximize the scientific impacts from user facility infrastructure and user support.

User Facilities Mission. In line with our proposed science strategy (***Section 3.a***), FRA will ensure that FNAL facilities and infrastructure are prepared to accommodate any of the anticipated programmatic mission activities and technological changes well into the 21st century. Facilities will be right-sized to the type and quality of space and equipment needed to meet mission needs, as well as to available funding. Activities and organizations that need to be collocated will be. Facilities will be readily adaptable to changing research requirements and technologies.

Working Environment. The laboratory will maintain a "quality of facilities" setting that provides a preferred working environment for our researchers. This includes employing best practices and the latest advances in communications and information technology such as video conferencing. These advances enhance worker productivity and facilitate interactions with other scientists at the facility and throughout the physics community.

Environment, Safety, Health and Security. As described in ***Section 4.b.4***, FRA will ensure that the FNAL infrastructure and facilities provide a safe, healthy, and secure working environment for laboratory employees and visitors. We accomplish this through Integrated Safety Management System (ISMS) approaches, programs, systems, procedures, and tools to achieve the FNAL site mission in a safe, secure, environmentally friendly manner.

Operations and Maintenance. As discussed more fully in ***Section 4.b.3***, FRA will ensure that user facilities are operated and maintained as efficiently and cost-effectively as possible. We will establish a new Office of Quality and Best Practices for FNAL—reporting to the Laboratory Director—to drive continuous improvement, benchmarking, and application of best practices across the organization to deliver more science per taxpayer dollar.

Performance Metrics/Change Indicators FRA will expand FNAL's use of performance metrics, including metrics to monitor our progress in meeting facility modernization goals and to highlight areas in need of improvement. Applying Oracle business software functionality, FRA will implement a new FRA Management and Decision Support Dashboard to monitor performance data on the secure FNAL network that allows our management team and DOE to assess ongoing operations in near-real time. This initiative is discussed further in ***Section 4.b.1.***

4.a.2.1 Enhancing and Optimizing the Use and Productivity of FNAL's User Facilities

FRA's approach to enhance and optimize the use and productivity of FNAL's user facilities is based on prioritization of resources for technical infrastructure upgrades in support of the FRA science strategy (***Section 3.a***). In this section, we discuss our plans to enhance and optimize the technical capabilities of the 6 major

FNAL facilities identified in the RFP. (***Section 4.a.3*** discusses our approach to prioritization of upgrade proposals competing for the same resources.) The 6 FNAL facilities include:

- Tevatron Collider
- LHC Support Facilities
- Neutrinos at the Main Injector (NuMI)
- Mini-Booster Neutrino Experiment
- Main Injector Particle Production (MIPP)
- Accelerator Operations

Tevatron Collider

The Tevatron Collider (***Figure 4.a–16***) program's scientific reach has been extended by several orders of magnitude over the past 15 years via upgrades to the accelerator complex and experiments. Its operation is scheduled for completion about the end of FY09. In the meantime, it remains the world's most capable facility for the attack on energy frontier questions. In maximizing the impact of the Collider facility, FRA will upgrade the capability of the collider, increasing the integrated luminosity (amount of data) by a factor of five from where it is now, significantly stretching the Tevatron's discovery reach.

The two detectors (CDF and DZero) are completing upgrades that will allow operation at the higher event rates anticipated; FRA plans to continue the upgrade of the computing resources, local and Grid-based, in collaboration with our partners worldwide to deal with the anticipated rich and expanded data set. We will continue to optimize the physics reach of the Collider program as long as it makes sense to do so, given the advent of the higher-energy LHC machine at CERN. We will also focus attention on enabling the human resources needed to operate the accelerators and detectors through to the end of the data accumulation and its analysis. The LPC is one example of how this will happen, providing a local site for shared effort on both the Tevatron Collider experiments and best access for US physicists to monitor the CMS experiment at the LHC and analyze its data.

LHC Support Facilities

Since FNAL is host to US CMS and LARP, FRA will continue to develop facilities to support these off-site efforts. These facilities include the LHC Physics Center (LPC), now located on the 10th and 11th floors of Wilson Hall, and the LHC Remote Operations Center (ROC), being prototyped on the 11th floor of Wilson Hall and being moved to an expanded site on the first floor of Wilson Hall. The LPC was created for US physicists to make a strong contribution to CMS physics. It is designed to be a service organization for the US CMS collaboration throughout the US. Its location at FNAL maximizes the synergy between the Tevatron program and the LHC

Figure 4.a–16. Tevatron Collider. FRA will upgrade the capability of the Tevatron, increasing the integrated luminosity by a factor of 5 and significantly stretching its discovery reach.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

program—collaborators on US CMS who are also CDF or DZero collaborators can do research on both efforts during a single trip to FNAL. In addition, the fact that the US is the repository of hadron collider expertise gives US physicists a great advantage in preparing LHC detectors and data analyses. The LPC has sponsored several joint Tevatron-LPC workshops that bring Tevatron experience to bear on LHC commissioning issues. The ROC currently provides remote access to the CMS data from test beams and calibrations. During the LHC physics run, the ROC will allow particle and accelerator physicists to participate in real-time data and accelerator monitoring.

Director Oddone initiated the joint CERN-FNAL combined summer school to teach hadron collider physics to young scientists from around the world. One hundred and fifty students and post-docs attended the first school held August 8–18, 2006 at FNAL.

A key element of our strategy is the provision of the CMS Tier-1 computing facility and the concomitant networking facilities that will build on the FNAL investment in dark fiber to the Starlight Center at Northwestern University. This fiber was used initially for high-bandwidth R&D, and recently has been integrated into the production network. It will become a key component of the Energy Science Network (ESNET) metropolitan area network in Chicago—anchored by FNAL and ANL.

Neutrinos at the Main Injector (NuMI)

FRA will maximize the impact of the NuMI facility (***Figure 4.a–17***) by implementing a staged program of increased performance of the neutrino beam of NuMI, as well as expanded use of the beam with new and increased experimental reach from both the beam and new detectors. We will increase the power of the primary proton beam used to create the neutrino beams from its current 200 kW to over 1000 kW. We will operate the MINOS experiment efficiently and effectively, and introduce the new neutrino-scattering experiment, MINERvA. We plan to build a new, off-axis detector (NOvA) to push the sensitivity of measurements of the

"The MINOS experiment now provides the best accelerator-based measurements for two neutrino oscillation parameters, delta m^2 and $\sin^2$ theta, improving on the results obtained by the K2K experiment in Japan. The best results so far stem from the Super-Kamiokande (SK) experiment, which studies extraterrestrial neutrinos."

Fermilab Today, August 7, 2006

Figure Figure 4.a–17. NUMI/MINOS Project. FRA will maximize the scientific impact of the NuMI facility by increasing experimental reach from both the beam and new detectors.

