Particle Physics at LBNL:

Status and Outlook

October 2003

1 Executive Summary

The High Energy Physics program at LBNL, comprising the entirety of the Physics Division and a portion of the Accelerator and Fusion Research Division, brings a unique combination of university and laboratory resources to the pursuit of high energy physics. This document provides a brief summary of our current research program, our relationship to other high energy physics institutions, and our plans for future work

The Berkeley HEP program makes essential contributions in four broad scientific areas: at the energy frontier through the search for the origins of mass; in the quark flavor mixing sector through the search for the mechanisms of CP violation; in the lepton flavor sector through the study of flavor oscillations of reactor and solar neutrinos; and in particle astrophysics through the study of dark matter and dark energy. These flagship science efforts are complemented by theoretical studies, and active program of technology development and accelerator physics, and the activities of the Particle Data Group. The science priorities of the Berkeley effort are directly aligned with those of the national program.

In each of our five major efforts, BaBar, CDF, ATLAS, Supercon and SNAP, we make significant and essential contributions. In addition, we lead the Particle Data Group, development of optical particle accelerators, the US KamLAND collaboration, oversee R&D for future neutrino factories, and participate in Linear Collider (LC) R&D.

LBNL's role has been one of physics from 'start to finish'. We participate in the conception, design, construction, commissioning, operation, physics analysis and preparation of upgrades in our experiments. The support and facilities of the Laboratory allow us to carry these roles very effectively in a way not possible even in large university groups.

The future program at Berkeley can be reliably extrapolated from the natural development of the ongoing activities. Our physics future will increasingly focus on discovery of the origins of mass, and on determining the nature of the Dark Energy. We plan to maintain the diversity of our program with a complementary effort in neutrino physics. Thus, ATLAS and SNAP will soon become the largest components of the Physics Division program. In AFRD the superconducting magnet program (including the National Conductor Development Program) and the laser-plasma accelerator programs will be supplemented with the LHC Accelerator Research Program (LHC-ARP). Neutrino experiments will be a joint effort with the Lab's Physics, Nuclear Science and Accelerator divisions. R&D efforts for both instrumentation and computing will be ongoing. We anticipate technical contributions to the development of the Linear Collider physics case as the next major element of the International Accelerator Program. The Linear Collider accelerator efforts will grow commensurate with the national linear collider collaboration.

Additional staffing and support will be necessary to carry this program. Detailed staffing and budget plans for the particle cosmology efforts and origin of mass efforts are outlined in Appendices I and II. Details of current funding are presented in Appendix III.

LBNL has been able to contribute major advances such as the TPC, high-resistivity CCDs and high performance superconducting cable because in the past it was able to set aside resources for fundamental research not directed towards an existing project. It has been able to provide the IC design that made possible the SVX and its descendents because it maintained a team of innovative chip designers at the Lab. These capabilities can survive only if they are provided adequate and sustained funding.

Berkeley has helped to shape high energy physics in the US over the past decades and is making crucial contributions to the program today. This record on innovative and outstanding performance justifies the budget increases we have requested.

2 LBNL Role in U.S. HEP program

The goal of the LBNL HEP effort is to advance and support the U.S. HEP program through the maximum usage of the unique capabilities available in a large national laboratory closely tied to a major university. LBNL staff and U.C. Berkeley faculty work closely together utilizing the excellent engineering and fabrication facilities and state-of-the-art computing resources available at the Laboratory and the large number of excellent graduate and undergraduate students who are part of the University.

Major HEP experiments require the fabrication and operation of complex particle detectors and the manipulation of huge sets of data, and LBNL, working in collaboration with numerous universities, is playing a major role in several of these experiments, including CDF, BaBar, ATLAS and SNAP. At the same time, while LBNL does not operate a large HEP accelerator facility, it carries out a substantial accelerator R&D program, and collaborates with HEP accelerator laboratories in the construction of new facilities. LBNL invented the concept and initiated accelerator studies for the asymmetric B factory and collaborated with SLAC and LLNL in building PEP-II. There is presently a collaboration with Fermilab, Brookhaven, and CERN in building the high luminosity interaction regions of the LHC, as well as a collaboration on future accelerators including potential upgrades of LHC and the Linear Collider. LBNL is leading the SNAP program to determine the characteristics of the Dark Energy.

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We elaborate below on this LBNL role in the HEP program emphasizing the elements that contribute to the Laboratory's effectiveness in this role. We treat separately the activities of the Physics Division in detectors and other areas, and the work of the AFRD in accelerator systems and components.

2.1 Development, Fabrication and Installation of Large and/or Sophisticated Detector Components

Some examples of these efforts in various detectors are given below:

CDF: LBNL was a lead institution in bringing the silicon strip vertex detector technology in CDF. This work had major impact on the top quark discovery, and led to the use of silicon trackers in virtually all collider detectors. LBNL has played a major role in the development of upgrades that led to the SVX-II system and the SVX3 readout chip. LBNL led the design effort for the SVX4 chip that was proposed for use in Run IIB by both CDF and D0.

BaBar: LBNL, in collaboration with others, developed several of the crucial readout chips. At the same time it designed and built mechanical systems for both the DIRC particle ID and the SVT silicon systems and was responsible for SVT final assembly and installation. Support from LBNL engineers was crucial to the success of these efforts. LBNL played a major role in the development of object-oriented software technologies for the experiment. LBNL designed the BaBar trigger and built the L1 charged track trigger. Most recently we have been involved in major upgrades to the computing and data analysis systems for the experiment.

ATLAS: LBNL has taken leadership responsibilities in both the silicon strip system and the extremely challenging pixel system, and is collaborating with many university groups on their construction. LBNL responsibilities include both electronic and mechanical aspects, and again engineering support is playing an essential role. LBNL also has a major effort on ATLAS software and computing. The Chief Software Architect and Software Manager is from LBNL.

SNAP: LBNL is the host institution on the SNAP project. We have pioneered the conceptual development of the experiment and are leading a large R&D effort to bring the concepts to technical readiness. This is the largest effort in the Division's program.

2.1.1 Detector R&D

All of the above projects, and many others, became feasible and affordable as a result of substantial levels of R&D, often in collaboration with university groups. Special state-of-the-art clean rooms and other facilities as well as the involvement of an outstanding engineering group have been critical for such recent developments as the ATLAS pixel system and the infra-red sensitive CCDs proposed for the SNAP billion-pixel camera project.

2.1.2 Project Management

For large and costly detector systems developed through collaborations of institutions, often geographically separated, project management is a vital responsibility especially appropriate to a national laboratory. LBNL has taken on numerous such responsibilities, including the BaBar SVT, the U.S. ATLAS silicon subsystem, the ATLAS software architecture, the U.S. effort in the KamLAND neutrino experiment, LHC accelerator components, and SNAP project direction. Collaboration with the Engineering Division for project management expertise has been a hallmark of these efforts. Jay Marx, as General Sciences Deputy for projects oversees these diverse efforts and facilitates our connections to the Engineering Division.

2.1.3 Individual Leadership

The activities already discussed require not only a laboratory with strong infrastructure, but individuals who can take on leadership roles. The quality of LBNL scientific staff, both UC Berkeley faculty and non-faculty senior staff, is evident from the large number of LBNL scientists carrying major responsibilities during the past year. We mention some examples: M. Shapiro (CDF B physics Convenor), M. Gilchriese (past U.S. ATLAS Silicon Systems Manger), I. Hinchliffe (U.S. ATLAS Physics Coordinator), K. Einsweiler (ATLAS pixel electronics project leader), M. Barnett (ATLAS Education Coordinator), R. Jacobsen (past BaBar Offline Coordinator), N. Roe (FNAL PAC), M. Strovink (past D0 Physics Coordinator), S. Perlmutter (SNAP Spokesperson, co-PI), M. Levi (SNAP Project Director, co-PI). W. Carithers was CDF co-spokesperson for six years.

All these roles carry responsibilities for the activities, not only of LBNL staff, but also of staff at collaborating institutions as well.

Individual leadership is not confined to large particle detector projects. S. Perlmutter has led the Supernova Cosmology Project to the totally unexpected discovery of so-called "Dark Energy". M. Levi and S. Perlmutter are leading the development of the SNAP project. G. Smoot and A. Lee have been leaders in the study of Cosmic Background Radiation.

2.1.4 Provision of Large-Scale Computer Facilities and Staff

The LBNL Physics Division has developed a strong and fruitful collaboration with NERSC and the staff of the Computing Division. NERSC software engineers have brought their expertise to the BaBar, ATLAS, CDF, and SNAP projects, in particular in the areas of data management, databases, and control software. In addition, the division is successfully using the NERSC PDSF facility as a main source of data analysis capability (CPU, tape handling, etc.) for several of its experiments (CDF, Supernova Cosmology, ATLAS, KamLAND). Collaboration between NERSC and the Physics Division on relevant issues of networking and GRID development is ongoing and is likely to increase in scope.

2.1.5 Fabrication of Large and/or Complex Detectors

LBNL physicists have taken advantage of the large machine shop with its state-of-the-art capabilities to fabricate technically demanding mechanical components for HEP. Examples include the BaBar supports for SVT and DIRC, pixel mechanical support structures, SNAP CCDs.

2.1.6 Special Services to the Scientific Community

The Particle Data Group is providing a major service to the worldwide particle physics community through the Particle Data Tables and associated mini-reviews in all areas of particle physics. It is also contributing to outreach and public information on particle physics research. Its leader, M. Barnett, is also one of the organizers of the QuarkNet educational program aimed at involving high school science students in particle physics research.

2.1.7 University Connection

The LBNL Physics Division has close connections to the UC Berkeley Physics Department. Students, both undergraduate and graduate, participate extensively in the research programs of the Division. The academic connection also helps attract an outstanding group of theorists (and theory students), many of whom maintain a close connection to the experimental program.

2.1.8 Experimental Operations and Analysis of Experimental Data

Given the major LBNL role in the development of sophisticated apparatus and computing capabilities, it is natural that this LBNL role turns into large operation and maintenance responsibilities when experiments turn on. At the same time, the LBNL scientific staff works in collaboration with the university groups to analyze the experimental data and derive the physics. We continually seek to balance the staff's ability to participate effectively in the physics analysis with its heavy operation and maintenance obligations.

2.2 Development of High Performance Accelerators for HEP

Like the Physics Division, AFRD, in partnership with the Engineering Division, is utilizing the core competencies in rf-technology, vacuum, cryogenics, and beam dynamics that have been built up over many years, to further the goals of the DOE/HEP program. In recent years we were responsible for developing the concept of an asymmetric energy collider to investigate the decay of B-mesons, and were responsible for the design, construction, and commissioning of the low-energy ring (LER). Together with FNAL and BNL, we have taken responsibility for the design and fabrication of critical components of the interaction regions for the LHC, which must operate at unprecedented beam power. More recently we have taken on major responsibilities in leadership roles, in R&D activities, and in delivering hardware for the linear collider.

2.2.1 Individual Leadership

AFRD staff continues to play key roles in the national program. W. Barletta is Chairman of the Board of Overseers of the US Particle Accelerator School. He and W. Turner are members of the US-LHC Accelerator Steering Committee. W. Leemans is Chair of the ICFA Sub-panel on Advanced Accelerators. In the Muon Collaboration, A. Sessler is the spokesperson and M. Zisman is the Project Manager, J. Wurtele joins Sessler and Zisman on the Executive Board, and J. Corlett joins these three on the Technical Board. In the LC collaboration, K. Robinson leads the LBNL effort that now coordinates all the work being carried out on the damping ring complexes. R. Ryne co-leads SciDAC efforts on high performance computing for accelerators. M. Zisman leads efforts at LBNL to assist FNAL in improving Tevatron luminosity performance.

2.2.2 Accelerator Modeling and Advanced Computing

The Accelerator Modeling and Advanced Computing program, led by R. Ryne, has been established to develop leadership in algorithms and software to enable large-scale simulations on parallel tera-scale (and later peta-scale) computers. The motivation for this effort is driven by the complex 3-D, nonlinear, multi-scale, many-body interactions characteristic of future accelerator design issues. Large-scale simulations can help to guide design choices, for example in elucidating the strong-strong beam-beam interaction to improve luminosity in colliders, in modeling beam-halo formation in high intensity proton drivers to determine technical specifications, and to model extreme conditions like those found in laser/beam/plasma interactions. The AMAC program has established strong and productive ties with other programs within AFRD as well as with the ALS Division and NERSC.

2.2.3 Optical Manipulation of Beams

The Center for Beam Physics through the l'OASIS program as well as in collaborations with the ALS and E-157 at SLAC has developed techniques for generating, diagnosing and manipulating multi-GeV beams on the sub-picosecond time. Examples include the invention of optical stochastic cooling, generating several nC electron beam pulses with a duration ~10 fs, measuring accelerating fields exceeding 10 GeV/m, generating coherent transition radiation, extending transition radiation as a diagnostic to 30 GeV beams. The "femto-slicing" technique invented at LBNL can be applied to provide a first ever synchrotron radiation based measurement of longitudinal bunch density of TeV proton and ion beams. The l'OASIS group is a world leader in the application of multi-terawatt, fs-lasers to the generation and rapid acceleration of extremely bright electron beams. Thanks to a substantial investment of infrastructure funds by top Laboratory management, the l'OASIS facility will be suitable for operation of a 1 GeV, 10 Hz all-optical accelerator.

3 Physics Division Programs

3.1 Discovery of the Origin of Mass

Exploration of the origin of mass plays a central role in the LBNL physics program. At the present time, the CDF and D0 experiments at the Tevatron form the center of this program through a program of precision measurements of electroweak parameters. In the middle of the decade, the ATLAS experiment at the LHC will become the premier facility for such exploration. Further in the future, the Linear Collider will complement LHC research.

3.1.1 CDF

LBNL has played an important role in the CDF Run II Upgrades. The group's largest hardware responsibility has been work on the new silicon tracker. This work builds on LBNL's extensive Run I expertise in silicon detectors hardware. LBNL's contributions to the Run II CDF silicon detector have been mostly in the front-end electronics and associated interfaces with the remote electronics. They include:

Design (in collaboration with Fermilab) the innovative deadtimeless SVX3 readout chip. Test and probe all production wafers.

- Design, fabrication and assembly of hybrids for the SVXII, ISL and Layer00 silicon detectors.
- Layout and fabrication of the thick film circuit board for the Port cards.
- Design, fabrication and test (with U.C. Davis) of the Mezanine cards.

Since installation of the silicon tracker in March 2001, the group has played important roles in the commissioning of the detector, most notably in the area of calibration, monitoring and trouble-shooting. This involvement includes also responsibility for elements of the offline software, including geometry description for both simulation and reconstruction, modeling of passive materials in the tracking volume, studies of charge deposition and hit efficiency, pattern recognition and track fitting ("outside-in" strategy for combining COT and silicon information). Members of the group have also worked on the commissioning of the silicon vertex trigger (SVT).

LBNL has also contributed to the construction of the new CDF Outer Tracker (COT) by fabricating field sheets using ingenious fixtures developed with the Engineering Division. An LBNL engineer designed in inner support tube for the COT. Electronics calibration for the COT system is in part the responsibility of the LBNL group.

The LBNL group has provided scientific leadership to CDFII. Marjorie Shapiro served for 3 years as Project Manager for Computing and Software. Young Kee Kim (now at the University of Chicago) served as Deputy Project Manager for Commissioning. LBNL has providing one FTE for Operation management (Bill Orejudos).

The group has a number of continuing responsibilities for maintenance of online and offline software in areas in which it has made major contributions. These include online monitoring (SVXMON) and offline calibration for the silicon detector system; online monitoring of detector modules (YMON); offline software for silicon geometry, for 3D tracking pattern recognition and for b-tagging. The group also maintains the HERWIG and ISAJET Monte Carlo generators packages and the GeneratorMods package. In one area, infrastructure software for database access, we passed the responsibility on to other members of the collaboration.

Substantial effort has been put into preparations for physics analyses through the development of lepton ID, b-tagging algorithms, the understanding of the jet energy scale, validation and tuning of the Plug Calorimeter simulation, the creation of standard CDF secondary datasets and studies necessary to characterize the performance of the detector and the software.

The LBNL group has taken on a number of data analysis responsibilities. Weiming Yao was co-convener of the Higgs physics group (recently replaced by Aaron Dominguez). Marjorie Shapiro was for a long time co-coordinator of the Monte Carlo generators and simulation. Lina Galtieri was until recently co-coordinator of the group responsible for jet corrections, which are essential for precision measurement of the top quark mass, Greg Veramendi was co-coordinator of the electron ID task force and Aaron Dominguez was until recently co-coordinator of both the silicon reconstruction group and the b-tagging group.

Members of the group have contributed to W and Z cross section measurements that were presented to HEP Conferences this year. Work on the Z asymmetry (to compare with Standard Model predictions) has being presented at Conferences, and it is being prepared for publication. It is the thesis topic of a PHD student.

