High Energy Physics Advisory Panel
August 27–28, 2012
Hilton Hotel, Rockville, Maryland

HEPAP members present:

Ursula Bassler
Edward Blucher
Karen Byrum
Andrew Cohen
Mirjam Cvetic
Peter Fisher
Bonnie Fleming, Monday only
Murdoch Gilchriese
Douglas Glenzinski
Donald Hartill
Klaus Honscheid
Andrew Lankford, Chair
Patricia McBride
Lia Merminga
Regina Rameika
Pierre Ramond
Ian Shipsey
Paul Steinhardt
Hitoshi Yamamoto

HEPAP members absent:

Daniel Akerib
Eric Colby
Robin Erbacher
John Hobbs
Leslie Rosenberg

Other Participants:

William Brinkman, Director, Office of Science, USDOE
Marjorie Corcoran, Physics and Astronomy Department, Rice University
Joseph Dehmer, Director, Division of Physics, National Science Foundation
Milind Diwan, Physics Department, Brookhaven National Laboratory
Fabiola Gianotti, Physics Department, European Organization for Nuclear Research
Marvin Goldberg, Program Director, Division of Physics, National Science Foundation
Young-Kee Kim, Deputy Director, Fermi National Accelerator Laboratory
John Kogut, HEPAP Executive Secretary and Deputy HEPAP Designated Federal Officer, Office of High Energy Physics, Office of Science, USDOE
Edward Kolb, Department of Astronomy and Astrophysics, University of Chicago
Richard Kron, Deputy Director, Dark Energy Survey, University of Chicago and Fermi National Accelerator Laboratory
Daniel Marlow, Department of Physics, Princeton University
Marsha Marsden, Oak Ridge Institute for Science and Education
Piermaria Oddone, Director, Fermi National Accelerator Laboratory
Frederick O'Hara, HEPAP Recording Secretary, Oak Ridge Institute for Science and Education
Stephen Parke, Head, Theoretical Physics Department, Fermi National Accelerator Laboratory
Michael Procario, Director, Facilities Division, Office of High Energy Physics, Office of Science, USDOE
Natalie Roe, Physics Division, Lawrence Berkeley National Laboratory

James Siegrist, Associate Director, Office of High Energy Physics, Office of Science, USDOE
Alan Stone, Research and Technology Division, Office of High Energy Physics, Office of Science, USDOE
James Strait, Project Manager, Long-Baseline Neutrino Experiment, Fermi National Accelerator Laboratory
Kathleen Turner, Program Manager, Office of High Energy Physics, Office of Science, USDOE
James Ulvestad, Division of Astronomical Sciences, National Science Foundation
Andreene Witt, Oak Ridge Institute for Science and Education

About 65 others were in attendance during the course of the two-day meeting.

Chairman **Andrew Lankford** called the meeting to order at 9:02 a.m. **John Kogut** was appointed as the Acting Designated Federal Officer. Lankford welcomed the members, agency representatives, and attendees.

He introduced **James Siegrist** to present the status of high-energy physics in the Department of Energy (DOE).

In accord with its strategic plan, the Office of High Energy Physics (HEP) is pushing ahead on the energy frontier, intensity frontier, and cosmic frontier through theory and experiment. On the energy frontier, it is exploring the TeV scale. The long wait is over. There is a Higgs-like boson at 125 GeV, which was discovered during Run 1 of the Large Hadron Collider (LHC), during which the LHC is ramping up to about 30% of its nominal luminosity and is delivering up to 15 fb^{-1} in 2012. HEP looks forward to continued LHC running through 2012, a repair of the splices in LHC magnets in 2013 and 2014, and phased resumption of running at about 14 TeV in 2014. The United States expects to participate in the LHC detector upgrades in 2017 and 2018 to cope with increased data rates and to participate in the LHC-velocity upgrade in or around 2022 that will increase luminosity to 2.2 times nominal and allow the collection of data to 3000 fb^{-1}.

HEP will work with the collaborations and CERN to understand the impact of the CERN LHC upgrades on detectors: the critical needs, the possible U.S. responsibilities, and the matching areas of U.S. technical expertise. The schedule needed to deliver upgraded detector components is being analyzed, and a cost estimate is being developed. The goal is to complete a mission-need statement in the next month for the near-term upgrades that keep the detectors running smoothly.

On the intensity frontier, the plan is to implement a comprehensive program to understand neutrino mixing to deliver much-improved limits of charged-lepton mixing and hidden-sector phenomena. The Daya Bay experiment has shown that the unmeasured neutrino mixing is large, which is valuable information for the Long-Baseline Neutrino Experiment (LBNE) restructuring.