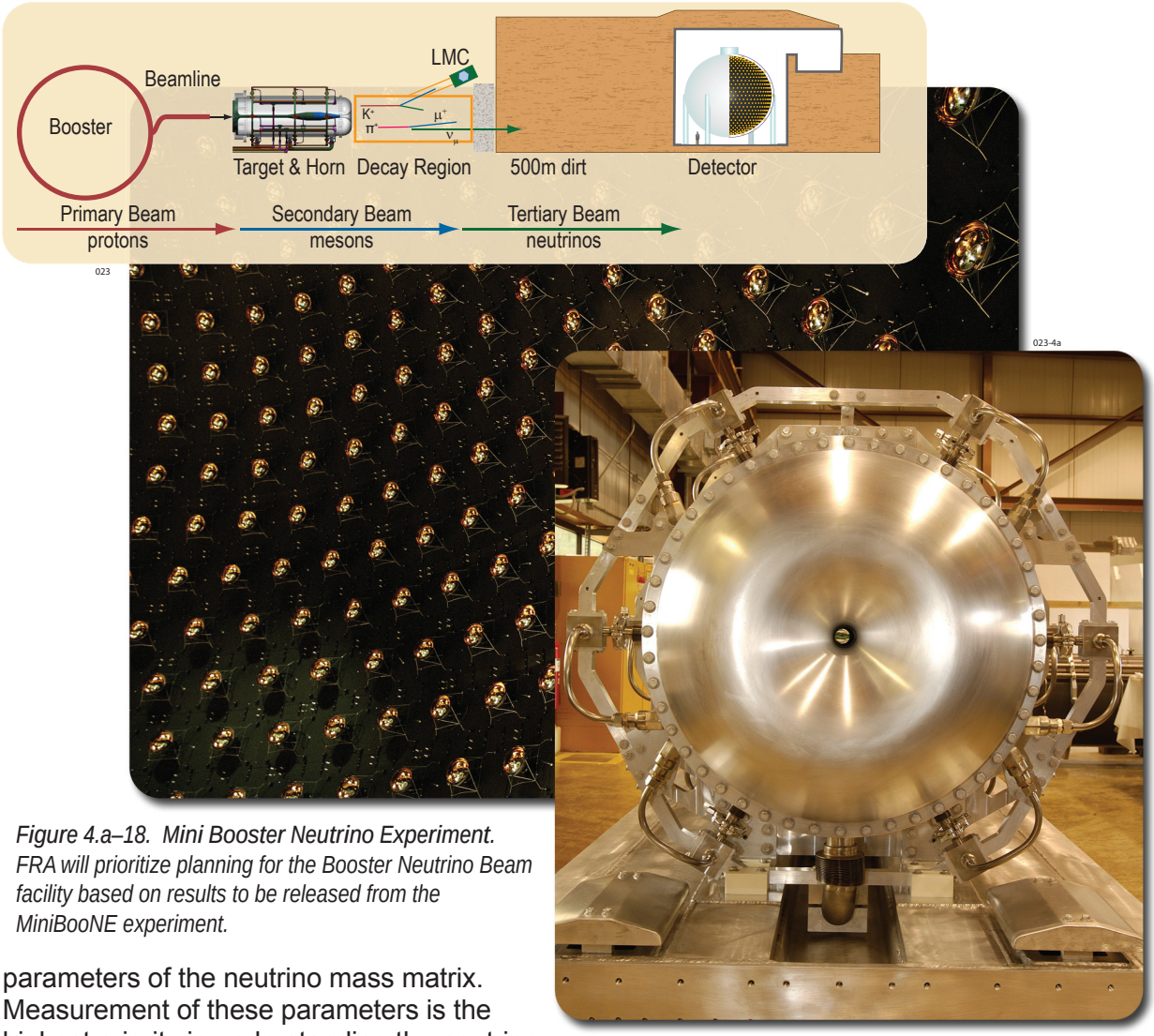


Figure 4.a–18. Mini Booster Neutrino Experiment. FRA will prioritize planning for the Booster Neutrino Beam facility based on results to be released from the MiniBooNE experiment.

parameters of the neutrino mass matrix. Measurement of these parameters is the highest priority in understanding the neutrino system itself, and perhaps the origin of the fact that the visible universe is made of matter, and not anti-matter, one of the great unanswered questions about the origin and development of our universe.

Mini-Booster Neutrino Experiment (MiniBooNE)

The optimal use of the Booster Neutrino Beam will depend on the results to be announced soon by the MiniBooNE experiment (***Figure 4.a–18***). This could be to better measure the relevant parameters in the event that MiniBooNE confirms the Liquid Scintillator Neutrino Detector result. The beam remains available for measurements of neutrino cross sections and measurements of intrinsic value. It is also needed to reduce the systematic errors of measurements of neutrino oscillation elsewhere. Many of the upgrades of the Booster for NuMI will be of use for the Booster Neutrino Beam should physics discoveries demand further exploitation of this facility. FRA will maximize the impact of these facilities by remaining flexible as the physics results are unveiled.

FRA plans an enhancement to the Booster Neutrino Beam facility, the SciBooNE experiment, which is to be carried out with the K2K SciBar detector. It will enable measurements of low-energy neutrino cross-sections of particular importance to the T2K (Tokai to Kamiokande) neutrino oscillation program in Japan. Data on these lower energy cross-sections would be complementary to the higher energy

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

data to be obtained by MINERvA. The SciBooNE program is a cost-effective use of an existing detector and beam. This experiment would also have the benefit of establishing a new international collaboration at FNAL in neutrino physics.

Main Injector Particle Production (MIPP)
The MIPP experiment, having recently completed its data taking, is part of a broader program of using the SY120 beams in fixed-target mode. These beams are currently directed at the MCenter and MTest areas; the first where MIPP is located, and the second where we operate a flexible test beam for detector R&D. We also have an opportunity to develop a beam line in the MWest area between MCenter and MTest. This flexibility may be useful as we respond to the needs of ILC Detector R&D for test beams. FRA will upgrade the capability of the existing test beam, creating a second, downstream capability for a lower energy beam as needed for ILC Detector (calorimeter) R&D. We will also consider establishing test beam capabilities in MCenter, perhaps reusing MIPP equipment to tag neutrons for ILC calorimeter R&D. We will maximize the utility and impact of these facilities by developing and optimizing the capabilities inherent in the SY120 program as the needs develop, remaining flexible in scheduling, and minimizing the overhead for supporting both short and longer-term use of beams for R&D tests. These developments also could facilitate mounting a new phase of experimentation using lepton pair (Drell-Yan) production. This planned program is an example of an ANL-led collaboration performing experiments at FNAL.

Accelerator Operations
Where appropriate, FRA will maximize the impact of our accelerator facilities beyond their direct use for FNAL experiments by:

- Encouraging the use of our accelerators for training of undergraduate students and Ph.D candidates in accelerator science
- Performing specialized experiments in beam dynamics and other accelerator research
- Making other tests of fundamental interactions as appropriate

FRA will continue the most visible current accelerator research of this kind in collaboration with Muons, Inc. and university groups on muon cooling. In particular, FRA will use the photo-injector at A0 as a major training ground for students once it is moved and upgraded.

4.a.2.2 Ensuring that Existing and Proposed FNAL User Facilities Are User-Friendly and Readily Accessible to a Diverse Group of Qualified Users

FRA's approach to user support applies continuous improvement processes to all support infrastructure and activities to ensure that users have a safe, healthy, secure working environment conducive to scientific research, and that scientists can concentrate on science. Our approach to achieving this objective (***Figure 4.a–19***) is scalable and can be tailored to a changing FNAL mission.

FRA will continue URA's innovative efforts to optimize FNAL working arrangements, including:

- Providing technology tools that minimize travel
- Allowing students and research associates to work on both analysis for one experiment and hardware for another, given the different stages of the two programs—optimizing the use of our business lines for training young students and researchers

As a means to ensure continuous improvement in user support, we will establish during contract transition an FNAL-ANL Laboratory Collaboration Council (LCC) co-chaired by the FNAL and ANL Directors on a rotating basis with working groups initially in the area of User Support, Operations and Business Management, R&D, and Technology Transfer. The object will be to explore ways in which the two laboratories may collaborate to promote efficiencies, share best practices and thereby realize cost savings in support of the research programs, which will assist SC in establishing best practice standards across the DOE system. The User Support Working Group will initially study, share best practices and recommend ways to generate efficiencies in all areas of user support. Improvements will focus