Studies of top quark properties will continue in Run II. To this purpose the group has heavily contributed to the development and optimization of the b-tagging algorithm. The group has concentrated on analyses that use b-tagging. A t-t bar cross section measurement has been completed and plans for publications are underway. Also work on a top mass measurement, using events with a tagged b jet, has been presented for the Summer 2003 Conferences. A new method for determining the top mass is being developed by an LBNL postdoc, with contributions from other members of the group. The aim is to reduce the statistical error by using a novel likelihood procedure.

A postdoc is carrying out work on search for a stable SUSY particle, the stop, with other members of the collaboration. Preliminary results on a mass limit have been shown at HEP Conferences. Also work on MSSM Higgs production in Run I has been the subject of a PHD thesis of an LBL student. Studies of MSSM Higgs continue in Run II with a postdoc and a student.

3.1.2 D0

The D0 Detector is one of two large multipurpose experiments at the Tevatron Proton-Antiproton Collider at the Fermi National Accelerator Laboratory, the highest energy accelerator in the world. The primary goal of the D0 Experiment in the current Run II is the precise measurement of the W boson mass and the mass, cross section and other properties of the top quark.

A member of the LBNL D0 Group is the co-leader of the Top Quark Production Sub-Group, and has the responsibility of measuring the production properties o the top quark, including the cross section. The very ambitious goal of having a preliminary measurement of the top quark cross section by the Spring 2003 international physics conferences was successfully met. Further data is being analyzed for a new result for the Fall 2003 physics conferences.

Another member of the LBNL D0 Group is analyzing the electron+muon+missing transverse energy (MET) data as part of the top quark analysis and the search for new physics analysis. He is also measuring the W boson cross section using muons, in order to verify the muon identification in the e+muon+MET analysis. As part of this work, he developed a powerful method for using the calorimeter information to find muons, thus increasing by 25% the efficiency for a Z boson decaying into 2 muons.

Two members of the LBNL D0 group are the “godfathers” for the Electron Identification and b-quark Identification Groups, and are responsible for certifying the new electron and b-quark identification algorithms, which will be, used in all Run II physics analyses.

3.1.3 ATLAS

LBNL has been a pioneer in the development of new silicon detector technologies for high-luminosity hadron colliders. The LBNL group is continuing this role and is currently leading the U.S. effort to develop and fabricate silicon pixel detectors for ATLAS. The design of the critical front-end integrated circuits for the ATLAS pixel detector is largely an LBNL responsibility. LBNL also has the major responsibility for the design and fabrication of the pixel thermal and mechanical structure, which has required the development of new concepts. The overall support structure for the pixel system is an LBNL responsibility as is fabrication of about one-third of the active detector elements, modules, and the corresponding mechanical supports.

In addition, LBNL, in collaboration with the University of California (Santa Cruz), will produce and test about one-third of the silicon strip detector modules for the central (barrel) region of ATLAS. A sophisticated system has been designed and fabricated at LBNL for testing the large number of integrated circuit wafers for the ATLAS silicon strip detector. This test system is being used at Santa Cruz, CERN, and RAL to cope with the testing of the large volume of integrated circuits that are needed for the ATLAS silicon strip system.

The LBNL group has had a seminal role in understanding the physics signatures at high luminosity hadron colliders. This work began in the 1980's and is continuing now for ATLAS. LBNL has a coordinating role in the development of the ATLAS physics simulation program. This ensures a close tie between the technical aspects of the experiment and the rich physics potential of the LHC.

The software and computing expertise available at LBNL is now being utilized to lead the development of the framework code (ATHENA) that will provide the backbone of the ATLAS software. This work builds on the experience of CDF and BaBar, and takes advantage of the strong team of physicists and computing professionals that has been brought together at LBNL.

3.1.4 Linear Collider (LC)

The Berkeley group has participated in the development of the community consensus in favor of the LC over the past few years. We have actively participated in community meetings on the LC, and brought our expertise to bear where appropriate. Most recently, we have recruited M. Battaglia from CERN, which brings instant world leadership to the U.S. LC physics program.

In addition, we have been active in studies of TPC hardware for application at LC. We have collaborated with nuclear physicists interested in upgrades of the STAR experiment at RHIC in order to form a critical mass of researchers in this area. Work on tracking detector simulations has concentrated on Java-based tool kits.

Faculty on the Berkeley campus have expressed interest in University-based accelerator research for the LC. Initial interest in the area of beam feedback and control near the interaction region, This particular area has significant overlap with expertise in AFRD on beam feedback systems, and connects with the design of the innermost layers of the vertex detector system, where we have significant expertise in CCD and active pixel detector systems. Participants from other University groups outside Berkeley will be solicited once an effort has been established.

3.2 Quark Flavor Physics

3.2.1 BaBar

The BaBar experiment, first conceived at LBNL by Pier Oddone in 1987, reached a milestone in February 2001 with the publication of a result for the CP measurement, sin2β. LBNL has made critical contributions to many aspects of the detector and to PEP-II itself, with important work by the Accelerator and Fusion Research Division on the Low-Energy Ring. The Physics Division played a leading role in the design and fabrication of the detector and of the software, particularly in the Silicon Vertex Tracker (SVT), the particle identification system (DIRC), the trigger, the drift-chamber readout, as well as in on-line, off-line software and computing generally. All the deliverables from LBNL were achieved on schedule and are performing very well. More specifically, LBNL provided a co-system manager for the SVT and led the development of the AToM readout chip, in collaboration with UCSC and INFN Pavia. LBNL also designed and built the SVT mechanical support system. For the BaBar drift chamber, LBNL developed the readout chip (ELEFANT). In the DIRC subdetector, LBNL designed and built the Barrel mechanical components and overall support system, as well as all the assembly fixtures. LBNL was the lead institution for the development of the trigger, in particular for the level 1 trigger and the drift chamber trigger. In addition, the group coordinated the work of the international team that developed the level 1 and level 3 triggers. Finally, in computing, many of the innovations in the BaBar software are already having an impact throughout the community. We continue to lead in the innovation of software systems for data analysis.

The excellent performance of PEP-II and the rapid commissioning of BaBar set the stage for exciting physics and has also highlighted the need for upgrades to accommodate the rapid advance to high luminosities. The LBNL group is getting increasingly involved in both areas, physics analysis and upgrades, while still fulfilling service responsibilities associated with its original hardware projects and improving the performance and data quality of the detector.

The physics analysis effort is stimulated by the large data sample already collected, already with more B meson data than CLEO collected in nearly two decades. The present LBNL analysis is focused on the following topics:

1. $\sin 2\beta$, B mixing and tagging;
2. charmless, quasi-two-body B decays, including first evidence of the decay to ϕK^+;
3. form factors in semi-leptonic $B \to Dl\nu$ decay;
4. rare tau decays to $\eta K\nu$, $\eta\pi\nu$;
5. branching fractions for double-charm decays, $B \to \bar{D} - D_s^+$;
6. longer-term studies of nonleptonic decays with second class current suppression, including the first observation of $B \to a_0\pi$; and
7. measurement of the angle alpha in $B \to \rho\pi$ decays.

In addition, the group is providing critical analysis support to improve the data quality from improved tracking algorithms and alignment studies.

3.2.2 CDF

CDF plans to take data up to FY09, in order to get as many significant results as possible before the LHC turn on. There is unique physics to be done in the area of CP violation, CKM matrix element measurements and many measurements of properties of B hadrons.

The CDF group at LBNL has been a member of the CDF Collaboration since 1981, making significant contributions to all aspects of the experiment. Section 3.1.1 describes these contributions as well as work on the tools necessary for physics analysis. Most of these tools are common to the different physics analyses the group is performing. The improved silicon detector in Run II allows for more precise measurements in B physics. The addition of a silicon detector based trigger (the SVT) has opened a new era in B physics at the Tevatron.

Group members have taken responsibilities within the B group: Marjorie Shapiro is co-convener of the B physics group, and Alex Cerri is co-convener of the semileptonic B physics group

The LBNL group has been heavily involved in the area of B physics analysis for many years, contributing to detection of several B decay modes and to mass and lifetime measurements (including the B_s lifetime). LBNL has also contributed to work towards measurements of B_d mixing and observation of time dependence of mixing. Work on flavor tagging using soft lepton decay products of B mesons has been the subject of a Ph.D thesis. LBNL students have completed two other Ph.D theses on B physics topics.

In Run II the LBNL initial physics interest is centered on precision measurements of CKM matrix parameters. In FY03 the main analysis is a measurement of the hadronic moments of semileptonic decays of charged B mesons which provide constraints on QCD corrections to |V_{cb}|. This puts to use the expertise of the group, including detailed knowledge of the hadronic trigger that uses the SVT, and prepares the group for more complex measurements later on.

In preparation for B_s mixing studies, the LBNL group has been working on full reconstruction of B_s decays. A first measurement of the branching ratio of B_s into $D^0\ \pi+$ relative to B_d into $D^-\ \pi+$ has already been made. The plan is to continue work on other decay modes.

3.3 Lepton Flavor Physics

3.3.1 KamLAND

The persistence of deficits in solar neutrino experiments and the impressive results from Super Kamiokande on atmospheric neutrinos are the impetus for new, higher sensitivity measurements of neutrino oscillations. The KamLAND experiment exploited the old Kamiokande underground site and the presence in Japan of large nuclear power rectors. The substantial investment ($20M) made by the Japanese government provided a firm basis for the development of this experiment. The LBNL-led US KamLAND Collaboration proposed several initiatives designed to make this experiment robust against potentially crippling backgrounds and to increase its sensitivity still further, enabling it to eventually measure directly solar neutrinos from ^{7}Be.

The one kiloton liquid scintillator target/detector results in approximately 750 neutrino events per year from the reactors, though they are 140 to 200 km away. The very large ration of this distance to the neutrino energy enables KamLAND to reach two orders of magnitude further in Δm^2 than any previous reactor experiment, making it the first terrestrial experiment to address the solution to the solar neutrino problem.

KamLAND may measure solar neutrinos directly, as well. This will place stringent demands on background reduction. In fact, the reactor neutrino experiment has been enormously enhanced by the measures required to prepare for the solar neutrino experiment. Reduced backgrounds and increased discrimination against surviving backgrounds will provide the kind of robustness so essential to producing a convincing result for a neutrino experiment.

LBNL's contribution to the experiment, in addition to management and oversight (with UCB) centers on specialized waveform capture electronics ideally suited to KamLAND's needs.

3.3.2 AMANDA/Ice^3

Since neutrinos are not deflected by magnetic fields and interact only weakly with matter, they can be used to find and study astrophysical sources beyond our galaxy. The main challenge for neutrino astronomy is to detect and reconstruct rare events while rejecting the relatively copious cosmic-ray muon background. A powerful new technical concept developed at Berkeley Lab combines analog and digital signal processing inside optical modules located at depth (in either the ocean or polar ice). Prototypes of these circuits have been tested at a depth of over a kilometer in South Polar ice and have revealed never-before-measured complex waveforms. A full "string" of 42 advanced digital optical modules was installed in Antarctic ice during the 1999/2000 Austral summer in collaboration with the AMANDA group. Data analysis and development of the IceCubed proposal are ongoing. R&D funds have been made available by NSF last March for further development of the IceCubed concept and we expect the project to proceed into construction next year.

3.4 Dark Energy and Dark Matter

The impact of Berkeley astrophysics programs has been tremendous. To promote the development of astrophysics at LBNL, we formed the Institute of Nuclear and Particle Astrophysics (INPA), joining efforts from the Physics and Nuclear Science Divisions. Within INPA are programs to investigate the early Universe (cosmic microwave background experiments, supernova measurements), to measure astrophysical neutrinos (AMANDA, IceCubed, SNO, KamLAND), and to attack the dark matter problem (CDMS).

3.4.1 Supernova Cosmology Project and the Nearby Supernova Factory

The LBNL Supernova Cosmology Project was the first group to show how distant supernovae could be discovered on a reliable basis and that their brightness and redshift could be properly interpreted to measure fundamental cosmological parameters. Their data gave the first evidence that the geometry and fate of the Universe do not conform to expectations. These results have been confirmed by their competitors and were heralded as Science Magazine's achievement of the year in 1998.

These astonishing conclusions are the impetus for further studies to reduce systematic errors and to probe more deeply the physics that underlies these phenomena. More low-redshift type Ia supernovae are needed for systematic studies and a broad effort for this is already underway. Even more ambitious is the SNAP proposal to take the supernova search into space.

The Nearby Supernova Factory (*SNfactory*) is designed to lay the foundation for current and next generation experiments to determine the properties of Dark Energy. It will discover and obtain lightcurve spectrophotometry (simultaneous broadband lightcurves *and* spectral time series) for more than 300 SNe Ia supernovae in the low-redshift end of the smooth Hubble flow. Their statistical power alone will lower the statistical error of the current SCP results by up to 50% and will help reduce the systematic error. In the longer term, they will improve *SNAP*'s constraint on Ω_M by 40% and on w_0 by a factor of two.

3.4.2 SNAP

With a 2m telescope and 600-million pixel imager, SNAP (Supernova/Acceleration Probe) can discover and obtain high-signal-to-noise calibrated light-curves and spectra for over 2000 Type Ia supernovae at redshifts between z = 0.1 and 1.7. This would help eliminate possible alternative explanations, give experimental measurements of several other cosmological parameters, and put strong constraints on possible cosmological models. The imager would use the CCD developed by the Physics Division. These CCD's have a high resistivity substrate with excellent quantum efficiency at long wavelengths. Their development was a direct spin-off of previous investments in SSC detector technology.

After a 2-3 year R&D period, the project would take approximately four years to construct and launch, followed by another three years of mission observations. SNAP's detailed budget and schedule is being developed in coordination with DOE's Office of Science/High Energy and Nuclear Physics program and NASA.

3.4.3 Cosmic Microwave Background

LBNL has maintained a strong program in CMB cosmology since the discovery of the CMB dipole from U-2 aircraft in 1977 and the anisotropy with the COBE satellite in 1992. Recently, the physics division played an important role in determining the curvature of space-time with degree scale anisotropy measurements using MAXIMA and BOOMERanG in 2000. The physics division has set new long term goals for the CMB program, which will cumulate, in a precise characterization of the CMB polarization[1]. This will provide insight on the early phase of inflation—a key element in the puzzle of understanding dark energy. A diverse team of both young and experienced innovators has been assembled to address these challenges, in a strong partnership with UCB campus and NERSC. LBNL's flagship CMB polarization experiment is POLARBEAR, which is a ground-based CMB observatory to be built in two stages over the next 3-5 years. POLARBEAR has the potential to probe GUT scale energies of 10^{16} GeV, by detecting the fingerprint that inflationary gravity waves (IGW) leave on the curl-component of the polarization. It will make precision measurements of the polarization signal down to angular scales of an arcminute, allowing it to precisely measure the cosmic shear signature. Cosmic shear carries information about the matter distribution and neutrino masses—and must be well understood to measure the IGW signal. On the road to these discoveries, LBNL is developing the instrumentation to be used in POLARBEAR through participation in two key CMB experiments being constructed to perform large scale surveys of galaxy clusters with the Sunyaev Zeldovich (SZ) effect, APEX-SZ (2004) and the South Pole Telescope (2006). Galaxy clusters can be used as test masses to trace the expansion history of the universe, allowing for independent confirmation of the SN1a acceleration results using a different technique with different systematics.

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[1] In the 2002 *Connecting Quarks to the Cosmos* report, the Turner panel's first recommendation is "Measure the polarization of the CMB with the goal of detecting the signature of inflation."

Complementing these instrumentation advances is a vigorous theory and data analysis effort. Currently it is focusing on the analysis of MAXIPOL (the polarization sensitive successor to MAXIMA) data and the development of algorithms for the analysis of the Planck satellite data. The new science and the large data sets expected from APEX-SZ, and POLARBEAR will require an expansion of our theory effort.

3.5 Theory

The Particle Theory Group, including its LBNL and Berkeley campus components, is one of the world's leading research groups and an important center for the training of students and postdoctoral fellows. The traditional coherence of theoretical research with the experimental program of the Physics Division is a special strength of the LBNL group. Research is carried out in the Theory Group over a very broad range of subjects, ranging from M-theory to phenomenological studies of immediate importance to experiments, especially ATLAS and BaBar. Recent work by Berkeley theorists and their collaborators on the possibility that there are extra macroscopic dimensions has inspired a profusion of new investigations throughout the field.

3.6 Particle Data Group

The Particle Data Group provides essential up-to-date summaries of experimental and theoretical particle physics to the HEP community and other physicists and to teachers and students. LBNL is the headquarters of a large international effort to provide compiled and evaluated information on particle properties and related areas, as well as reviews, tables, plots, and formulae. The PDG consults with over 700 physicists from every major particle physics institution in the world to obtain expertise on data and specialized topics, and to insure that the summaries reflect the current viewpoints of the community. An international advisory committee reviews all publications and operations annually.