New construction consists of the Neutrinos on the Main Injector (NuMI) upgrade and NuMI Off-Axis ν_e Appearance (NOvA); it is progressing well. The planned program of major projects, as listed by the Particle Physics Project Prioritization Panel (P5), includes the Muon-to-Electron Conversion Experiment (Mu2e) to explore charged-lepton mixing and the LBNE to make definitive measurements of neutrino properties.

Fermilab led an effort to redesign LBNE to achieve physics sooner and cheaper (as directed by DOE). The Steering Group was set up with broad community participation. They considered reusing the NuMI beam or building a new beam. They chose the latter option because it provided the best long-term program. This plan was presented to the DOE Office of Science (SC) management, and a decision to go for the CD-1 [critical decision] was made. The goal is to complete the CD-1 approval this year. DOE will seek international partners to strengthen the effort and will continue to engage the community in developing the science. It is expected that it will take some time to reach CD-2.

On the cosmic frontier, the near-term science goals are to discover (or rule out) the particle(s) that make up dark matter and to advance the understanding of dark energy. The 2011 Nobel Prize was awarded to Saul Perlmutter, Brian Schmidt, and Adam Riess for the measurement of the acceleration of the universe. The Baryon Oscillation Spectroscopic Survey (BOSS) has measured the characteristic length scale of the universe using baryon acoustic oscillations. The Dark Energy Survey has been commissioned, and the Large Synoptic Survey Telescope is moving ahead to make definitive ground-based dark-energy measurements using weak lensing.

On dark matter, the DOE funding opportunity announcement (FOA) for R&D on second-generation direct-detection experiments has closed, and the peer review panel meets Sept. 12–14. DOE is working closely with the National Science Foundation (NSF) on a coordinated program. Further selection of second-generation dark-matter (DM-G2) experiments after this phase is anticipated, leading to project(s) starting no earlier than FY14. The cosmic frontier group of the Division of Particles and Fields (DPF) of the American Physical Society (APS) will investigate all ways of searching for the particle nature of dark matter (direct, indirect, and accelerator production of dark matter) and try to see an appropriate balance in this program.

On dark energy, DOE is pro-actively developing a balanced, robust program in HEP with an independent plan that develops near-term and low-cost options that employ multiple methods (as agreed to by all the review panels). The first step was a community study to look at the science reach of current and planned projects and then to identify key missing components and opportunities for reaching full Stage-IV levels. HEP is working on a mid-sized dark-energy spectroscopic instrument for CD-0 approval. The next steps would be to determine the facilities needed to fill in the gaps in the program, to work with other agencies to investigate models for gaining access, and to identify project interdependencies.

On the Cerenkov Telescope Array (CTA), Astro2010 recommended a U.S. (DOE and NSF) contribution in the higher budget scenarios. DOE/HEP recently gave guidance to the U.S. CTA collaboration. In accord with the Astro2010 recommendations, DOE considers NSF to be the lead agency for the project. HEP has no funding identified for a contribution to CTA in the foreseeable future and therefore does not plan to fund R&D for it. HEP is not in the business of building telescopes; NSF is. Furthermore, DOE does not normally do civil construction in foreign countries. Therefore, this part of the U.S. plan would not be considered as an HEP contribution.

HEP will continue to use Particle Astrophysics Scientific Assessment Group (PASAG) criteria when considering contributions to projects and research efforts. It will consider community inputs in developing a staged, strong science program at the cosmic frontier. And it reserves the right to approve agreements on data policies and other aspects so that the maximum science from the investment portfolio can be assured.

Near-term priorities of the Office include developing a mission-need statement for U.S. participation in the LHC detector upgrades (which is nearing completion); making critical decisions on the LBNE (which decision is done; CD-1 based on a surface detector at Homestake Mine is being pursued); issuing a solicitation for R&D leading to next-generation dark-matter experiments and making selections (which has been done; the panel review is scheduled for this month); and developing strategic plans for the intensity-frontier and accelerator R&D programs (which is working its way through departmental concurrences).

The history of funding trends shows that, in the late 1990s, the fraction of the budget devoted to projects was about 20%. Progress in many fields required new investments to produce new capabilities. The projects started in 2006 are coming to completion now. New investments are needed to continue U.S. leadership in well-defined research areas. The possibilities for future funding growth are weak. One must make do with what one has. Research funding will decrease about 2% a year for the next several years. Program priorities and comparative reviews will be used to implement the cuts. Both the universities and the laboratories will be affected. Operations funding is approximately flat-flat. The Office is seeking approval of CD-0 for mid-scale dark matter; dark energy; ATLAS [A Toroidal LHC ApparatuS] and CMS [Compact Muon Solenoid] upgrades; and muon g-2 this fall. This agenda involves a lot of construction. The Office is also embarking on a community planning process, which is being organized by the APS DPF. Working groups are meeting now, and a major meeting is expected next summer.