FRA New Initiative 12

Features	Benefit
Involve Users in all Advisory Committees	
❖ As a matter of policy and for its utility, involve users in all Director- and FRA-appointed advisory committees ❖ Remain responsive to users' needs and suggestions	❖ Provides direct and relevant advice on issues affecting users ❖ Improves communication between lab and users
Provide full-service user support	
❖ Scientific staff support to users while participating in research collaborations ❖ Modern work space and accommodations provided for onsite users ❖ Short-term housing for users of facilities ❖ On-site taxi service to minimize local costs of collaboration ❖ Administration and monitoring of user funds in special accounts for their use ❖ Travel office support and car rental onsite ❖ Policy of providing open software used and supported by the Lab in convenient, documented, and easily transferred form for users ❖ Maintenance of computing and networking infrastructure for user collaboration on experiments and other projects ❖ Maintenance of video-conferencing and meeting capability for use by users ❖ FRA-subsidized Users Center for rest and recreation of users ❖ Newsletters, e-mail distribution and web-based information directed at users and used by users ❖ Video conferencing facilities and capabilities ❖ Users outreach efforts, including making facilities and materials available and user-friendly ❖ Maintenance of current web-based information on local travel, housing, and entertainment ❖ Training (ES&H, computing, and other relevant subjects) at minimal or no cost to users ❖ Streaming video and archiving of talks at Lab for viewing off-site in real time or later ❖ Support for computers brought from off-site to on-site networks, including software scanning and downloadable updates ❖ FRA support of Arts and Lecture Series, Film Series, and clubs to supplement locally available entertainment ❖ Help for users with their own computers in obtaining open source software supported as part of the FNAL program, getting their computers checked for local network connection, maintenance of Help Desk by phone and e-mail, and a host of user oriented support efforts ❖ Help for users in test beams to get approved with minimum of administrative requirements while ensuring safety—via assigned support personnel in PPD ❖ Provide technician and computer professional support to large experiments to allow users to focus on physics output from the research ❖ LHC Physics Center to optimize time users spend supporting both FNAL and LHC facilities	❖ Onsite FNAL facility users provided with a working environment conducive to research ❖ Offsite facility users linked via the Internet ❖ Makes on-site research as easy and cost effective as possible ❖ Makes use of materials and information beneficial to users at their home institutions for outreach as well as for their research ❖ Provides full range of user-friendly personal and professional support allowing researchers to focus on science ❖ Facilitates users' access to FNAL user-based news and services
Provide comprehensive and timely communications with the worldwide physics community	
❖ Continue URA's innovative web-based programs acclaimed by the physics community—maintaining the Quantum Diaries web site (http://interactions.org/quantumdiaries) which connects over 30 physicists in 16 countries ❖ Provide material for Interactions.org, a central resource for 22 of the world's particle physics laboratories and institutes	❖ Keeps physics community current on issues and activities
Support formal user groups	
❖ Support Users Organization and its elected Users Executive Committee (UEC), and Annual Users Meeting at FNAL ❖ Support strategic planning for physics community organizations	❖ Provides user communication/input to Laboratory and DOE

Figure 4.a–19. FRA's User Support Program. FRA's approach delivers user-friendly, accessible facilities through effective planning and regular communication with the national and international user community.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

Features	Benefit
Use performance metrics to measure our user-support effectiveness	
❖ The UEC will conduct polls of users on various subjects of user interest ❖ Monthly meetings of the UEC will include the Lab Director and other staff members to discuss status on issues and provide input	❖ Objective feedback on FNAL's support for user community ❖ Foundation for FRA continuous improvement process
Continue effective URA outreach programs	
❖ Offer postdoctoral, graduate, and summer student programs ❖ Pay for awards to encourage students and Post-Doctoral fellows ❖ Support outreach efforts by the Office of Public Affairs when inappropriate for contract funds—at no cost to the Government (Section 8) ❖ Support efforts of the Lederman Science Education Center when appropriate; receive funds (e.g., from NSF)	❖ Continues success in attracting world-class users to FNAL ❖ Maximizes scientific output
Collaborate with laboratories and user groups on ILC preparation	
❖ Create an ILC R&D Organization to serve as a primary point of contact for involved users and potential users ❖ Assign a senior FNAL manager (Robert Kephart), well respected by the HEP community, to lead the FNAL ILC Program effort ❖ Contact and stay in touch with the large, diverse set of ILC stakeholders ❖ Partner with the State of Illinois and local communities regarding ILC planning	❖ Coordinates ILC planning effort that incorporates the recommendations and concerns of the HEP community and addresses all stakeholder issues

Figure 4.a–19. FRA's User Support Program. FRA's approach delivers user-friendly, accessible facilities through effective planning and regular communication with the national and international user community.

on reducing bureaucracy and generating efficiencies through specialization and economies of scale between the two laboratories, such as visa processing with the Department of State for international users at both laboratories.

FRA's proposed dashboard (explained in ***Section 4.b***) will allow authorized users to monitor the effectiveness of our user-support program, including the following metrics:

- Number of users onsite/remote
- Beam availability
- User survey results
- Future program initiatives

4.a.3 Maximizing the Output of FNAL's R&D Programs *(L.4.a.3, M.4.a.3)*

FRA's approach to maximize the output of FNAL's R&D programs relies on the FNAL science strategy—frequently updated through FRA's institutionalized strategic planning process—and the ingenuity and creativity of FRA employees and FNAL users to deliver breakthrough scientific discovery. FRA, through the experience of URA and UChicago, brings more than a century of experience in focusing scarce resources on the most promising science through the disciplined proposal and academic peer-review process that is the hallmark of US preeminence in scientific research.

Resources to be balanced include those that support the FNAL science and technology R&D programs. Our Physics Advisory Committee (PAC) and Accelerator Advisory Committee (AAC) will apply this rigorous peer review process to evaluate proposals for user experiments and accelerator R&D projects, respectively, with leadership provided by the Laboratory Director and oversight provided by the Science Committee of the FRA Board of Directors. FRA divides FNAL R&D programs into four elements: 1) scientific research, 2) detector technology R&D, 3) accelerator R&D, and 4) computing R&D. In the subsections below, we discuss each of these four elements in the following categories:

- How our process maximizes scientific/R&D output based on the principles of DOE O 414.1C

- Current and future program direction aligned with the science strategy
- Collaboration opportunities to further maximize scientific/R&D output

4.a.3.1 Approach to Maximize Output of Scientific Research

Process to Maximize Output of Scientific Research

FRA's approach to maximizing the output of FNAL's scientific research program uses our Physics Advisory Committee (PAC) process, illustrated in ***Figure 4.a–20***. The FRA process applies DOE 414.1C principles (Management, Performance, and Assessment and their related criteria) to the academic proposal and peer review process resulting in a tight link between the leadership of the Laboratory Director and the physics output of the laboratory, and ensuring the highest possible quality and output of FNAL's science program.

The Physics Advisory Committee is composed of internationally renowned particle physicists and particle astrophysicists identified and appointed by the Director with a chair appointed from among the membership. Suggestions for membership are requested from the Users Executive Committee and senior Laboratory physicists. The committee meets three times annually including a week-long meeting focused on long-range planning for the science program. Proposals for specific experiments and overall scientific strategy are both considered. The Associate Director for Research will continue to coordinate the work of the PAC. In making critical choices about the science program of the laboratory, the Director weighs the advice of HEPAP and its subpanels. DOE presence in the public and executive sessions of this PAC's deliberations helps to ensure coherence between FNAL initiatives and program directives of DOE's High Energy Physics program.

Figure 4.a–20 illustrates two entry points for science program proposals: those that require significant detector technology R&D before a fully detailed experiment proposal can be formulated (discussed further in ***Section 4.a.3.2***), and those that are submitted as a fully developed experiment proposal. In both cases, programs may be initiated by the Director or by proposals to the Director from users or FNAL staff. The PAC then applies its management processes to weigh strategic alignment and resource allocations. The PAC provides the Director with explicit recommendations on the scientific merit and priority of the proposal.