The information is made available through the biennial publication of the "Review of Particle Physics" (an 800-page book), and the "Particle Physics Booklet." The "Review" is the definitive arbiter of particle properties and provides many vital reviews of experimental and theoretical physics. The information is updated every year on the PDG website.

14,000 people and the booklet version by 28,000 people request the Review. Over 10,000 papers in our field have cited the Review, far exceeding that of any other publication. Physicists from 116 countries have used the PDG WebPages, yielding 5-10 million hits per year. Particle physicists rarely travel without a copy of the "Particle Physics Booklet," ready to check out an ides while at an airport or hotel. The PDG is moving aggressively in the realm of electronic dissemination of their materials, and will link their databases with other databases and with the electronic preprint archives and with the journals.

The Particle Data Group has a large impact in science education and awareness. The "Review" and "Booklet" are used by thousands of students and teachers. The PDG collaborates on several educational projects including the QuarkNet program, the Contemporary Physics Education Project, the award-winning "Particle Adventure" website, the CDROM-based exhibition version, the “Quark Adventure,” and the Nobel Foundation’s Nobel Electronic Museum. These projects make particle physics accessible to non-scientists and enable high school and college teachers to use particle physics in introductory physics courses.

3.7 Advanced Detector R&D

The goal of this work is to provide a credible foundation for the construction of new detector systems needed in future High Energy or Nuclear Physics projects.

The principal focus of the detector R&D is to explore the use of deep sub-micron devices for next-generation detectors for both accelerator-based and non-accelerator based experiments. This technology offers two significant advantages for detectors: radiation hardness and high density. There are a number of potential applications of these devices in Adaptive Pixel Sensors (APD), and high-speed, high-resolution cameras. APS are of interest to the RHIC and LC programs and sample devices need to be tested for radiation hardness. The high-density devices have application in cameras.

Another of area of interest is in new electronics for time projection chambers (TPC). This will be needed for upgrades to STAR and for a TPC at the Linear Collider. Additional R&D work in the area of CCD detectors could have significant impact on other astrophysics projects (for example, there are potentially important applications in ground-based optical astronomy). Finally, the possibility of a new underground laboratory gives rise to other R&D issues that are not well understood at this time.

3.8 Computing R&D and support

The goal of this work is to provide computing support for current and future projects. The effort brings together computer science R&D as well as software engineering and systems maintenance.

A major challenge is in the development of software for large experiments. The principal focus at this time are the two large projects, ATLAS and SNAP. LBNL also continues to play a significant computing role in BaBar. Computing for astrophysics includes analysis of the Cosmic Microwave Background (CMB) and analysis of supernova data from the Supernova Cosmology Project and the Nearby Supernova Factory.

For ATLAS, LBNL is responsible for the computing architecture and the analysis framework. In addition, LBNL is participating in the ATLAS Grid testbed, a distributed system of computers at ATLAS university and laboratory sites that is experimenting with new software for the management of distributed computers. The Grid activities leverage funded projects, the Particle Physics Data Grid (PPDG) and the Grid Physics Network (GriPhyN) as well as the DOE Science Grid managed by NERSC and Esnet. The Grid efforts include people from the NERSC Distributed Systems department.

For SNAP, LBNL is overseeing the development of computing systems for the SNAP project, as well as connection to the supercomputing resources at NERSC needed to support the simulations required for the SNAP mission. Architectural and framework issues are currently being addressed. Outside partners are being recruited to lead portions of this work.

Development of core infrastructure software for ATLAS and for BaBar involves 7 FTEs from the NERSC Division. Astrophysics computing involves NERSC staff as well as staff in the Physics Division. Production computing for many of the Division's experiments is provided by the Parallel Distributed Systems facility (PDSF) operated by NERSC. PDSF is operated by 2 FTE from NERSC; Physics and Nuclear Science share one FTE to support PDSF software.

4 AFRD Programs Relevant to Particle Physics

The Accelerator and Fusion Research Division together with the Engineering Division, has developed a set of core competencies that have made significant contributions to existing HEP facilities, and that continue to make contributions to both the near term, and longer term national programs in particle physics. These activities are supported by the DOE through base-programs (resident in the AFRD Center for Beam Physics and the Superconducting Magnet Program), and through collaborative efforts associated with the US/LHC program, the LC collaboration, and the Neutrino Factory/Muon Collider collaboration. Areas of core competency include:

- accelerator lattice design coupled with beam dynamics theory and simulation'
- accelerator commissioning;
- diagnostics;
- beam control and fast-feedback;
- vacuum technology;
- beam/laser/plasma studies, both theoretical and experimental;
- RF cavity design, fabrication, and testing;
- superconducting magnet design and technology development;
- superconductor material, wire, and cable development;
- induction linac; and
- ion source and RFQ development (including intense H^+ and H^- sources).

These skills have been brought to bear in significant contributions to the Advanced Light Source (entirely designed, built, and commissioned by an LBNL team), the PEP-II B-Factory, the E157 experiment at SLAC, the LC, Neutrino Factory, and VLHC studies, and – in the case of ion sources and RFQs – to many of the operating HEP and Nuclear Physics facilities around the world.

It is worthy of note that the "national laboratory" environment, with its wealth of inter-disciplinary intellectual expertise, access to students and postdocs, and technical infrastructure and facilities, is an ideal place to nurture and develop the skills necessary to support future HEP endeavors. Indeed, LBNL strives to be the "partner of choice" in the development, design, construction, and operation of the next generation of accelerators for high energy physics.

4.1 Current Activities

Coming hot on the heels of the spectacularly successful involvement with the PEP-II B-Factory construction and commissioning, AFRD physicists, long with the Lab's Engineering Division, are now active in many aspects of the national HEP program. In particular, we are building components and designing diagnostics for the LHC, we lead the nation's research in the development of very high field accelerator magnets, we have taken responsibility for the damping ring systems for the LC, we provide the top management for the muon/neutrino collaboration, and we are exploiting our world class capabilities in beam/laser/plasma interactions – both theoretical and experimental. The following sections outline in more detail our current work in these areas.

4.1.1 The Large Hadron Collider

LBNL is making critical contributions t LHC accelerator systems as part of the US/LHC Collaboration, in partnership with BNL and FNAL (the lead laboratory for the collaboration). The LBNL contributions include the design of the coil packages and supply of NbTi cable for the interaction region quadrupoles (currently being fabricated at FNAL), and an ongoing investigation of the electron cloud instability – an effect that has the potential to deposit unacceptable amounts of thermal energy into the cryogenic system. Our current efforts are centered around the design and fabrication of eight technically challenging cryogenic feed boxes for the interaction regions, and on the beam collimators and neutral beam dumps that are critical to the protection of the interaction region quadrupoles from excessive radiation. We have also developed and tested a novel idea that will transform the otherwise passive beam absorbers into an active on-line bunch-by-bunch luminosity monitor.

4.1.2 The Superconducting Magnet Program

The AFRD Supercon Program, recently lauded as "the jewel in the crown of the national high-field magnet program" by DOE reviewers, has two main thrusts. (1) To collaborate with industry, university groups, and other national laboratories in the development of superconducting materials, wire, and cable necessary to push accelerator magnets to ever higher fields. (2) To make technological advances in very-high field magnets (design and fabrication) whose innovations can be transferred to full-scale accelerator quality systems.

The first of these endeavors is embodied in the DOE/HEP National Conductor Development Program, a \$500K per year effort administered through Supercon. The demanding goals are to develop conductor that can reach a superconductor current density of 3000 A/mm^2 (at 4.2 K and 12 T), at a net cost of \$1.5 per kA-m (i.e., the cost of NbTi superconductor at the time of the SSC). Now in its third year, the program has made impressive progress towards these goals, with Nb_3Sn

conductor reaching nearly 2900 A/mm^2, and prospects for the cost goals to be met when the processes now at the research stage, are properly industrialized.

The path to very-high field accelerator magnets is being pursued through the development of the common-coil magnet concept in the so called “racetrack dipole” (RD-series) program. To date this program has advanced through mechanical modeling (RD-1), a relatively low-field magnet using available NbTi conductor that reached its predicted (short-sample) field of 6.5 T (RD-2), and the first very-high field magnet, using Nb_3Sn conductor, that recently exceeded its design field of 14.2 T to reach a new record field of 14.7 (RD-3). The next step is to build a magnet that will have all the features of an accelerator magnet, including the requirements for adequate aperture and good field quality. This important work provides the practical experience with Nb_3Sn that will be needed for eventual luminosity upgrades at the LHC.

4.1.3 The Linear Collider

The road towards realizing the LC is being pursued with our partners at SLAC, LLNL, and FNAL. Within AFRD we have taken responsibility for the damping ring complexes for both the electron accelerator and the positron accelerator. This effort includes a detailed lattice design that incorporates “theoretically minimum emittance” (TME) are cells, and analysis of beam dynamics in these state-of-the-art machines – including error analysis, and the highly perturbative effects of the damping wigglers. We are assessing all component requirements leading to detailed specifications for the various accelerator systems. In particular we have established an impedance budget for the vacuum system, have made initial estimates of collective effects (including the electron cloud instability), and have established preliminary designs for the monochromatic RF cavities, the vacuum systems, and the damping wigglers. We have also initiated a study of the possible use of permanent magnet technology for the main lattice magnets, and the wiggler magnets. This work builds directly on the core competencies developed from our experiences in the construction, commissioning and operation of the ALS and the PEP-II Low Energy Ring. Collaborative experimental studies are being pursued with our accelerator physics colleagues at the ALS, and at the KEK Accelerator Test Facility in Japan, to understand the limits on emittance damping caused by beam heating mechanisms such as intra-beam scattering (IBS).

4.1.4 The Muon/Neutrino Collaboration

LBNL has taken the lead responsibilities for the US Neutrino Factory and Muon Collider Collaboration through providing the collaboration spokesperson and the R&D manager. These are significant tasks for the collaboration, especially since the collaboration has increased to include more than 140 members from over 30 institutions – and these numbers are growing! LBNL also provides three members of the collaboration Executive Board, and four members of the Technical Board. Technically the program has been divided into six major R&D areas: beam simulations, a beam cooling experiment known as MUCOOL, targetry, acceleration/storage ring physics, the proton driver, and beam phase-rotation. The immediate goal of the collaboration is to develop a “ZDR-level” understanding of a Neutrino Factory in about three years, leading to a conceptual design two years later. Within AFRD we are contributing to: the beam simulation and theory effort, and have completed a full front-end study; the MUCOOL experiment – through design and testing of the novel 201 MHz and 805 MHz RF systems, and the large-aperture superconducting solenoid magnet system, soon to be tested at FNAL; an the design of the induction linac system for phase rotation.

4.1.5 Beam/Laser/Plasma Interactions

The l'OASIS Group in AFRD studies, experimentally and theoretically, the interaction of high intensity lasers with particle beams and plasmas. The immediate goal is to develop very high gradient (10-100 GV/m) acceleration of electron beams with significant charge (~1 nC/pulse), and emittances comparable to, or better than, modern RF photo-cathode sources. Recently, the experimental program has utilized a 10 TW laser system to demonstrate laser wakefield acceleration of well collimated electrons of reasonably high charge (few nC/pulse), at 5 Hz, with energies of tens of MeV, in a plasma channel with a length of approximately 1 mm. The energy spread however was 100%. The next step is to reduce the energy spread to around 1% by implementing the so-called "colliding-pulse" optical injection method. The different components of the process – gas-jet, plasma channel, laser pulses, and electron beam – are very well characterized by a novel diagnostics package. The theory and simulation effort in the group has developed analytic and computational tools to understand the results of the experiments. These tools are also being used to develop new concepts. Thanks to substantial investments in l'OASIS by DOE/SC/BER a 100 TW, 10Hz solid state laser with automated optical phase front control is presently being installed. The new experimental area to house this laser system has been made possible by a substantial institutional investment of infrastructure funds. The collaboration with NERSC under SciDAC funding has allowed us to model gas jets with sufficient precision to allow us to design carefully tailored, 10 cm long plasma channels. With these developments, we envision a 10 GeV-class, all-optical accelerator module.

5 Future Directions for the Berkeley Program

The future program at Berkeley can be reliably extrapolated from the natural development of the ongoing activities. Our physics future will increasingly focus on discovery of the origins of mass, and on determining the nature of the Dark Energy. We plan to maintain the diversity of our program with a complimentary effort in neutrino physics. ATLAS and SNAP will soon become the largest components of the Physics Division program. In AFRD the superconducting magnet program (including the National Conductor Development Program) and the laser-plasma accelerator programs will be supplemented with the LHC Accelerator Research Program (LHC-ARP). Neutrino experiments will be a joint effort with the Lab's Physics, Nuclear Science and Accelerator divisions. R&D efforts for both instrumentation and computing will be ongoing. We anticipate technical contributions to the development of the Linear Collider physics case as the next major element of the International Accelerator Program. The Linear Collider accelerator efforts will grow commensurate with the national linear collider collaboration.

Over the past year, we have engaged in a planning process for future directions. Our process consisted of a number of meetings of the permanent scientific staff to discuss future program directions. A straw poll of the Physics Division staff showed strong support for further work on the origins of mass (LHC, LC) and for the development of studies of Dark Energy and Dark matter (SNAP, CMB). Significant interest but at a smaller level exists in a neutrino program joint with AFRD and NSD. These will be the main Physics Division program elements by mid-decade under current assumptions. Assumptions we made for planning purposes are shown in Figure 1. Key dates and elements of the LBNL program are shown in Figure 2. Resource adjustments will be made to match these priorities over the coming few years.

In the Physics Division the accelerator-based efforts can be mounted in scenarios with modest budget increases. However, an increased involvement in LC, additional efforts in neutrinos, or effort on other large new accelerator-based projects would require a restoration of buying power to the Division's budgets. For the particle cosmology program, additional funding will be required. R&D support of future efforts, both accelerator-based and non-accelerator-based, should be restored in parallel with strengthening the existing efforts in an increased buying power scenario. Our traditional contributions to the community should be maintained. In the following sections, we provide more details on each of the elements of our future HEP program.

5.1 High Energy Cosmology

Recent studies of high redshift type Ia supernovae (SNe) observed with the Hubble Space Telescope (HST) and ground-based telescopes confirm the Supernova Cosmology Project's (SCP) well known 1998 result, which, based on a sample 42 type Ia supernovae, excludes a simple $\Omega_M =1$ flat universe and presents strong evidence for the existence of a cosmological constant ($\Omega_\Lambda>0$). To fully exploit the use of SNe Ia as cosmological probes and to study the ``dark energy" that is causing the acceleration of the universe's expansion, a space-based telescope such as SNAP is needed. The conceptual design and requisite R&D for such a space mission form a large part of our program. For continued studies of SN Ia cosmology while SNAP is being prepared, the SCP will continue its program of supernova search/identification/and follow-up campaigns in the mid- to high-redshift region employing coordinated multi-epoch observations using the most powerful ground-based telescopes and the Hubble Space Telescope (HST). However, these high redshift studied will be completely dominated by known and potential systematics unless SNe Ia are better calibrated and scrutinized far more closely for (as yet undetected) systematic effects and towards this end we are developing the Nearby Supernova Factory (SN Factory) which will provide a major improvement on the low-z end of the Hubble diagram ($0.03 < z < 0.08$) by providing a substantial increase in statistics and greatly improved control of systematics.

5.1.1 Supernova Cosmology Project and the Nearby Supernova Factory

The goals of SCP program are to add statistics to the middle region of the Hubble diagram ($.3 < z < .8$) and extend it to $z > 1$. Prior to SNAP, such studies can provide a measurement of the dark energy equation of state, $<w>$ (time average) that is limited in precision, but may still be able to distinguish a cosmological constant ($w = -1$) from alternative models. The SCP is collaborating with a major five-year legacy survey using the Canada-France-Hawaii Telescope that will yield hundreds of SNe Ia in the mid-redshift range.

A second focus of the current program is to use HST to study SNe with $z > 1$. Though the statistics of these very high SNe will necessarily be small due to the limited field of view of the HST, such events will be of great interest as they allow us to look back to the acceleration/deceleration transition era.

The Nearby Supernova Factory *(SNfactory)* is designed to lay the foundation for current and next generation experiments to determine the properties of Dark Energy. It will discover and obtain lightcurve spectrophotometry (simultaneous broadband lightcurves *and* spectral time series) for more than 300 SNe Ia supernovae in the low-redshift end of the smooth Hubble flow. Their statistical power alone will lower the statistical error of the current SCP results by up to 50% and will help reduce the systematic error. In the longer term, they will improve SNAP's constraint on Ω_M by 40% and on w_0 by a factor of two. This SNe dataset will further serve as the premier source of calibration for the SN Ia width-brightness relation and the intrinsic SN Ia colors used for correction of extinction by dust (needed by SCP and SNAP). This dataset will also allow an extensive search for additional parameters, which influence the quality of SNe Ia as cosmological probes. Well-observed nearby SNe Ia, especially in host galaxies spanning a wide range in star-formation histories, are essential for testing for possible systematics.