Long-term priorities include taking the next steps on the energy frontier. Discussions are being held with CERN about follow-on to the LHC. This is a necessary precursor to planning for future upgrades. DOE and NSF agree on a framework of principles. The energy frontier science plan will require high-energy LHC running. The issue is, what are the real physics of the TeV scale? This question will likely take a few years to sort itself out. Consolidation at CERN and experience will be needed. The U.S. "Snowmass" process is an important element, along with European and Japanese HEP strategies. A world-wide linear collider organization is being established to replace International Linear Collider Global Design Effort (ILC-GDE). The ILC technical design review will be completed by the end of 2012 with major milestones having been met. Lyn Evans is to be the Director of the new effort. The new organization will balance the ILC-CLIC [Compact Linear Collider] as well as Physics and Detectors. The United States plans to be a part of that effort. Significant collaborations with other regions on future colliders will require a high-level approach among governments. Other governments also see a need for an international approach.

On the intensity frontier, the reconfigured LBNE is seen as the last major piece of the 2008 P5 Plan, and the Office is trying to implement that plan. It recognizes that there have been changes since 2008, like the significant recent discoveries regarding θ_{13} and the Higgs. The reconfigured LBNE has resulted in a reduced scope for the first phase, and some in the community are dissatisfied with this outcome. The Office agrees that a new Snowmass process is warranted to re-examine the science cases on the three frontiers; however, it does not regard this as a necessary precursor to proceeding with LBNE. There are additional reasons for moving ahead with LBNE in a timely fashion. The office is working with the DPF to help make the Snowmass process a success.

On the cosmic frontier, in dark matter, a path for direct-detection dark-matter experiments is clear. Comparative review of DM-G2 efforts in FY13 will lead to a future project start. A plan for other methods of detection is being developed in parallel with the DPF process. In dark energy, there is a science plan for developing a balanced, staged program from the Dark Energy Survey (DES) to the Large Synoptic Survey Telescope (LSST); other projects/facilities now need to be investigated. The Office is talking with other agencies to consider the needs and current assets. In other areas of the dark-energy effort, the Office will consider other program areas in parallel with the DPF process. In the overall program, the Office will be using the September operations review to get a handle on the portfolio and budget of operating experiments during the coming years. The shutting off of some experiments will be needed to make room to start new ones.

How has HEP done in the past? The P5 plan's diverse scientific portfolio was embraced by stakeholders. Clear priorities were set under realistic budgets, although we are at/below the lower limit of the plan by now. Generally, the plan had a very positive impact. There is a need to lay the foundation to update the P5 plan. More details and answers are needed. What other parts of the Office of Science (SC) have done needs to be looked at.

Looking to the future, the DPF planning process is frontier-oriented and is accepted in Washington. It is being done in partnership with DOE and NSF, and it is supported by all the national laboratories. More project ideas than one can afford must be developed as well as more-affordable ideas. The science case must be made first. Then one can worry about experiments. Continuous science *output* is needed; people are watching what is being done. Snowmass is *not* going to be either a shootout or a love fest. One must be critical about science goals and think outside of the box. Worthy science goals married to implausible assumptions will not advance the discussion. Technical and fiscal realism must prevail. Novel ideas for packaging programs should be considered. One needs to ask whether a critical mass of program elements, industrial participation, computing, materials, technologies, etc. will make a difference to how fast one can move on the science or in broader impacts. Compelling ideas have the potential to raise the budget and to expand the scope and impact if one has the patience and skill to develop them.

The Office's long-term goals are to ensure that the HEP program has a coherent program plan for each of the frontiers and for accelerator research, theory, etc., all integrated into one coherent, coordinated plan and prioritized. The plan does not need to be a consensus; rather, it can show the range of options available. The plan will show the current science reach and potential future science reach that can be achieved by experiments in the HEP program to make significant advances in the coming years. The plan should exhibit compelling science as well as technical and fiscal realism

A few comments on stewardship: The overall responsibility rests with the HEP Associate Director in close consultation with the SC Policy Committee. The stewardship program manager works with the technical evaluation group, stakeholder boards, and providers to develop a program. Through this process, a strategic plan has been prepared for Congress; it is awaiting DOE and Office of Management and Budget (OMB) approval before submission. Its key elements are to make the national-laboratory technical infrastructure more widely open to industry and to solicit community input for two new initiatives, a laser R&D program aimed at improved accelerator capabilities and a program to improve ion-beam-therapy delivery systems. Workshops are being organized on each of these topics. Both workshops will help develop ideas for accelerator stewardship R&D tasks in support of new initiatives. The information will be used in FY14 to develop open solicitations for R&D proposals aimed at innovative solutions. The proposal process will be transparent and inclusive and will include peer review.