If the Director approves an experiment, DOE performs its review with input from its advisory committees. Project execution commences on approval from DOE. The PAC then applies its performance oversight process in which the experiments are regularly asked to make presentations to the PAC about the construction, execution and analysis of the program. At the annual week-long meeting, extensive reports are also provided by the Laboratory concerning the support of the experiments, and difficulties and successes encountered in providing analysis support and facilities. These enable the PAC to furnish a balanced and objective view of the experiment's performance. During this phase, detector R&D focused on the implementation of the new technologies for this experiment, if required, is conducted in parallel with the development of the project plan. Oversight during this phase is provided via a Project Management Group (PMG) specific to this experiment drawn from experiment project managers, relevant Division management, and independent technical experts. The successful conclusion of this phase will be approval by DOE, through the process specified in DOE Order 413.3, to build the experiment.

At the Laboratory level, the leaders of the individual experiments and their support organizations meet regularly, often weekly for major experiments, with the Computing and Particle Physics Division leaders to discuss resource needs and allocations. The balance of these resources between laboratory and collaboration and the international character of the latter make it imperative that the partnership be real and the coordination tight. Any issues come to the attention of the Associate Director of Research or the Director quickly as a result of weekly meetings between the Associate Director and his Division leaders and Center

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

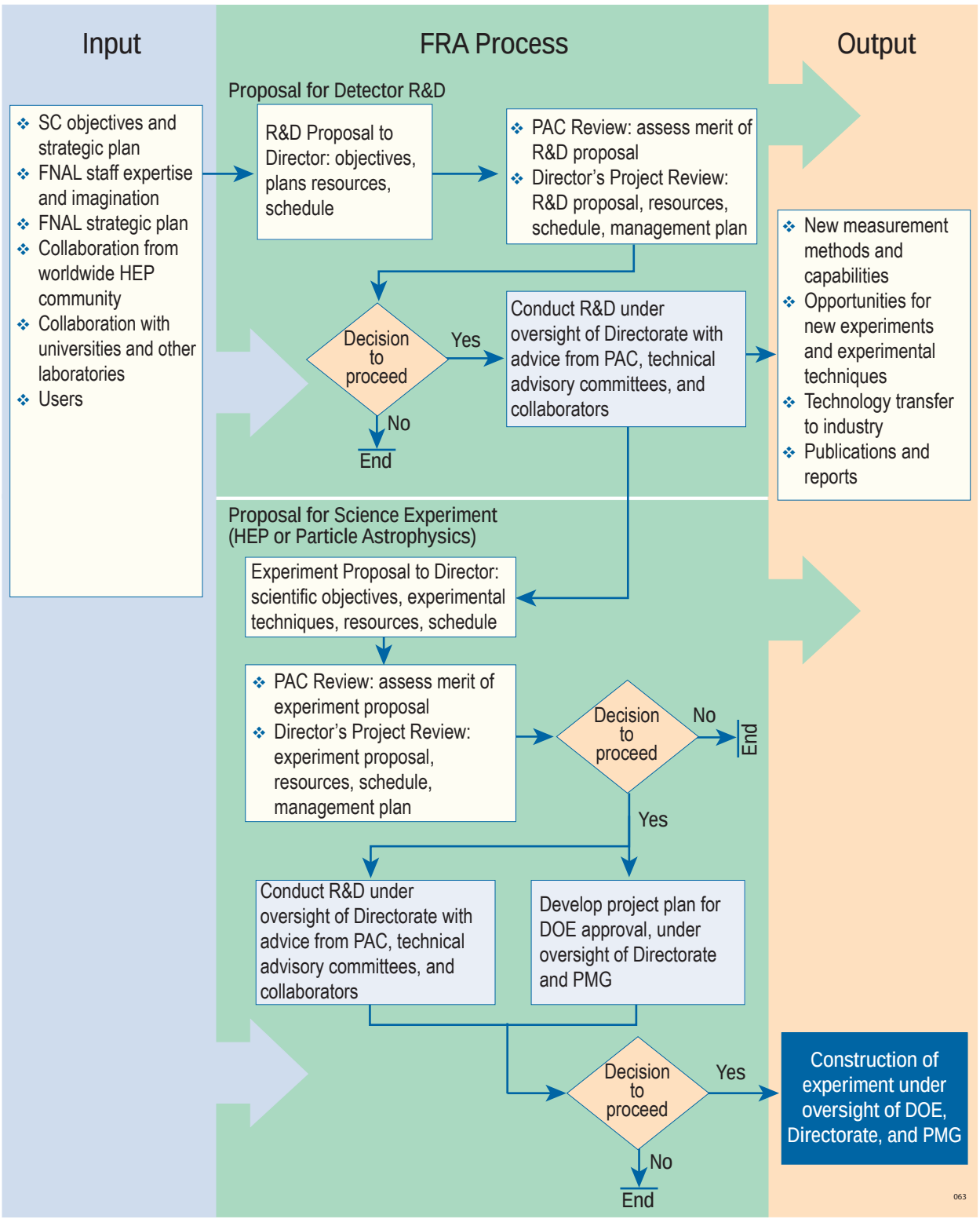


Figure 4.a–20. Scientific Research and Detector Technology R&D. FRA's approach to maximizing FNAL's scientific research and detector technology R&D programs is a proposal-driven process with peer review through the Physics Advisory Committee, which focuses resources on the most promising science.

Directors. In addition to receiving advice from the PAC on the progress of experiments, the Director, Deputy Director, and Associate Directors meet directly with the leaders of the experiments. These meetings inform the Director of progress with data analysis, the publication of results, and any resource needs.

The PAC's role in assessment (not shown in ***Figure 4.a–20***) is at the strategic level. In its regular and week-long meetings, the PAC evaluates the overall strategic direction of the FNAL science program as well as individual experiment proposals. The PAC then provides the Laboratory Director recommendations on whether the performance of, and resources allocated to, experiments are providing the maximum possible scientific output. The Laboratory Director then initiates corrective actions if required.

Current and Future Scientific Research Program Direction

The FNAL science program is multi-faceted; it encompasses theoretical and experimental particle physics and theoretical and experimental astroparticle physics, as described in ***Section 3.a***.

Collaborations to Further Maximize Scientific Research Program Output

The PAC is by definition a collaboration that maximizes FNAL scientific research program output through its diverse membership from the national and international particle physics community outside the Laboratory. The Laboratory Director ensures that the PAC membership is balanced, has expertise in all areas of the program, and has a broad perspective (***Section 3.a*** discusses the broad collaborations to carry out all FNAL scientific programs).

4.a.3.2 Approach to Maximize Output of Detector R&D

Process to Maximize Output of Detector R&D

FRA's process for maximizing output of detector R&D applies the same PAC process illustrated in ***Figure 4.a–20*** in ***Section 4.a.3.1***, but with increasing levels of oversight as the scale of the R&D increases. The goal is to benefit maximally from the creativity and drive of the laboratory's scientific and technical staff (and its community of users) to innovate while ensuring that only the most promising ideas are brought to the fore and that resources are used wisely and efficiently.

The top portion of ***Figure 4.a–20*** is drawn for the case of a large-scale detector R&D program. The proposal is presented to the Director who seeks advice from the PAC, which fulfills the management level of the process by providing the Director with recommendations concerning the scientific and technical merits of the R&D proposal, how it fits into the scientific mission and plans of the Laboratory, and its role in the context of world-wide HEP.

The Director may also empanel a special review committee to evaluate the work plan and its proposed cost and schedule. Based on this advice and after concerns and questions from the PAC and Director's Review Committee have been satisfactorily addressed, and if the proposed R&D program is compatible with the available resources and other elements of the Laboratory's program, the Director may, in consultation with DOE, give approval to proceed. The performance phase of the detector R&D program is conducted under the oversight of the Directorate, with periodic advice from the PAC, to whom progress reports are given by the R&D team, and possibly focused technical advisory committee(s) composed of independent technical experts. The successful conclusion of the R&D will yield new experimental methods and capabilities that will offer opportunities for new experiments, possible technology transfer to industry, and will be documented in journal and conference publications and internal reports.