The study of nearby supernovae poses special challenges that are different from those of the studies at high redshift. Several aspects of the *SNfactory* set it apart from other past and on-going nearby supernova projects. Foremost among these is that supernovae will be discovered using a blind wide-area CCD-based survey. The *SNfactory* will coordinate discovery and follow-up observations, eliminating the delays and spotty early-lightcurve coverage, which is now typical. Finally, *SNfactory* follow-up observations will use an integral field unit spectrograph, data from which can be used to construct both detailed flux-calibrated spectra and broadband images. The regular photometric spectral time series for nearby supernovae the SNfactory will generate will revolutionize the study of supernovae. This dataset will also eliminate several limitations (wavelength bandpass mismatch, wavelength-dependent slit losses, etc.) of all other currently available instrumentation used to study supernovae.

The *SNfactory* will also serve as a hardware and software testbed for *SNAP*: the efficacy of *SNAP*'s IFU spectrograph will be demonstrated, reduction and calibration techniques for accurate spectrophotometric spectroscopy will be implemented, and software algorithms and an automated pipeline needed for continuous CCD searching and follow-up will be developed and run for several years prior to *SNAP*'s launch.

5.1.2 SNAP

Studies of Type Ia supernovae, including compelling measurements by the Supernova Cosmology Project at Berkeley Lab, produced significant evidence that, over cosmological distances, they appear dimmer than would be expected if the universe's rate of expansion was constant or slowing down. This was the first direct experimental evidence for an acceleration possibly driven by a positive Cosmological Constant. However, only about 100 high redshift supernovae accumulated over several years have been studied and other explanations cannot be ruled out.

SNAP (Supernova/Acceleration Probe) is a space mission now under conceptual design that would discover and obtain high-signal-to-noise calibrated light-curves and spectra for over 2000 Type Ia supernovae at redshifts between z = 0.1 and 1.7. Discovery of so many more supernovae would help eliminate possible alternative explanations, give experimental measurements of several other cosmological parameters, and put strong constraints on possible cosmological models. SNAP is a space-based, 2-m three mirror anastigmat wide-field telescope which feeds a focal plane consisting of a 0.7 square-degree imager tiled with equal areas of optical CCD's and near infrared sensors, and a high-efficiency low-resolution integral field spectrograph. Such a satellite would also complement the results of proposed experiments to improve measurements of the cosmic microwave background.

In addition to the supernova discovery program itself, Berkeley Lab's Supernova Cosmology Group has unique expertise in large charge-coupled device (CCD) detectors. While smaller CCDs are now common, the Laboratory has developed techniques to construct the large mosaics required for SNAP. The LBNL new-technology n-type high-resistivity CCD's have high (~80%) quantum efficiency for wavelengths between 0.35 and 1.0 μm. The excellent efficiency at the red end of this range (where conventional CCDs have low sensitivity) is particularly important for studying distant Type Ia supernovae. Extensive radiation testing shows that these CCD's will suffer little or no performance degradation over the lifetime of SNAP. A pixel size of 10.5 μm has been matched to the telescope diffraction limit at 1000 nm of 0.1 arcsec.

After several years of research and development, the project schedule calls for approximately four years to construct and launch SNAP, and another three years of mission observations. SNAP's schedule is being developed in coordination with DOE's Office of Science/High Energy and Nuclear Physics program and NASA. While important roles will be played in the project by LBNL, many groups outside the lab are bringing important expertise to this project.

5.1.3 Cosmic Microwave Background

CMB observations have moved from relatively small experiments using a few noise limited sensors to a precision science employing large sensor arrays to provide the required sensitivity. LBL is in a unique position to take a leadership role in the development of instrumentation for the next generation of CMB observations. Having characterized the CMB temperature anisotropy, CMB science is taking the next observational step by measuring the polarization anisotropy and small angular scale CMB secondary effects, such as the Sunyaev Zel'dovich effect and cosmic shear. These measurements have the potential to provide insights into the expansion history of the universe that are perhaps even more exciting and ground breaking than the revolutionary insights provided by the temperature anisotropy.

The CMB effort can be split into two categories: instrumentation and theory plus data analysis. The primary focus for the current stage is instrumentation for experiments with large format bolometer arrays. Several key technologies are being developed for the next generation of CMB experiments. Each of the technologies will be proven in order of complexity by deploying them on a set of complementary experiments: large format bolometer arrays on APEX-SZ, polarization sensitive antenna coupled bolometers on POLARBEAR I, and readout multiplexing on the South Pole Telescope and POLARBEAR II.

APEX-SZ and the South Pole Telescope will utilize the Sunyaev-Zel'dovich (SZ) effect to search for distant galaxy clusters. The distribution of galaxy clusters vs. redshift is sensitively dependent on Ω_M, Ω_λ, and w. Unlike x-ray or optical surveys, the magnitude of the SZ signal is independent of redshift, so it is well-suited for deep searches. These experiments are complementary to SNAP as they attack the same physics with a completely different technique. The flagship LBL-based experiment, POLARBEAR, aims at detecting gravity waves generated by inflation, which could manifest themselves as a net curl in the polarization field of the CMB (commonly referred to as B-modes). CMB polarization is the only probe known to be sensitive to this inflationary fingerprint.

APEX-SZ will be the first experiment to deploy a large format wafer-scale integration of TES sensor arrays using the techniques of silicon microelectronics and micromachining. Since sensors for mm-wavelengths are already limited by the photon shot-noise of the CMB signal, increasing array size to perform many simultaneous measurements is a crucial step for increasing the sensitivity. POLARBEAR I introduces a further innovation by integrating polarization sensitive antennae directly on the wafer. Readout multiplexing is the remaining key technology. The sensors typically operate at about 0.3 K, so the heat leak due to many connecting wires is prohibitive and an economical readout technique is crucial. LBNL has been key in designing superconducting multiplexer technology and has engineered the associated readout electronics. The readout multiplexing technology will be deployed on the South Pole telescope. These three technological advances will come together for POLARBEAR II, our primary experimental initiative.

The instrumentation developments for POLARBEAR are a stepping stone towards the technology that will ultimately (post-SNAP timescale) be deployed on a CMB satellite mission, which is foreseen as one of NASA's Einstein probes. Our team includes a co-Investigator and three collaborators on a NASA proposal to develop a CMB polarization mission. Participation in this mission is a natural progression for both SNAP and CMB personnel on a timeframe beyond 2009.

The second category for the CMB effort is data analysis and CMB phenomenology, for which the physics division has nurtured a successful partnership with NERSC. This effort is growing, with LBL playing an important role in the analysis of MAXIPOL (the successor to MAXIMA) data and in preparing algorithms for the ESA Max Planck Surveyor satellite mission, APEX-SZ, and POLARBEAR. The future for CMB polarization may well be a satellite mission, on a timeframe that follows SNAP. LBL is positioning itself to play an important role in the design and data analysis of a future CMB polarization satellite.

A detailed staffing plan has been developed to facilitate the new directions and long term goals in CMB cosmology. Appendix I outlines this plan. The CMB team will be strengthened with the addition of a divisional fellow in 2005. As the number of experiments being deployed and supported grows, we will add roughly one postdoc for each, totaling three in 2006 when SPT is being deployed, POLARBEAR is running, and APEX-SZ is winding down. Our effort makes use of the strong cohesion within the CMB team at LBNL and the UCB campus, where five faculty members (three of which have joint appointments), four postdocs, and over a dozen GSRAs currently work on CMB experiments.

5.2 Discovery of the Origins of Mass

5.2.1 ATLAS and LHC-ARP

The ATLAS collaboration has started to plan for the pre-operation, operations and research phase of ATLAS. The LBNL construction responsibilities for the silicon strip detector will be completed in the next two years. It is planned to assemble the overall pixel system at CERN starting at the end of 2005. Thus a major part of the LBNL ATLAS work will shift to CERN from late 2004 through 2006 in order to assemble, install, commission and first operate those parts of the ATLAS detector that are LBNL responsibilities. Beyond 2007, LBNL will be required to assume operations and maintenance responsibilities for aspects of the pixel detectors. This ill require the continued involvement of technical personnel in both the mechanical and electronics aspects of these detectors, in addition to physicists. A continuous presence at CERN by LBNL personnel will be necessary to fulfill these responsibilities. Similarly, support of the initial operations of the framework code and other software developed at LBNL will be critical to the success of ATLAS in its first years of operation. LBNL computing professionals will be needed to provide this support and are resident now at CERN.

Together with FNAL and BNL, the Center for Beam Physics and Supercon Program are formulating a program of accelerator research and technology development in support of the commissioning and eventual upgrade of the interaction regions of the LHC. One principal focus of this work is the design and modeling of large aperture, high gradient quadrupoles that would replace the first generation magnets now being built by the US-LHC Accelerator Collaboration. In addition full development of specialized beam instrumentation such as the 40 MHz luminosity monitor and a bunch-by bunch longitudinal beam density monitor will be essential for getting the best performance from LHC in its early years of operation.

The number of physicists at LBNL involved in the ATLAS and LHC-Accelerator Research Programs will grow starting in 2003. We anticipate a modest growth in the number of faculty and senior physicists but a more substantial growth in the number of postdoctoral physicists and graduate students.

Although completion of the ATLAS detector is still some years away, concepts for upgrades are already under discussion. A major area for potential upgrades is in the tracking detector. The ATLAS design allows the silicon pixel detector to be removed and installed without disturbing substantially the remainder of the tracking detector. One can already foresee the desirability of improvements (finer granularity, improved radiation hardness, lower mass,…) to the pixel detector, and R&D to this end should begin already in 2004 if one is to be ready to install improved detector elements after the first few years of ATLAS operation.

Studies have already been done about increasing the LHC luminosity beyond $10^{34}cm^{-2}sec^{-1}$ and energy as high as 14 TeV per beam. If this were to occur, substantial upgrades to the tracking detector and interaction region components would be required. If history is any guide, we would expect to see greater utilization of pixel detectors and replacement of the current wire/gas outer tracker with silicon detectors. LBNL will continue to be a leader in the area of silicon detector R&D, and upgrades to ATLAS is one area in which focused R&D will require future support. Likewise the next generation magnets supporting an upgrade would be the exploitation of the Nb_3Sn high field magnet technology in which LBNL is the world leader.

5.2.2 Linear Collider

As mentioned above, AFRD has taken responsibility for the damping ring complexes for both the electron accelerator and the positron accelerator. We expect this work to continue and expand, depending on funds available. AFRD has also joined the A0 FNAL, ANL, and Northern Illinois University to develop a high repetition rate, photocathode injector to provide a linear collider with extremely bright electron beams with non-symmetric emittances.

Long term, an important goal is to introduce LC accelerator R&D to universities across the nation. Only then can the community bring to bear the resources needed to carry out the LC project. Recently , faculty at UC Berkeley have expressed interest in University-based accelerator research for the LC. Participants from other University groups outside Berkeley will be solicited once an effort has been established.

We expect the Linear Collider will be the next International Accelerator Facility proposed to be built. Berkeley will make both physics and technical contributions to this facility where we have key technologies to offer.

5.2.3 CDF

LBNL has made major investments over the years in the CDF experiment at FNAL. Most recently, we have provided personnel for leadership roles in Run II commissioning and offline computing, as well as important hardware contributions in the COT and silicon systems. In the coming years we plan to participate in the analysis of a vastly increased data set from Run II. This analysis activity nicely complements our future program in ATLAS at the LHC.

A number of upgrades to the Tevatron and the CDF and D0 detectors are planned for the higher luminosity, Run IIb period. The area where LBNL has made significant contributions to the CDF Run IIb upgrade is in our traditional area of silicon tracking, i.e., a replacement for L00, and SVXII, that would be necessary after 3-4 Mrad of irradiation. The LBNL group has been involved since FY00 in R&D, design and prototyping for a new silicon detector. The efforts here include the development of a new silicon readout chip (SVX4), the development of hybrids that will house the SVX4 chips, the design of the basic electrical readout unit of the detector (the silicon barrel "stave"), and in simulation and performance studies.

The LBNL group had a crucial role in initiating the design of the radiation-hard SVX4 readout chip. Our proposal, minor changes to the SVX3 chip and use of a deep submicron process, was adopted by both CDF and D0. LBNL has provided significant engineering effort and technical leadership. With design contributions from FNAL and the University of Padova a first full prototype has been obtained in FY02. Pre-production chips are on hand. No design changes are necessary before a final production submission. LBNL has also proposed a new design for the silicon modules themselves (the 'stave' concept). Each 'stave' is highly integrated, containing 12 silicon detectors, six hybrids and a control circuit, all linked by a custom transmission line bus cable buried beneath the active elements. The idea of a single module design makes for simplicity of construction as well as for simplicity in data analysis. Results on prototype testing have been presented at the IEEE Conference this year. LBNL has completed the pre-production of the hybrids necessary for the completion of 15 staves. We are now working with FNAL on testing the electrical properties of the pre-production staves, which will be used for system testing.

After over three years of work on the new silicon detector, in early September, 2003, the Fermilab director canceled the Run IIb silicon project because the expected luminosity at the Tevatron is now about 4 fb-1, rather than the 15 fb-1 that were projected in FY00. The silicon project is at the stage of pre-production as all prototypes (chip, hybrids, stave) have been successful. It is a pity that the cancellation of the project comes when it is ahead of schedule and most arrangements for the final production have been made! The project is expected to end by March 31, 2004.

So far the collected luminosity is less then twice that of Run I. A factor 10 increase from Run I is expected by the end of FY05. We plan to continue working on top physics, on searches for new phenomena (SUSY) and searches for the Higgs within extensions of the Standard Model.

The outlook for support of this program is very bad at this point. In FY03 a strong team including permanent staff members, temporary staff members and graduate students carried out the CDF program. In FY03 the group had 6 postdocs and 2 physicists with European Fellowships. By FY05 the expectation is: 2 postdocs and one European Fellow. By FY06 is very likely that the temporary staff members in CDF will be zero or one at most. This is very unfortunate for LBNL, as activities in CDF are very important for a smooth transition into the LHC era. Efforts need to be made to change these projections!!

5.3 Quark and Lepton Flavor Studies

5.3.1 BaBar

The present upgrade plans for the LBNL group are concentrated in two areas, namely, a hardware upgrade for the SVT and upgrades in computing to contend with the likely order-of-magnitude increase in the size of both the incremental and integrated data samples in the next four years. The short-term SVT upgrade involves removing and replacing the SVT last summer. LBNL is procuring and testing the new AToM ICs and is also responsible for the assembly procedure and re-installation of the SVT. These current plans require only a modest LBNL effort. Longer term upgrade plans are still under discussion as they depend on the accelerator upgrade program, which is not yet fully defined. Nonetheless, LBNL will contribute as plans become more definite, albeit at a level much reduced compared to our previous efforts. The computing upgrades will require a substantial effort of experienced physicists and computing professionals, well-versed in the BaBar computing paradigm. Fortunately, LBNL has such a core group, with physicists from BaBar and computing professionals from NERSC. We place a high priority on maintaining support for this group through FY04 at least. The goal here is to address longer-term improvements to the BaBar computing model, to provide physicists with faster and easier access to BaBar data for physics analysis purposes. This can, in principle, lead to a reduction in CPU time and disk space overhead resulting in significant cost saving. The group is presently implementing the ideas of this computing upgrade physics data model project in concert with BaBar management.

5.3.2 CDF

We have begun a vigorous program to exploit the physics opportunities in RUN II. The LBNL physics interest is centered on precision measurements of CKM matrix parameters.

In FY03 the main analysis has been a measurement of the hadronic moments of semileptonic decays of charged B mesons which provides constraints on the QCD corrections to |V_{cb}|. This puts to use the expertise of the group, including detailed knowledge of the hadronic trigger that uses the SVT.

Observation and measurement of B_s mixing and determination of x_s is a hallmark measurement for CDF. In order to resolve these oscillations at large x_s, the proper decay length of B_s must be determined with high precision. This forces CDF to use fully reconstructed decays for the measurement. To prepare for the future, the LBNL group has been working on full reconstruction of B_s decays. A first measurement of the branching ratio of B_s into $D^0\ \pi^+$ relative to B_d into $D^-\ \pi^+$ has already been made. The plan is to continue work on other decay modes. Also the group plans to begin studies of b tagger optimization.

Another important project that will be started soon is the study of the Cabibbo suppressed decay B_s into $D^0\ K^+$. This decay is of considerable interest because it provides a route towards measurement of the angle γ. A goal for FY04 is to measure the branching ratio for this decay.

5.3.3 Neutrino Physics

Important upgrades are planned to allow KamLAND to be sensitive to solar neutrinos. Strong support from the US-Japan agreement is anticipated to help carry out this effort. The solar neutrino measurements place stringent demands on backgrounds, requiring purification of the scintillator oil. LBNL's Physics and Nuclear Science Divisions support this effort jointly. Possible construction of a National Underground Laboratory in the US and the opening of the JHF facility in Japan are both important opportunities for neutrino physics in the future. Future efforts in this area will be joint with Nuclear Science and Accelerator Divisions in order to achieve critical mass. Recently, we have obtained support through LDRD to investigate the possibility of a US-based θ_{13} reactor experiment.

5.4 Future Directions in AFRD Particle Physics

AFRD programs are well positioned to provide a wide array of critical R&D activities of central relevance to the national program in particle physics. We have a highly talented team of scientists and engineers who have developed an impressive arsenal of skills and tools. In the immediate future our experts in beam electrodynamics and rf-systems are providing assistance to Fermilab in its luminosity improvement efforts. When we look to the future, we anticipate taking major responsibilities in the R&D and construction activities associated with large facilities built elsewhere – as we do now within the US/LHC program. We foresee a fruitful collaboration with CERN as part of US support to LHC accelerator commissioning and operations. Berkeley's expertise in computer networking and visualization makes LBNL a natural testbed for a Global Accelerator Network. The main elements of our future program are superconducting magnet development principally aimed at upgrades for the LHC, and in the development of all-optical acceleration techniques and beam diagnostics.

6 Meeting Our Commitments

Leadership for many of these future projects can be readily identified within the Physics Division. What cannot be identifies are the staff, scientific and technical, needed to carry them out. Over the past few years, LBNL has managed to disguise the continuing contractions of its scientific and technical staff in part by relying on retired staff, a strategy that must run into the limits of longevity. Over the next few years, we will increase our efforts on LHC and SNAP while supporting a modest LC and neutrino effort, in part at the expense of the other elements of our program.

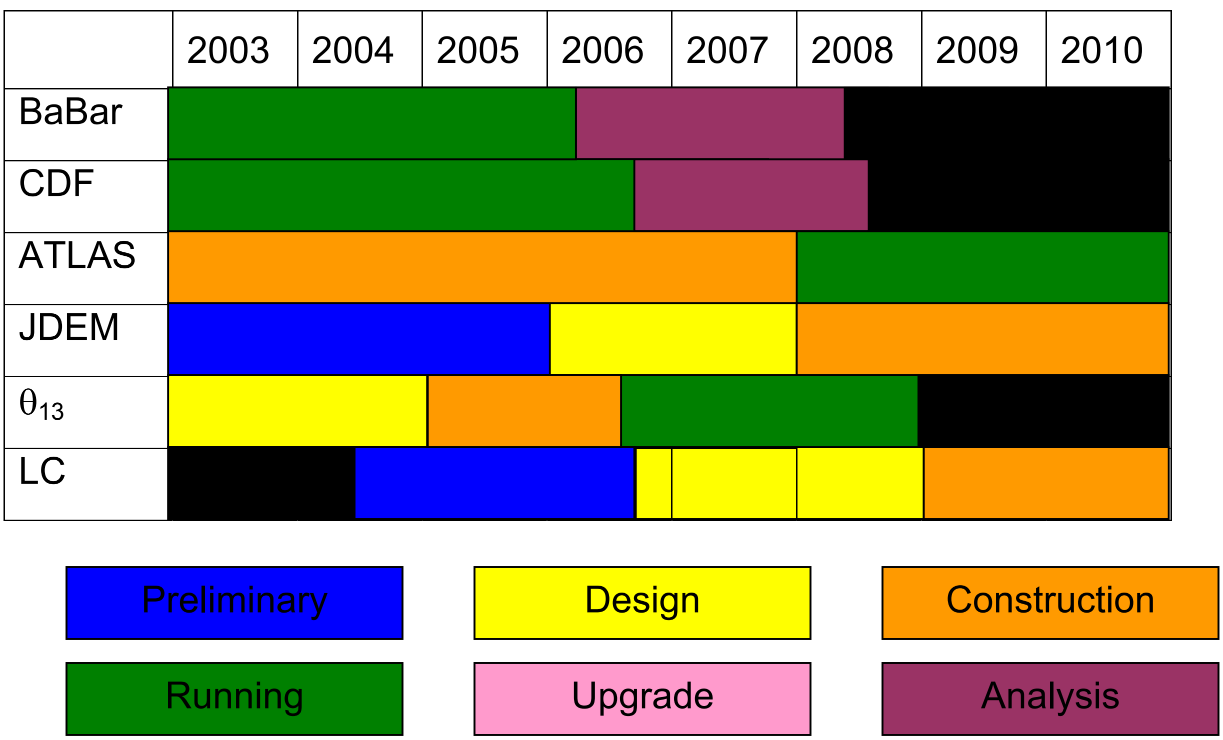
7 Conclusion

LBNL has helped to shape high energy physics in the US over the past decades. It has transformed hadron collider physics with the SVX at Fermilab, proposed building an asymmetric electron-positron collider, and then was a major partner in the PEP-II construction and in the design and construction of BaBar, led the development of smart pixel technology for the LHC, and opened the field of supernova cosmology. This record of innovation and outstanding performance justifies the requested increases in the base program budgets outlined in Appendices I and II.

Figure 1: Planning assumptions

JDEM CD-0 submitted	2004 (In preparation)
JDEM CD-1	2006
LC Approval	2007
LHC Commissioning	2007
ATLAS Physics Run	2008
JDEM Launch	2014

Figure 2: Program Elements



Appendix II *Draft* **ATLAS Staffing Plan** *Draft*

Background

The Standard Model of particle physics has been enormously successful in describing a wealth of data from experiments using electron and proton beams. Precision measurements have confirmed its ability to make predictions at the 0.1% level. The fundamental unanswered question in High Energy Physics is that of the origin of mass. In the Standard Model all of the particle masses arise from interactions of the particle in question with a "Higgs field". The simplest implementation of this Higgs field involves the existence a single new particle, the Higgs boson, whose mass is not predicted by the theory but whose interactions are. In order to be consistent with experimental measurements, its mass should lie between the current lower limit of 114 GeV and approximately 200 GeV. In more complicated implementations, there can be more Higgs bosons with masses ranging up to 1 TeV. In order to understand the mass generation mechanism it is necessary to discover these Higgs bosons and any other associated particles (such as those predicted in models of super symmetry) and to measure their couplings to the other particles of the standard model.

The LHC is designed to have sufficient energy and luminosity (event rates) to discover at least one Higgs boson, independent of the actual implementation. The LHC will search for Higgs bosons via decays into photons, W and Z bosons, τ leptons and b-quarks. The mass will be measured and some of the couplings and decay properties determined. The LHC has a much larger available energy than the Tevatron and this opens up a new energy regime that will allow the LHC to conduct extensive searches for other new phenomena such as super symmetric particles and the existence of extra dimensions. It is also possible that the LHC could produce the particle responsible for the Dark Matter that permeates the universe according to astrophysical observations.

The study of electroweak symmetry and the origins of mass will be a major focus of the Berkeley Lab program for the next decade. Our ongoing commitments in ATLAS hardware design and construction and core software do not permit us to devote sufficient effort to the development of analysis strategies and tools. This effort is important for ATLAS because the LBNL group has expertise that is crucial to fully understand and exploit the data. Additional support for the LBNL ATLAS program is needed to allow us to play a major role in the discovery of the Higgs or of other new phenomena. Because these discoveries are very likely to happen soon after the commissioning of the LHC, groups with major detector responsibilities will be at a severe disadvantage in doing physics during the early discovery phase of the LHC. This plan addresses both the LBNL hardware and software responsibilities and the growth of a significant physics analysis program by the time of first LHC running. All projections are based on the planned LHC schedule and milestones given below.

ATLAS Milestones

Data Challenge 2	March 2004
Pixel System delivered to CERN	April 2005
Computing Technical Design Report	June 2005
Data Challenge 3	Fall 2005
Install Pixel System	April 2006
Physics Readiness Report	Summer 2006
Global Commissioning starts	August 2006
First LHC Beam	April 2007

Appendix I *DRAFT* Supernova Science Staffing Plan *DRAFT*

<u>Background</u>

The study of cosmology has entered a new era in which empirical data can play a decisive role in determining the correct theory of the history and fate of the universe. While previously this theory was heavily dependent on aesthetic considerations, we now are beginning to have a range of experimental and observational tools that can directly measure the relevant cosmological parameters. Supernova studies pioneered at LBNL have demonstrated that, contrary to all expectations, the expansion of the Universe is not slowing, but rather accelerating. Combining these results with measurements of the cosmic microwave background, another area in which Berkeley has a long history, shows that two-thirds of the energy density of the universe must be a previously unknown component, termed “dark energy,” whose distinguishing characteristic is that its pressure is negative. Nearly all the remainder is dark matter, an unidentified substance not made of protons, neutrons, and electrons. Together, these two sources appear to provide just enough density to render the universe flat, in accord with the predictions of the inflationary model. Evidently, the successful model of particle physics describes only a tiny fraction of the composition of the universe, since neither dark matter nor dark energy is encompassed in our current picture: We are ignorant of the dominant constituents of the universe, those that shape its structure and determine its ultimate destiny. The goal of the Berkeley Cosmology and Astrophysics program is to continue to make significant contributions to the understanding of the dark energy and dark matter that constitute approximately 95% of the universe, building on our traditional areas of expertise and using a number of complementary observational tools.

Among these tools, supernovae stand out as potentially the most direct, least model-dependent, for studying the energy-densities of the universe and the relative contributions of mass energy and vacuum (or “dark”) energy. SNAP is a major step beyond the ground-based supernova studies that revealed the existence of dark energy, and is designed to study the properties of dark energy in detail. Its power derives from the simplicity with which its results can be interpreted. The Type Ia supernovae are nearly uniform beacons, distributed through space and time. By observing their brightness and redshifts, we map the history of the expanding universe. Results first reported in January 1998 by the Berkeley-based Supernova Cosmology Project (SCP) showed that distant supernovae were dimmer than was expected for their redshifts. It was in this way that the unexpected acceleration was discovered. Detailed study of the brightness as a function of the redshift measures the equation-of-state ratio, w, of the dark energy pressure P to its energy density, ρ. To fulfill its role as the source of expansion, w must be less than -1/3.

LBNL is now leading a new proposal, the SuperNova Acceleration Probe (SNAP), a space-based mission that will observe thousands of Type Ia supernovae with better precision than any single supernova has ever been measured. SNAP will measure the history of the universe’s growth over the past 10 billion years – and thus determine the value of w to $\pm$5%, if w does not vary in time. The traditional view of the expanding universe was overthrown only when the supernova measurements revealed the time variation of that expansion – the acceleration. In the same way, real insight into dark energy may come only with measurement of the time variation of w. If dark energy is actually due to a cosmological constant, then w will be -1 always and its time derivative w' will vanish. If dark energy is dynamical, w need not be -1 and will likely show a non-zero time derivative. SNAP can measure a variation in w with redshift, $w'=dw/dz$, to an accuracy of ±0.2. Measurements of w and w' will provide the basis for understanding dark energy.

Table 1: Astrophysics Milestones

Supernova Factory starts taking data	October 2003
APEX data-taking starts	April 2004
SNAP ZDR (Zeroth-order Design Report)	September 2004
SNAP CD-1 and Conceptual Design Report	September 2005
PolarBear I Commissioning	February 2006
SNAP CD-2 and Preliminary Design Report	September 2006
South Pole Telescope Commissioning	October 2006
Planck Surveyor Launch	February 2007
PolarBear II Commissioning	March 2007
SNAP CD-3 & Final Design Report	October 2007
SNAP Launch	August 2010

LBNL Program

LBNL maintains an active, robust and scientifically exciting cosmology and astrophysics program that has produced a number of the major results and highlights in the last decade and probes fundamental physics. These include the discovery and exploitation of CMB anisotropies and the acceleration of the Universe from supernova Type Ia observations. This program is made from a core collaboration with NERSC and UC Berkeley campus and involves projects with substantial support from the DOE, NASA, and NSF. Our goal is to pursue first-rate fundamental science and we have developed a broad-based program to achieve that.

The largest portion of the LBNL program consists of an integrated program of activities to study supernovae and utilize them to probe cosmology. The principal supernova activities are shown in Table 2. The next major program is the study of the Cosmic Microwave Background (CMB) as a diverse and powerful cosmological test bed and probe of cosmological parameters. This program has extended to include the polarization of the CMB and the Sunyaev-Zeldovich (SZ) effect. We have also been developing an active program in large-scale structure observations and simulations and in gravitational lensing as a probe of both Dark Matter and Dark Energy. A strong theory program is developing and essential to these efforts. All of these programs take substantial advantage of collaborations with NERSC and with UCB. An integral part of the effort is to closely coordinate an innovative program of detector and algorithm (computation) development. We take advantage of the nearness to the University and the keen interest by students and post docs in this science.

Building on our pioneering studies that provided evidence for the acceleration of the expansion of the universe, the goals of Supernova Cosmology Program (SCP) are to confirm and extend this result by adding statistics to the middle region of the Hubble diagram ($.3 < z < .8$), extending it to $z \sim 1.2$ or higher, and understand the systematics of SNe Ia at both high and low redshift. Working towards these goals, the SCP conducts a program of SN search/identification/and follow-up campaigns that consist of coordinated multi-epoch observations using the most powerful ground-based telescopes in operation and the Hubble Space Telescope (HST). This program discovers and studies about 20-40 SNe per year. A new partnership with CFHT Legacy Survey project will enable progress on the mid-z region of the Hubble diagram. Access within the collaboration to the Subaru telescope will allow study of higher redshift SNe, and an ambitious HST search and follow-up program associated with a new HST treasury survey will allow study of a limited number of very high ($z > 1.2$) redshift SNe.

The other short-term component of the supernova observation program is the Nearby Supernova Factory (SNFactory). This project is designed to take the range of techniques that we have developed and perform the definitive measurements that will make the supernova results one of the solid foundations on which future cosmological investigations will build. By studying an order-of-magnitude more supernovae in a much larger, systematic program, we can address many of the main remaining sources of uncertainty (primarily systematics). The "supernova values" for the mass density, vacuum energy density, and curvature of the universe will then become the benchmarks for the other, more model-dependent cosmological measurement techniques. In particular, the cosmic microwave background measurements will be able to use these values as both a starting point and a benchmark as they fit the eleven or so parameters to which their power spectrum is sensitive.

This project will provide Berkeley Lab with the capability to dramatically scale up discovery of nearby supernovae. Instead of finding dozens of supernovae during a semester, we would gear up the search to discover several hundred and therefore are calling this a Supernova Factory (SNfactory). We are learning how to do this in an efficient manner, and learning which telescopes are most suitable for the task. In particular, the NEAT [Near Earth Asteroid Tracking program operated by the Jet Propulsion Laboratory (JPL)] search runs are going to increase. Over a three-month span, we would expect NEAT to find over 200 supernovae in the Hubble Flow.

The core of our long-term supernova program is the Supernova Acceleration Probe (SNAP). Dramatic reduction in systematic errors is critical to the measurements of w and w'. This will be possible by working beyond the earth's atmosphere with SNAP's wide-field 2-m telescope, half-billion pixel imager, and spectrograph, all specifically designed for this comprehensive study. The resulting instrument will also have broad capabilities for complementary measurements, especially the study of the spatial distribution of dark matter through weak gravitational lensing. This will enable a determination of the total matter density to high precision and help constrain w'. Moreover, SNAP will survey an area of sky several thousand times larger than the Hubble Deep Field, and with somewhat greater depth.

The three Supernova projects (SCP, SN Factory, SNAP) form an integrated program that keeps the LBNL group at the forefront of current scientific work while preparing future projects that have intermediate and long time scales. As is often the practice in HEP, where long design and construction phases are common, it is important for us to keep fully engaged in current developments in the field while preparing for a long-term project such as SNAP. Only by continuing to conduct research, analyzing data, and publishing results can we maintain the intellectual vitality of our program and build the intellectual base needed to conduct SNAP. The interleaved timescales of our SN Cosmology projects allow us to keep leading scientists focused on this area. On going data analysis and publication of results is also essential for effective training of the next generation of postdocs and graduate students. Moreover, the information exchange between current results and future design are mutually beneficial.