Successful R&D may also result in a full proposal for a new experiment, or major upgrade to an existing experiment, which is presented to the Director following the process described in ***Section 4.a.3.1***.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

FRA will follow the process outlined above for large-scale R&D programs, particularly those that are clearly aimed at the development of a new, major experiment or a significant upgrade to an existing one. A similar process to that sketched in the first half of ***Figure 4.a–20*** will be followed also for smaller scale R&D programs that are developing basic technologies but are not yet focused on a specific experimental proposal. Decision processes and day-to-day oversight may be delegated by the Director to a Division Head for smaller programs, particularly in their earlier stages. Delegation to this level, with a correspondingly lower level of formality, is important to encourage new, speculative ideas to be brought forward and rapidly developed. Those that continue to show promise and consequently require significant resources, then enter into the more formal system.

Current and Future Detector R&D Program Direction

FRA's ability to advance the understanding of nature depends strongly on technological advances in particle detection techniques. Many of the great discoveries in particle physics have come from new devices that give experimenters a new window on unsearched regions. We will continue to pursue a broad range of R&D on detectors in collaboration with and in support of the world-wide High Energy Physics user community. This program ranges from basic R&D on cutting-edge devices, aimed at potential future experimental programs, to highly specific development of devices and technologies that will be used in approved experiments.

Basic R&D is currently being pursued on a number of technologies that hold promise to provide new tools for discoveries and precision measurements at the proposed ILC or the LHC, for neutrino physics, and for direct searches for dark matter particles. For the ILC and LHC, we will pursue cutting-edge R&D on the next generation of pixel tracking detectors that allow precision event reconstruction in very complex events and permit reconstruction of short-lived bottom and charm particles. This will be key to our searches for and understanding of the Higgs particle and supersymmetric particle expected to be discovered at the LHC and ILC. The key technology for the ILC is to develop pixel detectors that are much thinner than the current generation of detectors, to allow full exploition of the precision offered by the ILC. FRA engineers and physicists will lead in the development of "3-D" devices, which offer the possibility to integrate into a single chip the pixel sensor and front-end readout electronics, each utilizing silicon with properties optimally chosen for that layer, and with a total thickness less than the current generation of sensors alone.

Collaborations to Further Maximize Detector R&D Program Output

All major detector R&D at FNAL will continue to be done in collaboration with university groups and other laboratories, and many will benefit strongly from the expertise brought by collaboration between FNAL and UChicago. All current programs grew from initiatives of individual scientists or engineers from FNAL or collaborating universities.

The current and next generation of neutrino experiments are based on well-established techniques involving plastic and liquid scintillator or water čerenkov detectors. However, to take the next step, new technology will be needed that will allow more precise measurements, better background rejection, and higher efficiency. The liquid argon Time Projection Chamber (TPC) is an excellent candidate for neutrino experiments that will be mounted after the round of experiments currently being planned and built at FNAL and in Japan and Europe. This technology has been proven in principle for many years, but the problem of how to scale to very large mass in an affordable way is the current challenge. New ideas for how to build a liquid argon TPC with mass in the tens of kilotons range using tanks similar to those that store liquid natural gas hold promise of yielding a cost effective device. FNAL, in collaboration with several American universities and potentially with Italian institutions, is currently working on new argon purification techniques, and on new methods for removing air from large tanks that cannot be

pumped to vacuum. FRA will support development of plans for a series of devices of increasing size that can validate this technology.

After detector technologies have been developed sufficiently, they can form the basis for new experiment proposals. However, additional focused R&D is generally required to adapt those technologies to the particular needs of a given experiment. Currently FNAL, in collaboration with universities and other laboratories, is performing this focused R&D in support of several new experimental initiatives in neutrino physics and astrophysics.

NOvA is the next generation neutrino oscillation experiment proposed for the NuMI beam line. It is a nearly totally active detector utilizing liquid scintillator in a segmented plastic containment structure. R&D topics include developing plastic extrusions with the proper mechanical and reflective properties, lifetime tests of wavelength shifting fibers in liquid scintillator, optimization of structural and optical properties, and planning for a prototype detector that will shake down the design, fabrication and assembly methods for the whole system. FRA will perform this R&D cooperatively with ANL, collaborating universities, and industrial partners who will provide the materials and components from which the experiment will be built.

MINERvA is a proposed neutrino experiment for the MINOS near cavern. Based on the well proven technology of extruded plastic scintillator readout with wavelength shifting fibers, this experiment requires only modest R&D, focused mainly on optimizing the extrusion process, in which triangular bars are co-extruded with a light-tight reflective coating, and demonstrating adequate light yield of the final design. This experiment is largely driven by a university collaboration, but FRA will continue to support it utilizing FNAL's excellent facilities, engineering expertise, and R&D facilities.

The Dark Energy Survey proposes to build a 500 megapixel CCD camera and place it on a telescope operated by the NOAO in Chile. It will conduct an extensive sky survey using several observational techniques to measure the equation of state of the dark energy that is driving acceleration of the expansion of the universe and dominates the universe's energy density. The major R&D challenges here are the manufacturing and processing methods for the CCD sensors, and the development of low-noise electronics that can be read out at a rate sufficient to support this ambitious sky survey. The CCD development is being done in close cooperation with industry and LBNL. The electronics development is a collaboration of FNAL and several domestic and foreign institutes.

R&D has also been successfully completed on a number of upgrades which have recently been installed in the CDF and DZero detectors at the Tevatron collider. These included development of new silicon tracking detectors, improved readout and triggering electronics, and additions of detector elements to provide improved solid angle coverage. All benefited from the powerful combination of skills and facilities at FNAL and collaborating universities and laboratories. Several resulted from the strong collaboration with UChicago, and exploited the complementary skills and facilities of the two institutions.

FNAL and ANL collaborate with local universities in northern Illinois on advanced ideas for extremely fine-grained calorimeters, that will be required to implement "particle flow algorithms," which hold the promise to yield unprecedented jet energy resolution. Early ideas are being pursued for extremely radiation hard pixel systems for the LHC, anticipating a future upgrade in which the luminosity will be increased by an order of magnitude above the baseline value. FRA will vigorously pursue ILC and LHC R&D aimed at demonstrating significant advances in these detector technologies that will lead, in turn, to specific experimental designs and experimental proposals that will be developed towards the end of this decade, and to operating experiments in the middle or last half of the next.

Based on an idea that originated at UChicago, FNAL and UChicago are collaborating on the development of a quasi-stable, fully-live, room-temperature bubble chamber that is sen-

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

sitive only to nuclear recoils. This device holds the promise of being a cost-effective route to a very massive, and therefore very sensitive dark-matter detector. A one liter prototype is being operated in the MINOS near detector cavern on the FNAL site, and is used as a test-bed to understand the technology, with the goal of reaching a trigger rate that is limited only by cosmic rays at this depth. FRA will support design of a 30-liter version that could eventually be placed in the Soudan Mine, the location of the MINOS far detector and of the CDMSII dark matter search.

The final example of basic detector R&D is a small initiative that also originated at UChicago for an extremely fast timing counter, using a micro-channel plate with a segmented anode and special electronics. The goal is a time-of-flight counter with resolution in the 1-10 ps range, which could greatly extend the particle identification capability of future collider experiments.

Each of these programs is developing technology that is not yet part of any proposed or approved experiment. However, all are part of FRA's approach to maximizing scientific output due to their potential to substantially expand our ability to measure particle interactions with greater precision and efficiency, and thereby give us an expanded view of nature while maximizing the output of future science programs.

4.a.3.3 Approach to Maximize Output of Accelerator R&D

Process to Maximize Output of Accelerator R&D

FRA's process to maximize the output of FNAL's accelerator R&D programs is illustrated in ***Figure 4.a–21***. Programs are established through the Accelerator Directorate, with management recommendations and oversight provided by the Accelerator Advisory Committee (AAC), a panel of internationally respected external experts similar to the PAC, which reports to the Laboratory Director and assesses the objectives, balance, and progress of the entire program. The Laboratory Director provides management leadership and the Science Committee of the FRA Board of Directors provides oversight of the AAC.