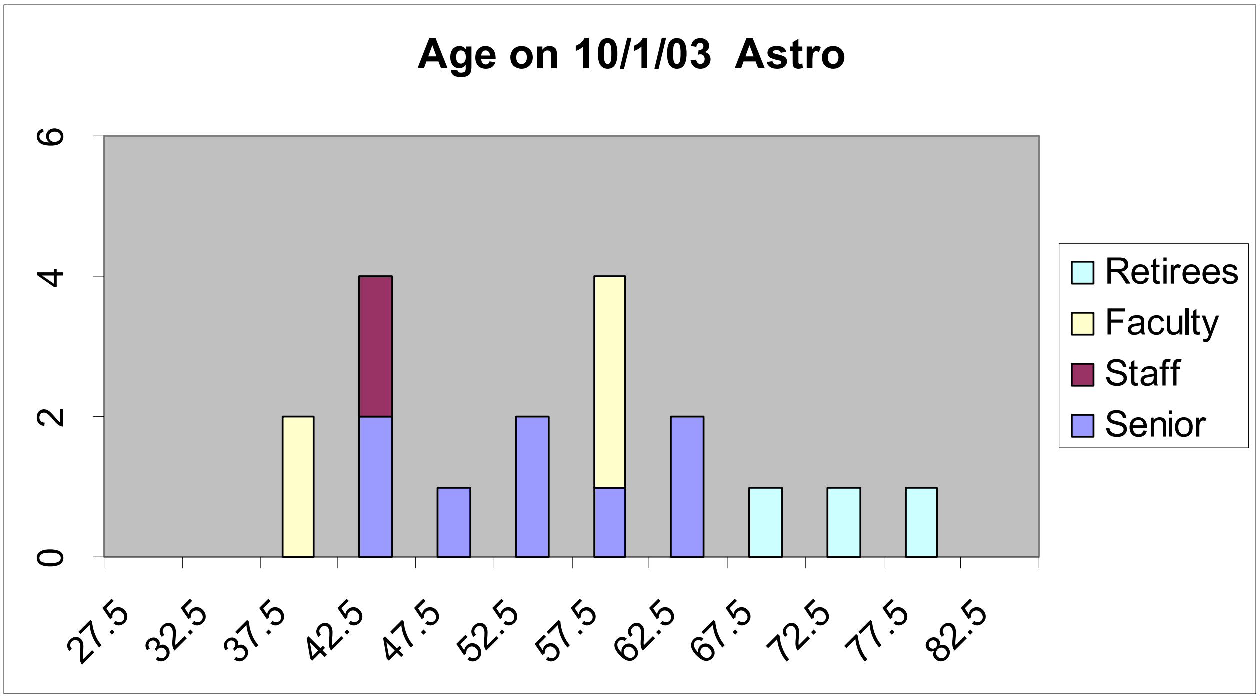
The cosmology program depends on advances in detector technology. In particular, the SNAP project benefits from the development of thick, fully depleted CCD with enhanced sensitivity in the NIR and improved radiation tolerance, as well as on work on developing ASICs for low-noise, low-power CCD readout co-located with the sensors on the back of the focal plane.

Table 2: Program Activities

Project	**FY03**	**FY04**	**FY05**	**FY06**	**FY07**	**FY08**
SCP	Subaru SN search; CFHTLS search; data analysis	CFHTLS search; HST treasury search; data analysis	CFHTLS search; HST treasury search; data analysis	CFHTLS search; HST/ground searches; data analysis	CFHTLS search; HST/ground searches; data analysis	HST/ground searches; data analysis
SNFactory	Search pipeline commissioning; Spectrograph construction; system integration; Software development;	Spectrograph hardware & software commissioning; system integration; scheduling software commissioning; start operations	operations; data analysis	operations; data analysis	operations; data analysis	data analysis
SNAP	Theoretical studies, Simulations, mission preconceptual planning, CCD & ASIC development, Instrument concept development, CD-0 software development	Theoretical studies, Simulations, Conceptual design ZDR; CCD & ASIC development, Instrument concept development; software development	Theoretical studies, Simulations, Conceptual design CDR, CCD & ASIC development; System requirements SRR, Instrument CDR, CD-1; software development	Theoretical studies, Simulations, Preliminary Design PDR, Instrument PDR, Detector fabrication, CD-2; software development	Theoretical studies, Simulations, Final Design FDR, Detector fabrication, CD-3b, CD-3c; software development	Theoretical studies, Simulations, Construction software development

Demographics

Figure 3 shows the age profile of the career staff and retirees now active in the astrophysics program at LBNL. We expect that the astrophysics program will last beyond 10 years. Our staffing plan includes openings for Division Fellows, the "tenure-track" appointments at the laboratory. In the tables that follow, division fellows are included in the SNAP staff although they will likely work on either SCP or SNfactory as well. It is expected that these will be promoted to senior staff and will help address the demographics problem. In addition, we expect that faculty appointments on the Berkeley campus will help here although these appointments are not under our direct control.



Description of Projects

Supernova Cosmology Project:

Over the past decade, the Supernova Cosmology Project (SCP) has carried out a series of measurements of supernovae and used them to determine the expansion rate of the universe. This program will continue until SNAP is launched. It will continue to provide important new data on Dark Energy. The SCP will also be a testbed for new analysis approaches and it will be a training ground for scientists who are new to cosmology and who are joining SNAP.

The SCP program over the next few years (Table 2) will include both the analysis of existing data and new measurements with ground-based and space-based instruments. There are approximately a dozen individual projects ranging from a new search using the Hubble Space Telescope to studies of dust. Each of these provides a project suitable for a postdoc or graduate student. Each also needs guidance from one of the senior people in the group. Because some of the senior people from SCP are now concentrating their efforts on SNAP and the SN Factory, the group needs to recruit new senior people as well.

The planned SCP effort will be at the level of 10-12 FTE beginning in FY04 until the SNAP launch expected at the end of FY09. This includes career scientists, division fellows, postdocs and students. When the SNAP science program begins, the SCP team will move to SNAP. The effort levels shown in the staff tables include all staff on SCP. Some of this staff will be funded by HST grants; the remainder by the Physics Division base program.

Nearby Supernova Factory:

The search pipeline for the SN factory is now operational and is finding supernovae at the expected rate. The follow-up instrument will be commissioned in FY04 on the 2.2Meter telescope in Hawaii. The software for scheduling and telescope control is being developed and tested. The experiment is expected to operate through FY07 and complete data analysis by FY09.

The optimum staff level includes 4-5 postdocs who will run the search, manage data-taking, do the data reduction and analysis and contribute to scientific papers. The effort in FY04 also includes a computing professional who is developing and testing the scheduling software. The University of Hawaii, the owner of the telescope, is considering a possible change in the long-term schedule for the instrument. If they decide to shut it down in this timescale, the experiment will either have to accelerate its data-taking or move to another telescope. Either of these would increase the manpower needs for the experiment. The staffing tables below are based on the optimum level.

It is expected the SNfactory will be completed before the launch. This may change depending on the needs for data to study SNAP systematics or to provide a low-z point for fitting cosmological parameters.

SNAP Science:

The SNAP program is currently in the R&D phase. The goal of this effort is to create a conceptual design and cost estimate for the SNAP mission. A major component of that planning will be to develop a staffing plan for the project. In this document, we look only at the science and instrument components that are part on the LBNL base program. The R&D phase is described in detail in the SNAP R&D Plan. Beyond the R&D period, our estimates are rough and are intended only to set the scale of effort that will be involved in the science program. The SNAP collaboration is likely to be small on the scale of major Fermilab or LHC experiments but the size of the LBNL group is expected to be comparable to the size of the groups who were involved in the construction and commissioning of BaBar or CDF.

The SNAP Science program includes project leadership as well as simulation and computing. This effort currently (FY04) consists of 2 senior scientists (1.5 FTE), 1 Staff Scientist (1FTE) and term appointments (1.55 FTE). The simulation effort is focused on generating detector requirements from physics needs and on building the simulation framework in collaboration with the computer science team. This program will grow in FY05 and will continue beyond the R&D period. The group will evolve to include all SNAP analysis.

SNAP Instrumentation:

The instrumentation effort is focused on developing the instrument suite and electronics for SNAP. In FY04, it consists of 3 senior scientists (2.6 FTE) and a mechanical engineer (.5 FTE). The senior scientist effort in FY05 will be 3 FTE and the engineering effort will grow to 1.75 FTE. Beyond the R&D phase, the instrument effort is expected to focus on construction, testing and detector assembly.

Micro Systems Lab:

The micro systems lab is currently dedicated to the production of CCDs for SNAP. It is funded entirely by SNAP program funds, not by base, and is not included in this plan.

Planned Staff

We have estimated the effort required for the ongoing and planned tasks. The tables here include both current and planned staff. All staff including faculty and graduate students are normalized to 1 FTE, that is a faculty member or student who devotes 100% of his or her time to a project is shown as 1 FTE on that project. The staffing levels and staff mix are our best estimate of the effort needed to meet current commitments and to have a leadership role in physics analysis. The staff schedule is adjusted to meet the program milestones shown in Figure 1.

Supernova Science Staffing Summary

SCP Staff (FTE)	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
career/staff	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
div_fellow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
faculty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
term/pd	4.8	3.8	4.0	4.0	5.0	4.7	3.0	3.0
gsra	3.0	4.0	3.0	4.0	4.0	4.0	4.0	4.0
technical	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
retiree	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Totals	11.2	11.2	10.4	11.4	12.4	12.1	10.4	10.4

SN Factory (FTE)	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	0.0	0.0	0.0	0.5	0.5	0.5	0.3	0.3
career/staff	1.0	0.9	0.6	0.6	0.6	0.6	0.6	1.0
div_fellow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
faculty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
term/pd	1.0	2.5	4.0	4.0	4.0	4.5	3.0	2.0
gsra	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0
technical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
retiree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	3.0	5.4	4.6	5.1	5.1	5.6	3.9	3.3

SNAP Program

SNAP Science	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	1.5	1.5	1.5	1.5	1.5	1.5	1.8	2.8
career/staff	0.0	1.0	1.0	2.0	2.0	2.5	2.5	2.5
div_fellow	0.0	0.3	1.0	1.0	2.0	2.0	2.0	2.0
faculty	0.0	0.0	1.0	1.5	2.0	2.0	3.0	3.0
term/pd	2.0	1.5	3.0	3.5	6.0	7.8	9.0	9.0
gsra	0.0	0.0	1.0	2.0	3.0	4.0	6.0	8.0
technical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
retiree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	3.5	4.2	8.5	11.5	16.5	19.8	24.3	27.3

SNAP Instrumentation	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	2.1	2.6	3.0	3.0	3.0	3.0	3.0	3.0
career/staff	0.0	0.0	0.0	1.0	1.0	1.0	1.0	1.0
div_fellow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
faculty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
term/pd	0.0	0.0	1.0	2.0	2.0	3.0	3.0	3.0
gsra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
technical	0.0	0.8	1.8	2.0	2.0	2.0	2.0	2.0
retiree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	2.1	3.4	5.8	8.0	8.0	9.0	9.0	9.0

Total Staffing Projections

The total staff needs to have a leadership role are shown in table yy and figure 2. These are the sums of the individual tables above. The table indicates the minimum level needed to meet all current obligations.

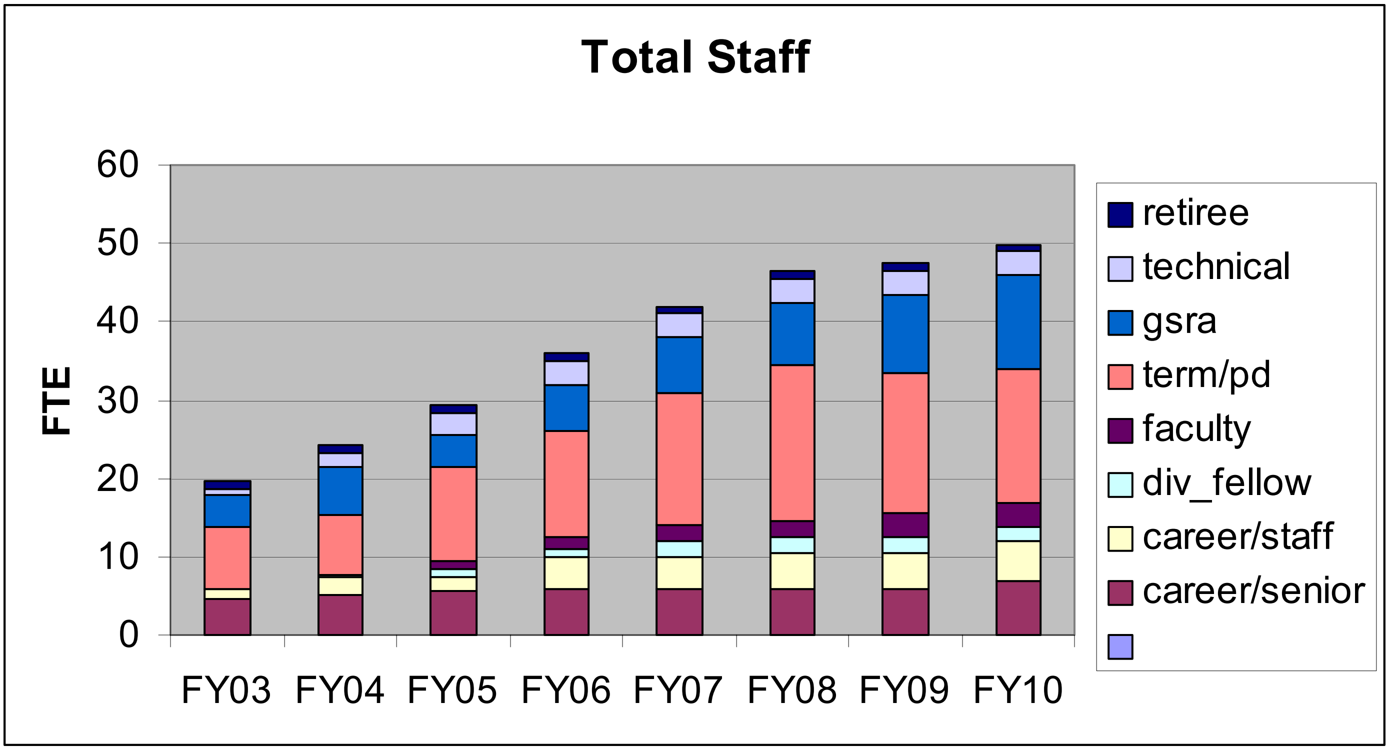
SNAP Program

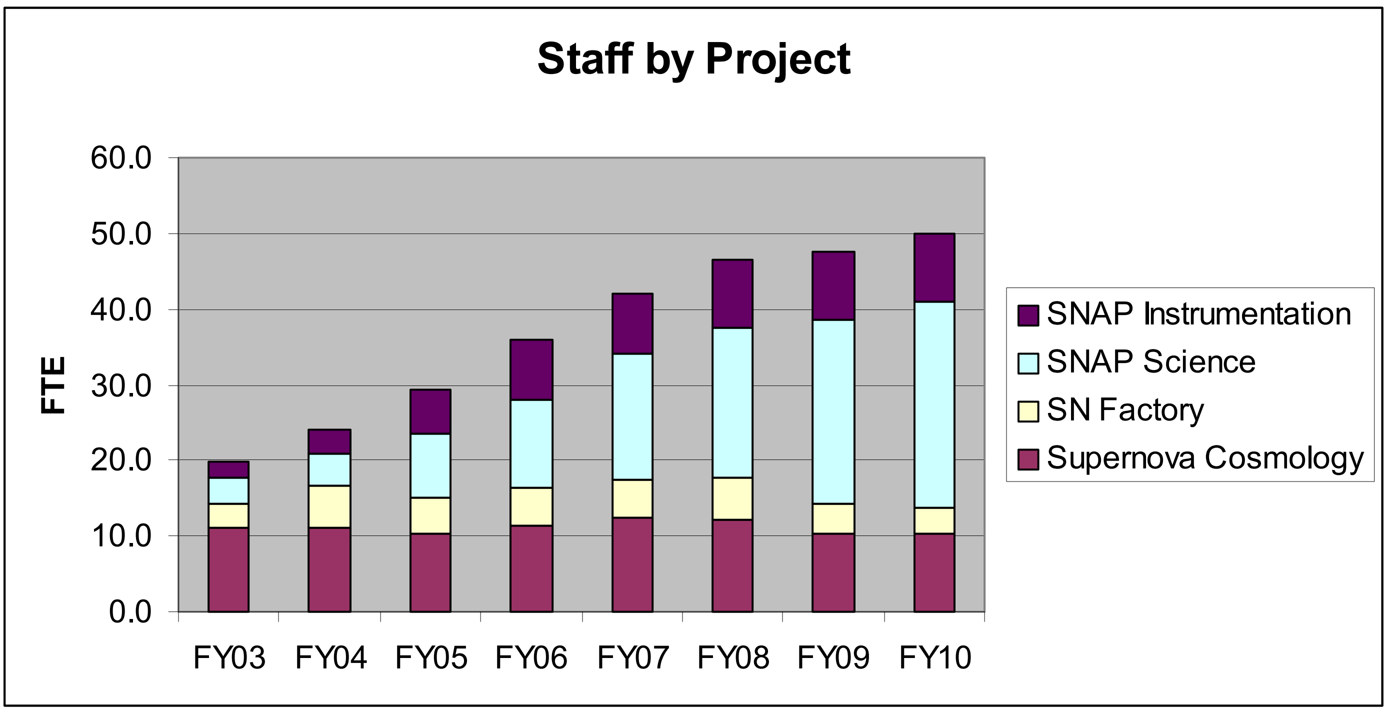
career/senior	3.6	4.1	4.5	4.5	4.5	4.5	4.8	5.8
career/staff	0.0	1.0	1.0	3.0	3.0	3.5	3.5	3.5
div_fellow	0.0	0.3	1.0	1.0	2.0	2.0	2.0	2.0
faculty	0.0	0.0	1.0	1.5	2.0	2.0	3.0	3.0
term/pd	2.0	1.5	4.0	5.5	8.0	10.8	12.0	12.0
gsra	0.0	0.0	1.0	2.0	3.0	4.0	6.0	8.0
technical	0.0	0.8	1.8	2.0	2.0	2.0	2.0	2.0
retiree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	5.6	7.6	14.3	19.5	24.5	28.8	33.3	36.3

TOTAL STAFF

Classification	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	4.6	5.1	5.5	6.0	6.0	6.0	6.0	7.0
career/staff	1.4	2.3	2.0	4.0	4.0	4.5	4.5	4.9
div_fellow	0.0	0.3	1.0	1.0	2.0	2.0	2.0	2.0
faculty	0.0	0.0	1.0	1.5	2.0	2.0	3.0	3.0
term/pd	7.8	7.8	12.0	13.5	17.0	20.0	18.0	17.0
gsra	4.0	6.0	4.0	6.0	7.0	8.0	10.0	12.0
technical	1.0	1.8	2.8	3.0	3.0	3.0	3.0	3.0
retiree	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Totals	19.8	24.1	29.3	36.0	42.0	46.5	47.5	49.9

SN Staff by Project	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Supernova Cosmology	11.2	11.2	10.4	11.4	12.4	12.1	10.4	10.4
SN Factory	3.0	5.4	4.6	5.1	5.1	5.6	3.9	3.3
SNAP Science	3.5	4.2	8.5	11.5	16.5	19.8	24.3	27.3
SNAP Instrumentation	2.1	3.4	5.8	8.0	8.0	9.0	9.0	9.0
Micro Systems Lab	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Totals	19.8	24.1	29.3	36.0	42.0	46.5	47.5	49.9


Total Staff
60
50
40
30
20
10
0
FTE
FY03
FY04
FY05
FY06
FY07
FY08
FY09
FY10
retiree
technical
gsra
term/pd
faculty
div_fellow
career/staff
career/senior


Staff by Project
60.0
50.0
40.0
30.0
20.0
10.0
0.0
FTE
FY03
FY04
FY05
FY06
FY07
FY08
FY09
FY10
SNAP Instrumentation
SNAP Science
SN Factory
Supernova Cosmology

Staff Development

The Physics Division is committed to the professional growth of staff on term and postdoctoral appointments. Each staff member will be assigned a supervisor who will also serve as mentor to ensure both a productive experience at Berkeley and the best possible opportunity for successful job placement at the end of his/her term appointment.

We expect that term appointments in astrophysics will last up to 5 years. New staff will likely spend the first 2-3 years working on hardware or in a service role for the experiment. Beginning near the end of the third year, he/she will begin to work on physics- related analysis or software. In year 4, he/she should begin to make presentations on analysis work and begin planning for his/her job search. Depending on the actual schedule for SNAP and future cosmology projects, the physics opportunities may be in other ongoing experiments at LBNL such as the SCP or the Supernova Factory.

Our plan includes 21 postdoc appointments by the time of the SNAP launch in 2010. We expect that approximately 16 of those will be working on physics and 5 will be in operational aspects of SNAP. Four postdocs and one division fellow will work on the CMB line of experiments.

Graduate Students

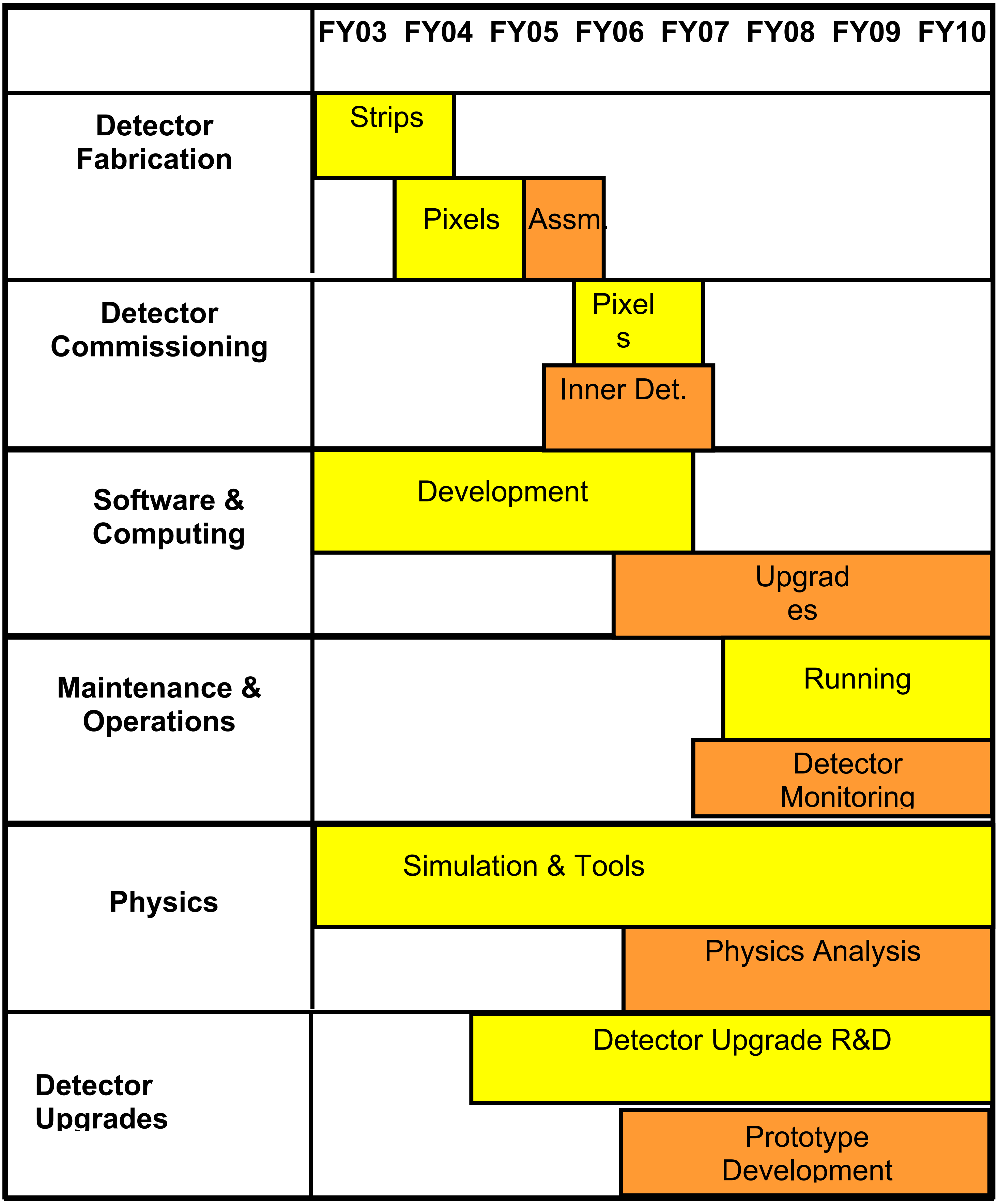
The training of graduate students continues to be a high priority for LBNL and will be a major focus for our astrophysics program. The faculty members on SNAP will begin to recruit students for astrophysics beginning in the fall of 2003. Depending on the SNAP schedule, those students who join before turn-on may do their these work on another experiment such as SCP. In the steady state, we expect 12 students to be part of the LBNL astrophysics program. Some of the senior staff will supervise students in addition to the faculty.

Funding Implications

The total costs of the planned staff have been estimated starting with current costs (fully loaded salary costs) inflated at 5.0% beyond FY03. In addition to labor, the costs include non-labor such as telephones, travel, small purchases and equipment. The total costs are shown in the following table.

SN Staff by Project	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
Supernova Cosmology	1.14	1.17	1.21	1.34	1.54	1.58	1.41	1.48
SN Factory	0.35	0.53	0.57	0.82	0.87	0.98	0.70	0.69
SNAP Science	0.58	0.71	1.06	1.40	2.07	2.52	3.23	3.85
SNAP Instrumentation	0.40	0.34	0.57	0.96	1.01	1.19	1.25	1.31
Totals	2.47	2.74	3.42	4.53	5.49	6.27	6.58	7.33

LBNL Project Schedule



Current Responsibilities

A. Tracking Detector Construction and Assembly

We have two major detector responsibilities: fabrication of 500 silicon strip detector modules and fabrication of a substantial fraction of the silicon pixel detector system. The strip fabrication is ongoing and will be complete by July 2004. The pixel fabrication at Berkeley Lab will end in April 2005 with completion of delivery of items to CERN. Once the pixels have been delivered to CERN, we will have responsibilities for the assembly of the pixel detector.

B. Pixel Detector Commissioning

We will have major responsibilities for the commissioning of the pixel detector. Knowledge of the detector's performance will be integrated into the simulation code as part of the analysis effort described below.

C. Software and Computing

Berkeley Lab currently has a major role in software and computing for ATLAS. We expect this role to continue and to include upgrades to the software after the detector is operational. The costs of computing staff are not included in this plan. Management of the computing effort is included as part of the physics program below.

D. Physics Generators

LBNL has responsibilities for physics generators and has a major role in the leadership of the physics groups for ATLAS and U.S. ATLAS. One postdoc, Georgios Stavropoulos, is hired through the Berkeley campus on U.S. ATLAS funds; he is not included in this plan.

E. Inner Detector and Global Commissioning

Berkeley will participate in the commissioning of the inner detector with particular responsibilities for the pixel system.

Future Roles

After commissioning of the detector, we expect to have major roles in physics analysis as well as fulfilling our obligations for operation and maintenance of the detector. We will also have a leading role in R&D for upgrades of the pixel detectors and tracking in general. It is expected that the challenging upgrade R&D will begin years before the first LHC turn-on.

Demographics

Figure 1 shows the age profile of the career staff and retirees now active in the proton-based research program at LBNL. Based on the experience of CDF and D0, we assume that there will be a vigorous physics program at the LHC extending from turn-on for at least 10 years. With upgrades the program will likely extend more than 20 years. Our staffing plan includes new Division Fellows, the "tenure-track" appointments at the Laboratory. It is expected that these will be promoted to senior staff and will help address the serious demographic problem of insufficient staff 40 years and younger. In addition, we expect that faculty appointments on the Berkeley campus will help here although these appointments are not under our direct control.

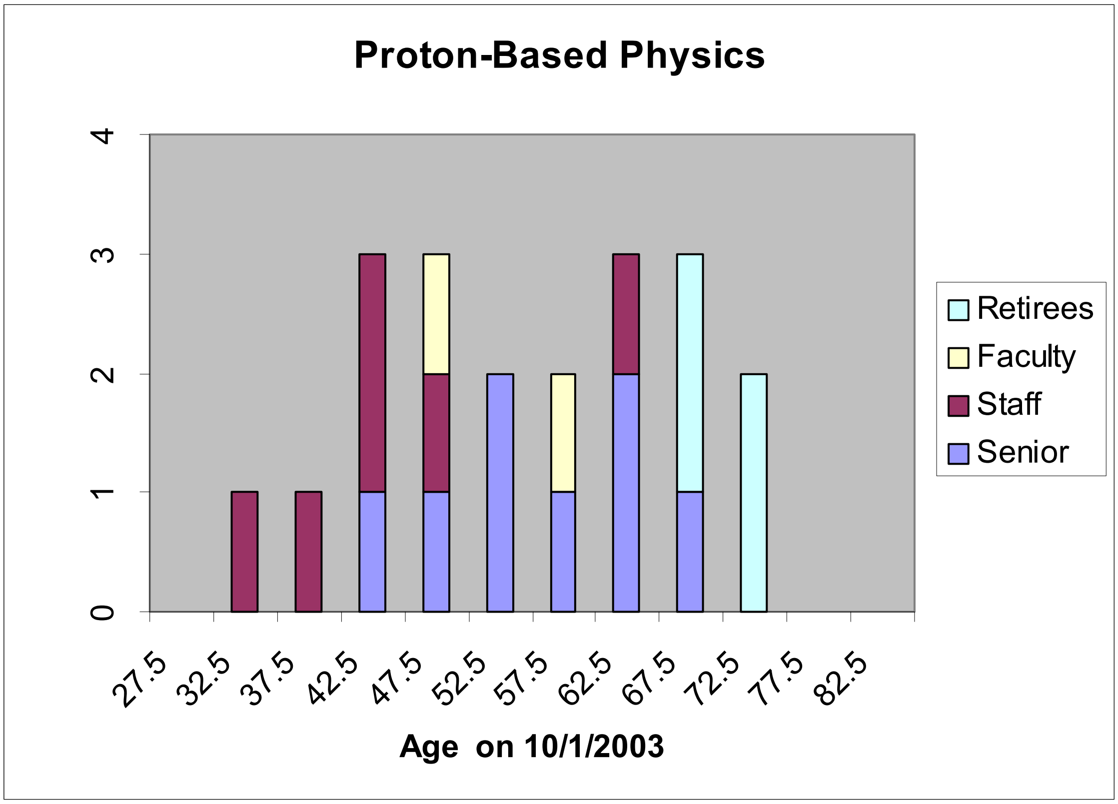


Figure 1

Meeting Commitments

We have estimated the effort required for the ongoing and planned tasks. The tables here include both current and planned staff. The staffing levels and staff mix are our best estimate of the effort needed to meet current commitments and to have a leadership role in physics analysis. The staff schedule is adjusted to meet ATLAS milestones shown in Figure 1. Faculty and GSRAs are normalized to 1 FTE; a faculty member or student who devotes 100% of his or her research time to ATLAS is counted as 1 FTE.

Strip Construction	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	1.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0
career/staff	1.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
div_fellow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
faculty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
term/pd	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0
gsra	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
technical	1.9	2.9	0.0	0.0	0.0	0.0	0.0	0.0
retiree	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS	5.1	6.5	0.0	0.0	0.0	0.0	0.0	0.0

Pixel Construction	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	1.8	1.9	2.2	1.2	0.0	0.0	0.0	0.0
career/staff	1.0	0.9	0.9	0.5	0.0	0.0	0.0	0.0
div_fellow	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
faculty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
term/pd	1.0	2.9	3.6	1.9	0.0	0.0	0.0	0.0
gsra	1.0	1.0	2.0	2.0	0.0	0.0	0.0	0.0
technical	5.2	3.6	3.4	0.0	0.0	0.0	0.0	0.0
retiree	0.2	0.2	0.6	0.0	0.0	0.0	0.0	0.0
TOTALS	10.2	10.5	12.8	5.6	0.0	0.0	0.0	0.0

Detector Comissioning	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	0.0	0.0	0.2	1.4	1.6	0.0	0.0	0.0
career/staff	0.0	0.3	1.0	0.7	0.3	0.0	0.0	0.0
div_fellow	0.0	0.0	0.3	0.3	0.5	0.0	0.0	0.0
faculty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
term/pd	0.0	0.0	0.0	1.6	1.3	0.0	0.0	0.0
gsra	0.0	0.0	1.0	1.0	1.0	0.0	0.0	0.0
technical	0.0	0.0	0.0	0.2	0.2	0.0	0.0	0.0
retiree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS	0.0	0.3	2.5	5.1	4.9	0.0	0.0	0.0

Operations	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	0.0	0.0	0.0	0.0	0.4	0.9	0.9	0.9
career/staff	0.0	0.0	0.0	0.5	1.0	1.0	1.0	1.0
div_fellow	0.0	0.0	0.0	0.0	0.0	0.5	0.5	0.5
faculty	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
term/pd	0.0	0.0	0.0	0.2	0.5	2.0	1.6	1.8
gsra	0.0	0.0	0.0	0.0	1.0	2.0	2.0	2.0
technical	0.0	0.0	0.0	0.0	0.0	0.2	0.2	0.2
retiree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS	0.0	0.0	0.0	0.7	2.9	6.6	6.2	6.4

Software Support	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	0.3	0.3	0.3	0.3	0.3	0.5	1.3	1.3
career/staff	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.5
div_fellow	0.0	0.0	0.3	0.3	0.3	0.3	0.2	0.2
faculty	0.0	0.0	0.7	0.7	0.8	0.8	0.8	0.8
term/pd	0.5	0.6	1.0	1.7	2.7	3.8	4.2	4.3
gsra	0.0	0.0	0.0	0.0	1.0	2.0	2.0	2.0
technical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
retiree	0.0	0.0	0.0	0.2	0.2	0.2	0.2	0.2
TOTALS	0.8	0.9	2.1	3.1	5.2	7.7	9.1	9.2

Physics Analysis	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	0.3	0.4	0.7	1.0	1.8	2.7	3.5	3.5
career/staff	0.0	0.0	0.0	0.0	0.0	0.3	0.5	0.5
div_fellow	0.0	0.0	0.5	0.5	1.0	1.0	1.0	1.0
faculty	0.2	0.3	1.0	1.0	1.9	1.9	1.9	1.9
term/pd	0.7	0.7	1.3	1.9	3.2	4.3	4.6	4.3
gsra	0.0	0.0	0.0	1.0	2.0	3.0	4.0	6.0
technical	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
retiree	1.0	1.0	1.0	1.2	1.2	1.2	1.2	1.2
TOTALS	2.2	2.3	4.4	6.5	11.1	14.3	16.6	18.3

Detector Upgrades	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	0.0	0.2	0.6	0.6	0.6	0.7	0.7	0.7
career/staff	0.0	0.1	0.1	0.3	0.7	1.0	1.0	1.0
div_fellow	0.0	0.0	0.0	0.0	0.3	0.3	0.4	0.4
faculty	0.0	0.0	0.0	0.0	0.3	0.3	0.3	0.3
term/pd	0.0	0.0	0.0	0.0	1.0	1.7	1.7	1.7
gsra	0.0	0.0	0.0	1.0	1.0	1.0	2.0	2.0
technical	0.0	0.5	0.5	1.0	1.0	1.0	1.0	1.0
retiree	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
TOTALS	0.0	0.8	1.2	2.9	4.9	6.0	7.1	7.1

<u>Total Staff</u>

The total staff needed to meet our current commitments and have a significant physics role are shown in the Table below and in Figures 2-4. These are the sums of the individual tables above. The Table indicates the minimum level needed to meet our current obligations and to develop a team capable of taking a leadership role in key physics analysis topics. Without the additional staff, we will not be able to ramp up our efforts on Monte Carlo and physics analysis tools and meet the detector assembly, commissioning and operation responsibilities LBNL is a world leader in silicon tracking detector technology, mostly recently the development of the new pixel technology. Again, without additional staff, we will not be able to continue this leadership role in the technically demanding ATLAS upgrades.