As shown in ***Figure 4.a–21***, accelerator R&D projects may be initiated by the Director or by proposals to the Director from users or FNAL staff. The AAC then applies its management

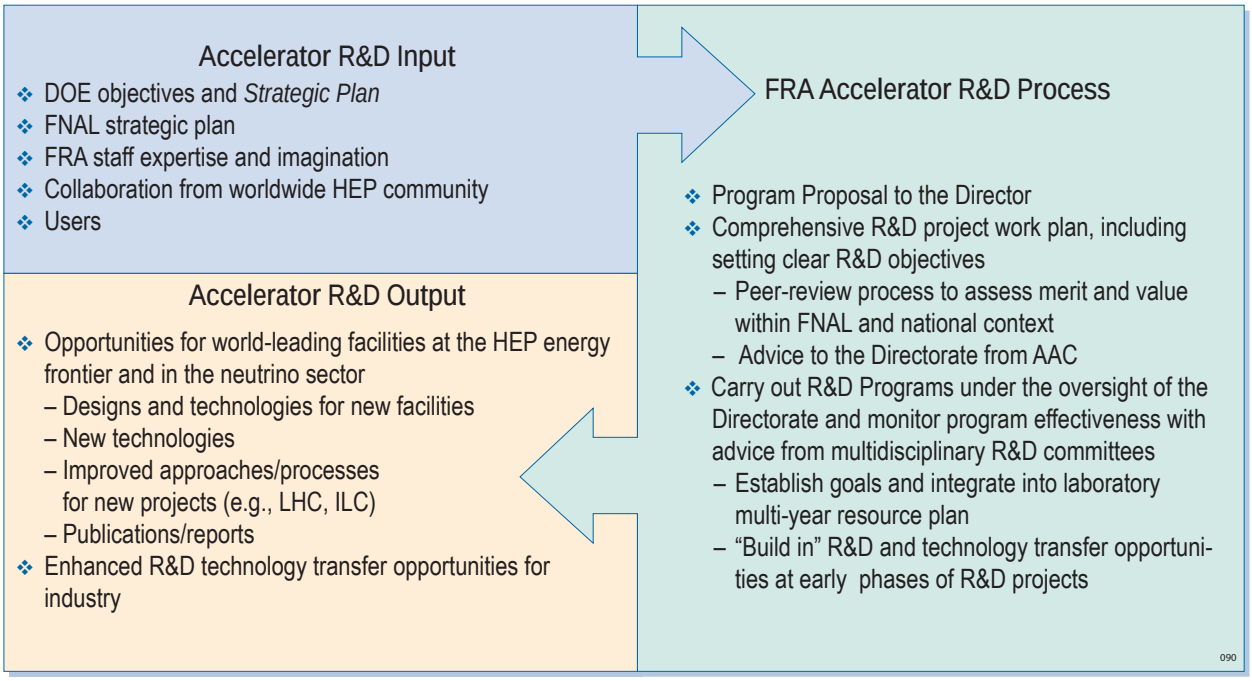


Figure 4.a–21. FRA Accelerator R&D Process. FRA's approach to maximizing accelerator R&D output involves a proposal-driven, peer review process that focuses resources on the most promising projects.

processes to weigh strategic alignment and resource allocations. The AAC provides the Director with explicit recommendations on the merit and priority of the project proposal.

If the Director approves a project in conjunction with DOE, the AAC applies its performance oversight process in which the project leaders are regularly asked to make presentations to the AAC about the project performance. Once established, R&D programs are performed under the authority of the Accelerator and Technical Divisions, with oversight provided by the Directorate. This oversight actively involves Program Management Groups (PMGs) and external advisory committees as appropriate. In cases where the program is embedded within a large, external collaboration, the primary external advisory role may be provided by a body sponsored jointly by the collaborating institutions. ***Figure 4.a–22*** lists the advisory groups associated with existing and envisioned accelerator R&D programs: all activities are under the advisory purview of the AAC, even if not explicitly listed as such.

The AAC's role in assessment (not shown in ***Figure 4.a–21***) is at the strategic level. The AAC evaluates the overall strategic direction of the FNAL accelerator R&D program as well as individual R&D project proposals. The AAC then provides the Laboratory Director written recommendations on whether the performance of and resources allocated to accelerator R&D projects are providing the maximum possible output. The Laboratory Director then initiates corrective actions if required.

This AAC process, fine-tuned by URA at FNAL, has helped the Tevatron maintain its position at the cutting edge of the energy frontier for two decades while spawning major industrial applications, which include:

- Superconducting cable development for the Tevatron, leading to its use in MRI scanner magnets
- Cryogenic heat exchangers built by Meyer Tool, Inc. for the Tevatron, leading to similar devices sold to other institutions
- Electronic module development and testing, helping LeCroy, Inc. to market improved NIM and CAMAC devices to a large laboratory and industrial market

Current and Future Accelerator R&D Program Direction

FRA's accelerator R&D program will support FNAL's long-range mission objectives as developed through the strategic planning processes of FNAL and DOE/Office of Science. The program is constructed and managed to provide appropriate balance between the needs of the short term and the opportunities of the intermediate and longer terms. Management of the program is based on Directorate-level review and oversight, augmented by advice from external experts as appropriate. To the extent achievable, national and international collaborations are utilized to leverage FNAL resources. The FNAL accelerator R&D program is divided into three components—current, next-generation, and long-term—as described in ***Figure 4.a–23***.

Current FNAL Accelerator Programs

The goal of these programs is to improve performance of the existing accelerator complex in support of the current research program. Accelerator R&D in support of Tevatron operations is conducted within the context of the *Run II Luminosity Upgrade Plan*. The upgrade program will be completed over the next 12 months and has already featured major advances in the realization of relativistic electron cooling and direct beam-beam compensation

R&D Program	Oversight
Run II	Run II PMG
Proton Improvement Plan	Proton PMG
ILC	ILC PMG/ ILC MAC
LHC Accelerator Research Program (LARP)	LARPAC
Super NuMI	AAC
High-Intensity Neutrino Source	HINS PMG
Muon Collider	MUTAC
Advanced Accelerator R&D	AAC

Figure 4.a–22. R&D Advisory Groups. These groups provide oversight and report to the Directorate regarding program status and issues.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

using electron beams. Both of these areas have potential application in other high energy accelerators.

The *Proton Improvement Plan* aims at improving performance on the proton complex in support of the NuMI/MINOS long baseline neutrino program. This program will continue through 2008 and will roughly double the average beam power delivered to the NuMI target.

FRA's approach to both of these programs is to apply DOE O 413.3 project management principles and processes to maximize project performance and utilization of resources even when the DOE Order is not explicitly required. Our approach is more fully described in ***Section 4.b.***

R&D Program	Current	Next Generation	Long-Term
Run II	❖		
Proton Improvement Plan	❖		
ILC		❖	
LHC Accelerator Research Program (LARP)		❖	
Super NuMI		❖	
High-Intensity Neutrino Source		❖	❖
MuonCollider			❖
Advanced Accelerator R&D			❖

Figure 4.a–23. FNAL R&D Programs. FRA groups these programs into 3 categories to balance resources and management attention, resulting in maximized output from accelerator R&D investment.

Next-Generation FNAL Accelerator Programs

These programs target opportunities for the post-Run II era. Priority among these programs is assigned to preparations for the ILC. The priority of the ILC is balanced with delivering on the current program and making the best resource allocations to other accelerator R&D priorities, including the LHC support and neutrino program accelerator technologies.

International Linear Collider. FRA will support the ILC program within the context of an extensive international collaboration. Within this collaboration, FNAL retains responsibility for coordination of the Americas' effort on the superconducting Linac technologies that form the heart of the facility. This task includes both the development and transfer of this technology to US industry. Planning proactively for the ILC, Laboratory Director Oddone has created the ILC Program Office, directed by Dr. Robert Kephart, to develop and execute FNAL's contribution to the ILC. Dr. Kephart is leading the FNAL participation supporting the GDE and all follow-on phases. This office will identify all technical, infrastructure, funding and local community support required for a U.S.-based machine and develop detailed plans for addressing each item. The ILC Program Office will work with DOE, universities, and the international scientific community to ensure that their perspectives are integrated into our ILC planning—including the design of optimal user programs and facilities.

Capitalizing on the synergies of ANL and FNAL in accelerator R&D and technology transfer (discussed in the Collaboration section below and in ***Section 4.b***, respectively), FRA will enhance the intellectual foundation of accelerator technology development as well as the involvement of industry in the region. This combination will create a center of excellence for both accelerator R&D and manufacturing in Illinois, which will provide major support to the U.S. bid to host the ILC.

Large Hadron Collider. The LHC Accelerator Research Program (LARP) provides US support for the full utilization of the LHC via participation in the commissioning process and development of technologies that could be used in a performance upgrade in the first half of the coming decade. The LARP is being undertaken as a multi-laboratory collaboration, with FNAL as the lead US laboratory. Working within a collaborative framework, we will apply our experience in the construction, operations, and upgrading of the Tevatron—combined with world-leading expertise in superconducting magnet technologies—to provide critical program support.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

Neutrino Accelerator Technologies. Both the Super NuMI and High Intensity Neutrino Source programs are aimed at supporting world-leading neutrino capabilities in the post-Run II era. The Super NuMI program is developing technologies that could be implemented over the period of 2009 to 2011 to provide up to a factor-of-three increase in beam power delivered to the NuMI target in support of the NOvA experiment. This program relies on re-utilization of existing accelerator assets that become available following the completion of the collider program, which maximizes output with minimum resources.

The High-Intensity Neutrino Source Program is developing technologies that could support a beam power in excess of 2 MW based on a new proton Linac. This activity, which is being conducted in collaboration with, and has significant overlap with, programs at ANL and other national laboratories, is likely to result in a facility construction only in the event that the ILC is significantly delayed (as discussed in ***Section 3.a***).

Long-Term FNAL Accelerator Programs
These programs are more speculative, developing technologies for possible implementation 15 to 25 years from today. The Muon Collider represents a potential approach to a lepton collider in the energy range above 1 TeV. FRA will continue to focus FNAL efforts on design concepts and development of the underlying ionization cooling technologies. The MuCool Test Area was constructed with support from the national Muon Collaboration for this purpose. This program is also conducted within an international collaborative framework, and features strong connections to small business via the Small Business Administration's (SBA) Small Business Innovation Research (SBIR) Program.

The Advanced Accelerator R&D program is centered on a 15 MeV electron beam that was constructed as part of FNAL participation in the TESLA Test Facility development at DESY. The TESLA facility has made crucial advances in the production of flat beams (i.e., large horizontal-to-vertical aspect ratio), plasma acceleration, and advanced instrumentation techniques. The facility is one of the areas in which the 30 graduates of the Joint University-Fermilab Doctoral Program in Accelerator Physics have performed their research. FRA will support plans have been developed to upgrade the facility capability to about 40 MeV over the next two years.

Accelerator Physics Center (APC). Accelerator R&D is a critical element of a world-competitive US particle-physics program (as enunciated by the reports of the EPP2010 panel and the Advanced Accelerator R&D sub-panel of HEPAP). FRA will establish the FNAL APC to emphasize the importance of accelerator R&D and maximize its impact and efficiency. The mission of the APC is to do research for near-term and next-generation accelerator facilities and to train the next generation of accelerator physicists and engineers. The activities of the APC will include:

- Accelerator theory
- Accelerator research for programs including Run II and Super NuMI
- Simulations and beam physics experiments for the ILC
- Instrumentation development and beam commissioning and studies for the LHC
- Muon collider R&D including the six dimension muon cooling experiment
- Development of generic simulation tools for advanced accelerator calculations such as energy deposition, beam-beam and space-charge effects, and Linac beam dynamics
- Advanced accelerator R&D such as for acceleration in plasmas or crystals and acceleration by lasers
- Accelerator education by hosting the US Particle Accelerator School, and creating the accelerator undergraduate program
- Organization home for the Accelerator Ph.D program and Peoples Fellows

Collaborations to Further Maximize Accelerator R&D Program Output
On April 21, 2006 FNAL Director Pier Oddone and ANL Director Bob Rosner signed an historic memorandum of understanding (MOU) between ANL and FNAL to increase or initiate collaboration on a number of projects, including the ILC. Illinois Department of Commerce

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

and Economic Opportunity (DCEO) Director Jack Lavin signed the MOU as a witness on behalf of Illinois Governor Blagojevich, signaling a new era of cooperation between these two laboratories and the State of Illinois on Accelerator Research.

The FNAL Accelerator Physics Center (APC) and Argonne Accelerator Institute (AAI) are being established to coordinate accelerator research efforts at FNAL and ANL, respectively. The collaborative connection between these two institutes will be coordinated by the Accelerator R&D Working Group of the new Laboratory Collaboration Council (LCC). The Directors of FNAL and ANL will charter the LCC within 60 days of the FNAL contract award to explore ways in which the two laboratories may collaborate to promote efficiencies, best practices and cost savings in support of the research programs. The Accelerator R&D Working Group will manage collaborations on a wide variety of projects, only a few of which are described below.

ILC Collaboration

Since FNAL is the site designated by the DOE Office of Science for a US-hosted ILC, FNAL and ANL collaboration on the International Linear Collider (ILC) is important and natural and it will be facilitated by URA and UChicago teaming to forming FRA. It is expected that significant accelerator R&D funding will be available for the next few years to develop this machine. ANL brings to this effort nearly 20 years of experience on Superconducting Radio Frequency (SCRF) cavities from its ATLAS accelerator operations and RIA R&D program. Similarly, FNAL brings more than 20 years of experience in building and operating the Tevatron, a complex energy frontier HEP machine that was the first large accelerator to extensively employ cryogenic magnets. Currently:

- A joint FNAL/ANL SCRF cavity processing facility is under construction at ANL
- SCRF cavity and cryomodule beam test facilities are under construction at FNAL
- ANL and FNAL collaborate on ILC damping rings and control system designs
- A 5-8 GeV ILC test linac has been proposed for FNAL

FNAL is concentrating on development and industrialization of main linac components such as SCRF cavities and the main accelerator cryomodule that houses eight of these cavities. ANL, capitalizing on its SCRF experience, is working with FNAL to develop cavity processing techniques to obtain the necessary ILC gradients. Both FNAL and ANL work on ILC accelerator science: ANL has placed its emphasis on the positron source, undulators, and damping ring design, while FNAL has focused on design issues associated with the main linac. FNAL also works on the civil design of the ILC. The programs are complementary and will bring a wealth of expertise to Northern Illinois, enhancing the qualifications of the region to host the ILC.

ILC-related Resources:

- ***FNAL***—ILC Cavity test facilities, ILC Cryomodule assembly facility, A0 photo-injector, ILC RF unit test facility at New Muon lab, and potentially a future 5-8 GeV ILC test linac
- ***ANL***—Argonne-FNAL Joint SCRF processing facility, SCRF electro-polishing expertise, beam dynamics expertise at AWA and APS, APS injector test stand, APS insertion device facility

Collaboration Topics. Positron source, undulator for positron source, damping ring design, SCRF cavity development and processing, SCRF cavity testing, ILC cryomodule testing with beam, ILC test linac, and ILC controls

Illinois Accelerator Research Center (IARC) Collaboration

Particle accelerators, used in medicine, industry, and physics research, have played a key role in the progress of S&T in the past and will play an even greater role in the future. The planned IARC at FNAL will provide facilities that serve as a focal point for accelerator research, education, and industrialization of the SCRF technology envisioned for ILC. IARC will also strengthen the technological and economic health of Illinois, promote coopera-

tive research between FNAL and ANL, and provide unique educational opportunities, in collaboration with Northern Illinois University (NIU), for a new generation of RF engineers and accelerator physicists.