Total Staff	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	3.5	3.8	3.9	4.8	4.9	4.8	6.3	6.3
career/staff	2.0	2.0	2.0	2.0	2.0	2.5	3.0	3.0
div_fellow	0.0	0.0	1.0	1.0	2.0	2.0	2.0	2.0
faculty	0.2	0.3	1.6	1.7	2.9	2.9	3.0	3.0
term/pd	2.2	5.0	5.8	7.5	9.0	12.0	12.0	12.0
gsra	1.0	1.0	3.0	5.0	6.0	8.0	10.0	12.0
technical	7.0	6.9	3.9	1.1	1.1	1.1	1.1	1.1
retiree	2.3	2.3	1.6	1.4	1.4	1.4	1.4	1.4
TOTALS	18.2	21.2	22.9	24.5	29.3	34.8	38.9	40.9

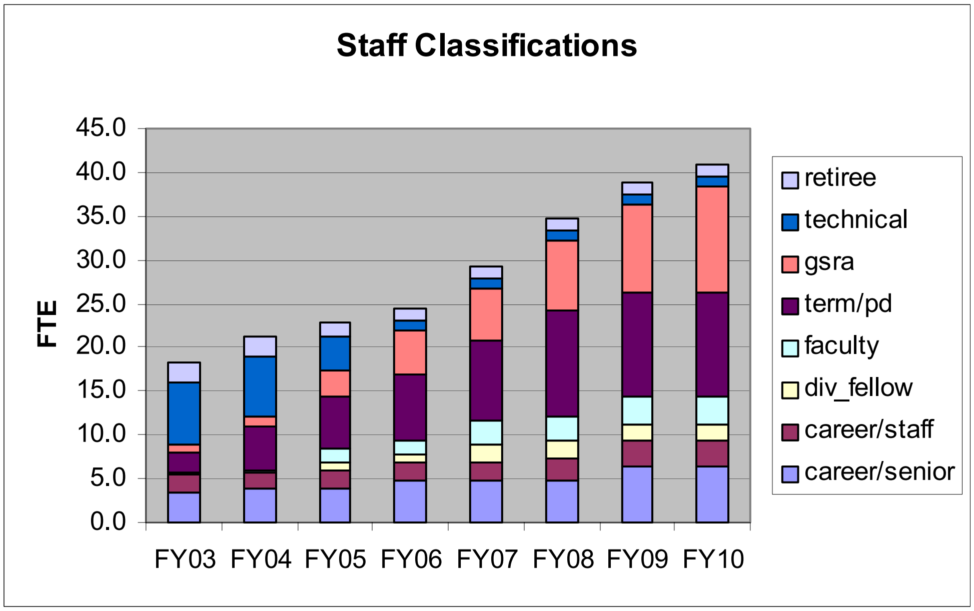


Figure 2

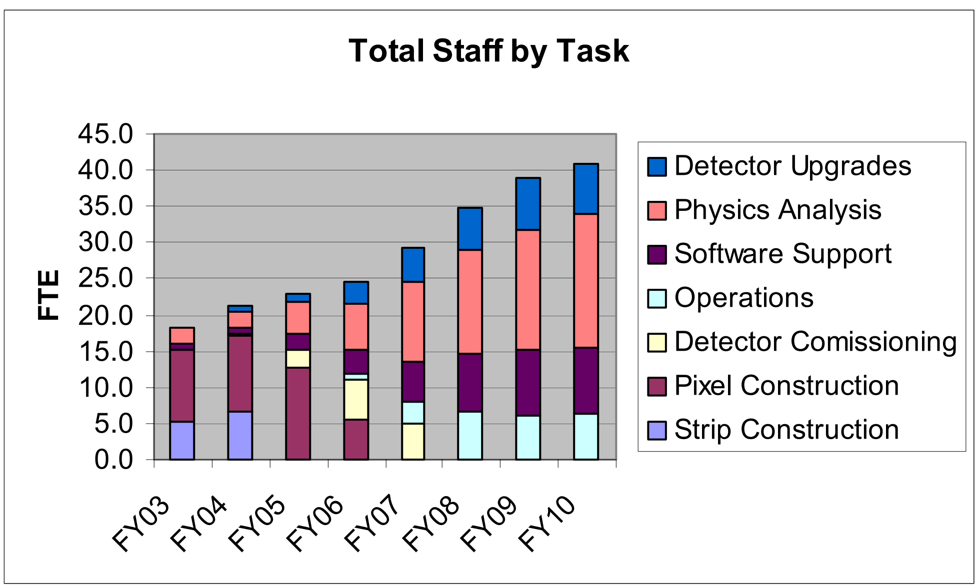


Figure 3

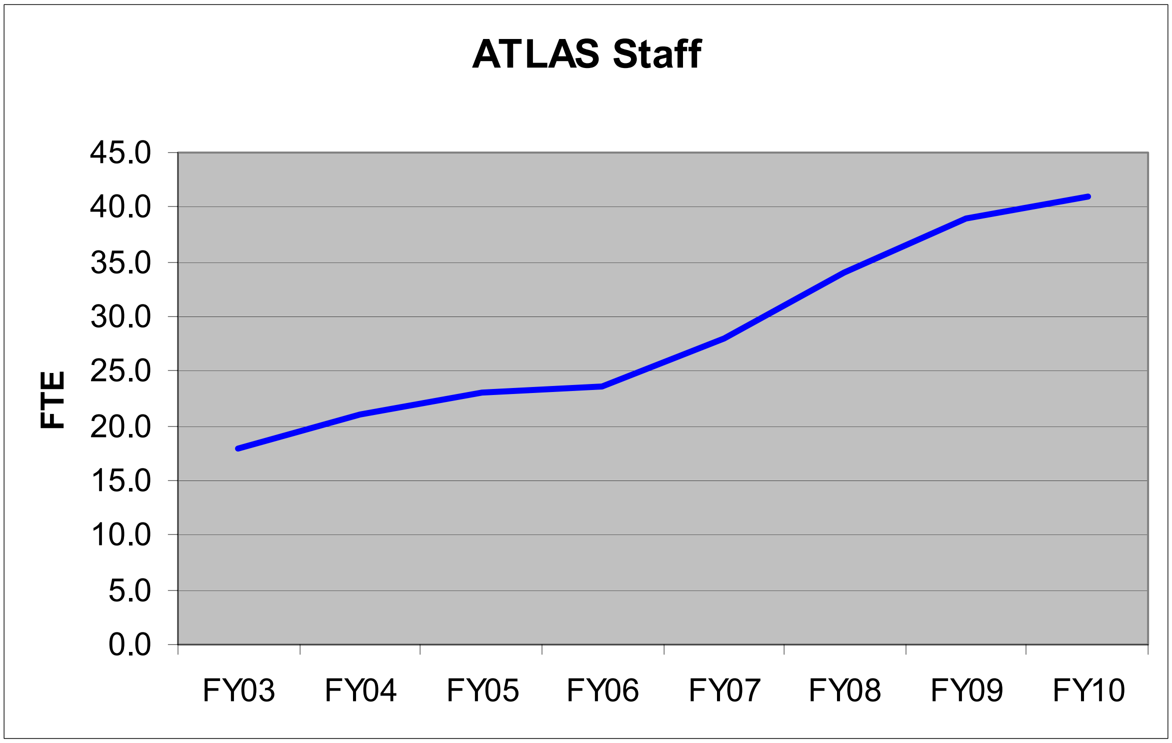


Figure 4

Staff Development

The ATLAS project is committed to the professional growth of staff on term and postdoctoral appointments. Each staff member will be assigned a supervisor who will also serve as mentor to ensure both a productive experience at Berkeley and the best possible opportunity for successful job placement at the end of his/her term appointment.

We expect that term appointments on ATLAS will last up to 5 years. New staff will likely spend the first 2-3 years working on hardware or in a service role for the experiment. Beginning near the end of the third year, he/she will begin to work on physics- related analysis or software. In year 4, he/she should begin to make presentations on analysis work and begin planning for his/her job search. Depending on the actual schedule for the LHC and ATLAS, the physics opportunities may be in other ongoing experiments at LBNL such as CDF.

Our steady-state plan includes 13 postdoc appointments. We expect that approximately 10 of those will be working on physics analysis and software development/support and 3 will be in operational aspects of the experiment and upgrades. The number of appointments will ramp up in the period between now and FY2009.

Graduate Students

The training of graduate students continues to be a high priority for LBNL and will be a major focus for ATLAS. The faculty members on ATLAS will begin to recruit students for ATLAS beginning in the fall of 2003. Depending on the LHC schedule, those students who join before turn-on may do their these work on another experiment such as CDF. In the steady state, we expect 12 students to be part of the LBNL ATLAS program. Some of the senior staff will supervise students in addition to the ATLAS faculty.

Funding Implications

The total costs of the planned staff have been estimated starting with current costs (fully loaded salary costs) inflated at 5.0% beyond FY03. The total costs are shown in the following table. The labor totals are determined by adding the total costs of each category of effort. Non-labor costs include travel, telephone, space and small purchases. The numbers are based on the typical ratio of labor to non-labor in our current program. Equipment estimates are based on expected purchases to refurbish equipment in the detector laboratory to support the detector upgrade research and development.

The numbers labeled “Proton Base” come from the FY03 Financial Plan and the FY04 President’s Budget. For years FY05 and beyond, we project with an increase of 2% per year. For the line “Proton Base from FY04” we use the FY04 President’s Budget and increase by 2%. The line “Modified Base (FY03)” takes FY03 as the basis for calculating the base for FY04-FY10 again with 2% increase per year. The lines “ATLAS Fraction” show the fraction of the Proton Base needed to Support the ATLAS program in either the FY04 base scenario or that based on FY03. The non-ATLAS Proton costs are based on current staff for CDF, D0 and E871. These non-ATLAS numbers decline each year with the planned end of current postdoc appointments and the end of E871. The numbers do include new ATLAS postdocs who move from ATLAS to CDF to do physics analysis in the last 2-3 years of their appointment.

The final two lines of the table show the funds remaining from the base in either scenario. Using the President’s Budget for FY04, we are already $370K short in FY04 due to the significant funding reduction that is planned. The deficit would grow rapidly by the time of the LHC turn-on.

ATLAS Cost Plan	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10
career/senior	746.1	849.8	918.4	1453.7	1555.1	1606.1	2212.6	2323.3
career/staff	306.2	321.5	337.5	427.5	448.9	607.8	781.4	820.5
div_fellow	0.0	0.0	199.2	252.3	529.8	556.3	584.1	613.3
faculty	6.4	8.4	51.5	67.4	122.9	129.0	140.6	147.7
term/pd	181.3	465.3	560.4	921.2	1173.1	1642.3	1724.4	1810.7
gsra	35.4	37.2	117.2	247.4	311.8	436.5	572.9	721.8
technical	966.9	919.7	591.8	257.2	270.1	283.6	297.8	312.7
retiree	199.3	209.2	92.9	73.0	76.6	80.5	84.5	88.7
Labor Totals	2441.5	2811.1	2868.9	3699.8	4488.3	5342.0	6398.3	6838.5
Recharge, Travel etc.	549.3	632.5	645.5	832.5	1009.9	1201.9	1439.6	1538.7
Equipment			100.0	50.0	200.0	100.0	200.0	100.0
Total Costs	2990.9	3443.6	3614.4	4582.3	5698.1	6643.9	8038.0	8477.2
In $M	2.99	3.44	3.61	4.58	5.70	6.64	8.04	8.48
Proton Base from FY04	6.70	5.30	5.41	5.51	5.62	5.74	5.85	5.97
Modified Base (FY03)	6.70	6.83	6.97	7.11	7.25	7.40	7.55	7.70
ATLAS Fraction	45%	65%	67%	83%	101%	116%	137%	142%
	45%	50%	52%	64%	79%	90%	107%	110%
Non-ATLAS Protons	2.76	2.58	1.95	1.39	0.96	0.61	0.50	0.52
Remainder	0.95	-0.72	-0.16	-0.46	-1.03	-1.51	-2.68	-3.03
Using FY03 as Base	0.95	0.81	1.41	1.14	0.60	0.15	-0.99	-1.30

Appendix III

Table 1 shows the Physics Division budget by major expenditure category. Note the large fraction of the budget tied up on labor. Table 2 shows the heads per group.

Table 1: Base Budget by major expenditure category

	FY03	FY04	FY05					
Protons	6,669	5,300	5,212					
Electrons	2,240	2,514	3,040					
Non-Accelerator	5,835	6,856	6,045	\	research	2,400	3,906	3,095
Theory/PDG	2,723	3,335	3,300		SNAP	3,435	2,950	2,950
Technology	2,480	5,274	5,273					
	19,947	23,279	22,870					

Table 2: FY03 Staff by Head Count

FY04	TOTAL	20.7	7.5	24.9	3.5	56.5	16.9	13.8	0.0	13.8	2.5	103.5
	CDF	1.2	0.5	4.0	0.2	5.9		0.0		3.6	0.0	9.5
	Neutrino Research	1.0		1.0	0.2	2.2					0.1	2.3
	D0	0.5			0.2	0.7				0.1		0.8
	BABAR	3.2	0.0	4.2	0.8	8.2		1.5		1.8	0.2	11.6
	ATLAS	6.5	0.0	5.0		11.4	2.0	3.0		1.11	1.6	19.1
	SNAP/SCP	3.9	2.8	5.0		11.6	14.9	5.4		3.4	0.1	35.4
	other astro physics			1.8	1.1	2.9					0.1	2.9
	LHC accelerator	0.5				0.5						0.5
	Accelerator R&D					0.0						0.0
	Theory/PDG	2.5	4.2	4.0	1.1	11.8		1.9		3.7	0.5	17.9
	MSL/Detector Development /Other	1.5				1.5		2.0			0.1	3.6
% change (FY03 to 04)		21.8%	-6.3%	-1.9%	-1.7%	4.9%	181.7%	55.1%		7.9%	-19.2%	22.3%

head count, December 2003												
	CDF	1		5	1			1		7		15
	Neutrino Research			1	1		1				2	5
	D0	1			1					1		3
	BABAR	4		5	3			3		5	3	23
	ATLAS	5	3	5			2	3		2	6	26
	SNAP/SCP	6	3	9			15	7		5	1	46
	other astro physics			1	3							4
	LHC accelerator											0
	Accelerator R&D											0
	Theory/PDG	3	3	3	9			3		9	4	34
	MSL/Detector Development/Other	3									1	4
		23	9	29	18	0	18	17	0	29	17	160