The center will be housed in a new $35M building with 50,000 square feet of usable space built on the FNAL site and funded by the State of Illinois. The building will provide a high-bay heavy-assembly area and an underground enclosure of 20,000 square feet with state-of-the-art test space equipped with cryogenics, RF Power, and x-ray radiation shielding for high-power testing of SCRF components, the key technology required to build the ILC. This test area will be the largest and best equipped facility of its type anywhere in the world. The building will be designed for handling large equipment and will have cryogenic infrastructure, AC power distribution, temperature and humidity control, a low conductivity water system, and connections to existing FNAL industrial water systems.

IARC-related Resources:

- ***FNAL***—SCRF cavity test stands, ILC cryomodule test stands, high power-pulsed RF systems, Low Level RF development area, office space, conference facilities, and laboratory work space.

Collaboration Topics. SCRF cavity development, SCRF cavity testing, ILC cryomodule testing, RF system design—ILC controls and low-level RF development, industrial technology transfer

Collaboration on Advanced Accelerator R&D Facilities

The Advanced Wakefield Accelerator (AWA) group at ANL has been pursuing research on advanced acceleration schemes based on wake fields induced in dielectric structures, an effort complementary to plasma-based acceleration schemes pursued elsewhere. There is also a good possibility that ANL will acquire a new, 50-MeV SCRF linac that will be available from decommissioning the Stanford HEPL.

FNAL has been pursuing advanced beam manipulation techniques and other basic research at the A0 photo-injector facility at FNAL. FNAL has also constructed the MuCool Test Area as part of its collaborative advanced research on neutrino factories and muon colliders. These facilities form the basis for an FNAL-ANL collaboration in advanced accelerator physics and provide a vehicle to support advanced accelerator training programs that will develop next-generation accelerator physicists.

Advanced Accelerator-Related Resources:

- ***FNAL—***A0 photo-injector and MuCool test area
- ***ANL—***AWA and possible new 50-MeV SCRF Linac facility

Collaboration Topics. Dielectric wakefield acceleration, advanced beam manipulation, plasma wakefield acceleration, bright electron gun development, polarized electron gun development, muon ionization cooling experiments, and studies of 6D phase space cooling of captured muons

4.a.3.4 Approach to Maximize Output of High Performance Scientific Computing and Networking R&D

Process to Maximize Output of High Performance Computing R&D

FRA's process for maximizing output of High Performance Computing R&D starts with identification of the computing capacity, capability, security, and performance needs of an approved experiment or initiative. The requirements and expectations are presented and reviewed through a combination of annual reviews of the computing models and plans. Areas where the needs cannot be met without innovation, dramatic reduction in costs, marked increase in performance that does not follow technology trends, or new approaches (such as to matters of computer security and trust relationships) are defined as specific activity areas where R&D work is needed.

In such areas, work is undertaken to find collaborative partners, others who have either

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.

complete or partial solutions that could be applied to our problems, or industrial partners who might be able to work with us to innovate and evolve solutions. Where possible the work to be done, in collaboration with others, is written up as a specific proposal for R&D work and submitted to DOE or NSF for funding. The outputs of these efforts are tracked through regular reports (to agencies and internally), regular status reports internally and regular meetings with stakeholders to assess the progress and benefits of the effort.

Current and Future High Performance Computing R&D Program Direction

Powerful, effective, and innovative computing solutions are essential elements for maximizing the science from each of the strategic elements that have been outlined in FRA's long term strategy to support DOE missions. Computing and networking, including information systems, databases, data analysis tools, and data handling and storage systems play essential roles in the specific challenge of running the accelerator and detectors. The handling of large data sets and the enormous computing loads associated with the future experiments are already evident for the current Tevatron collider experiments. The hallmark of the current and future vision is for solutions in which the users are hundreds of physicists distributed throughout the world. FNAL has a world-renowned and highly respected scientific approach and computing program. FRA will collaborate with UChicago and ANL leadership on the Teragrid Program and petascale computing. FRA will also move forward enhancing its efforts in this area through expanded collaborations with the local and international partners employing the process described above to maximize the effectiveness of such work.

Collaborations to Further Maximize High Performance Computing R&D

Accelerator Modeling tools and components. FNAL is a member of the SciDAC collaboration which has an R&D component—both in terms of investigating and building new tools and frameworks, but also in terms of the application of these tools to accelerator problems. A broadly recognized suite of code which has resulted from this work is called Synergia. This R&D program is also discussed in the context of accelerator R&D in ***Section 4.1.3.3***. This is an area where FRA will expand effort and work ever more closely in both national and international collaborations. In particular FRA will expand the collaboration with ANL (and others) in the context of ILC Damping Ring. This has been an opportunity to work with SBIR funded Tech-X.

Network Research. FNAL with a modest dedicated effort receives funding from ASCR for networking research. It is now seen as especially important for making use of our very high bandwidth networks and integrating them with storage systems. The LamdaStation project is an R&D project and collaboration with Caltech and the DOE Science UltraNet that is producing prototype systems that are already useful.

FNAL is also a member of the Ultralight collaboration and has received network equipment as part of it. In the future FRA will seek increased funding in this important area, and will continue to collaborate with ANL, LBNL, ORNL, Caltech, and other universities. We will seek to expand these collaborations to include NU, BNL, and UIUC. There is also a need to carry out some of this R&D on an international scale in order to deliver the promise of the Grid.

Grid security, Trust, Monitoring, and Resource Management. The use of grid computing is ubiquitous and forms the basis for access to the large data volumes by researchers from around the world. However, the issue of validation of the user immediately appears. This has been an area of advanced R&D in which FNAL has taken a strong role. Progress requires consideration of advanced computer science techniques and considerable abstract thinking. FRA will extend the FNAL collaboration on this work with ANL and with the University of Wisconsin who have been leaders in providing core elements of grid middleware. In the future FRA will expand this collaboration to include European and Asian groups since the grid covers the earth.

Data Management and Storage Systems. SciDAC funding has supported work on common storage interfaces and this represents an ongoing R&D direction. FRA will continue to invest effort in this line through collaboration with DESY, CERN, LBL, UChicago, ANL, and possibly Vanderbilt University and others. New ideas are needed to scale up tape storage and disk caching systems. New global file system technology will be essential in the future for analysis systems.

Lattice Computing Architectures, Fabrics and Software. The ability to represent quantum chromodynamics and other physics systems with lattices permitted the application of new computer architectures to the solution of problems such as the calculation of the masses of mesons made up of bound systems of quarks. However, there is no unique architecture; different architectures take and retake the ascendancy as technological advances are made. URA obtained funding from the SciDAC project in this area in the past. In the future, FRA will investigate how to best use emergent technologies. This R&D may take the form of continuing to evaluate new processors and evolving communication fabrics. One possible direction working with ANL and NCSA is to make new “leadership” computing architectures and machines more usable for LQCD.

Remote Operations Centers and Videoconferencing. The telescopes used by Astroparticle physics are sited at a few sites around the world. Similarly, the accelerators used by particle physics are now confined to fewer than five sites worldwide. Collaboration at a distance is the paradigm of physics research in the twenty-first century. R&D is needed to work on the issues related to trust, networks, and quality of service. FRA will carry out R&D together with CERN and other sites on these issues. There is an immediate need for R&D to make things work well for the LHC accelerator and the LHC detectors. This will be a key role for the LHC Physics Center and its Remote Operations Center. While the use of high bandwidth networking has been key to particle physics research, this is a new area of R&D initiated under Director Oddone to support his vision of expanded collaborations relying more on technology and less on expensive travel.

Use or disclosure of data contained on this sheet is subject to the restrictions on the title page of this proposal.