In the Office, Eli Rosenberg is returning to Iowa State after four years as an Intergovernmental Personnel Act (IPA) staffer. Peter Kim started as a detailee on detector R&D. Abid Patwa is joining the staff as the federal program manager for the energy frontier. Jim Stone is joining as an IPA on the energy frontier and LHC operations. Tim Bolton is joining as an IPA on the intensity frontier. Fred Borcherding is now full-time on projects. Simona Rolli is moving to manage the LHC upgrades and theory. The HEP budget restructuring along the frontiers basis was approved between Congress and the Department for FY13.

In summary, the P5 Strategic Plan is still the roadmap. There is a balanced program across the three frontiers. A near-term implementation is understood and is moving forward on all frontiers. HEP has under-invested in new facilities in the recent past; correcting this will squeeze research for several years. Updates and revisions to the P5 plan for the longer-term starts with the Snowmass process. An effort is being made to recognize the new physics landscape. Future activities must be driven by compelling science but also must be realistic. The accelerator-stewardship initiative continues to move forward.

Blucher asked Siegrist how he expected the budget cuts to be distributed. Siegrist responded that the whole research program will suffer. The mix between universities and national laboratories will be maintained. Support will be balance between new and experienced researchers. The Office will work closely with the principal investigators (PIs) to ensure that things are not skewed.

Cohen asked if there were a rationale for keeping the mix the same. Siegrist replied that there was no high-level advice to do anything else.

Yamamoto noted that projections called for –25% funding over 5 years. Siegrist responded that it is hoped that the problem does not last that long.

McBride asked what the difficulties were with meetings and what was planned to deal with those difficulties. Siegrist answered that there is a government-wide order constraining how much can be spent on meetings, including schools/workshops and travel expenses to meetings. Brinkman added that there is an SC plan for all of next year. It hits the national laboratories hard. People on grants are exempt. There are two levels of conferences: over $500,000 for the Department and lower. Participation in the major ones needs OMB approval. The issue is administrative and affects all departments. Ramond noted that the American Institute of Physics has a Division of Particles and Fields meeting coming up in October but does not have approval for it, yet. They had tried to keep the budget under $100,000 so it did not need approval.

Byrum questioned whether the decrease in the research budget is being redirected to the facilities budget. The Siegrist said that that is correct.

Lankford asked how one goes about having "high-level" discussions. Siegrist said that a global project for a Higgs follow-on is beyond the Office's budget. One needs to know the best energy for the future machine. There will be a lot of discussion at the Snowmass meeting at the University of Minnesota.

Joseph Dehmer was asked to present status of the NSF's Division of Physics.

Ed Seidel will leave NSF to go to the Skolkovo Institute of Science and Technology in Moscow, Russia. Celeste Rolfing will be Acting Assistant Director for Mathematics and Physical Sciences (MPS). Gail Dodge has joined the staff as Director of Nuclear Physics.

The Division of Physics runs across numerous fields of physics. Funding for big-scale instrumentation and for support for university accelerator research is needed. There have been three briefings on the prospects for such research and accelerator technologies. This will now be moved on. The NSF currently supports $4 to 5 million of accelerator physics and is adding $10 million for seed money. This program will support the LHC upgrade and dark matter detectors. It will be a capitalization fund and base support for accelerator physics.

The community that the Division of Physics supports adds up to about 5000 people. The laboratory/university mix will be held the same.

In facilities, the Laser Interferometer Gravitational Wave Observatory (LIGO) is to complete its construction in FY15. LHC began operations in FY10. IceCube began operations in FY11 on time and on budget. The National Superconducting Cyclotron Laboratory (NSCL) is going great guns and will be succeeded by Facility for Rare Isotope Beams (FRIB). DOE is managing the Deep Underground Science and Engineering Laboratory (DUSEL) because NSF's Major Research Equipment and Facilities Construction (MREFC) project has been canceled. The Cornell Electron Storage Ring/CLEO (CESR/CLEO) was phased out in FY09. At the midscale, a large number of projects have been cofounded with DOE and other agencies. They are being continuously funded but are being squeezed.

There will be a continuing resolution. MPS is being supported at an increase of 2.8%. The majority of funding goes to unsolicited, reviewed proposals in accord with NSF priorities.

NSF put out a dear-colleague letter about redirecting its future-generation facility investments in underground research to the site-independent nearer-term development of individual underground experiments and experimental techniques. The review of the responses to that letter is under way. NSF received 24 proposals requesting a total of $78 million. They were subjected to ad hoc reviews and two panels. Currently, nine awards totaling $13.6 million over 2 years are being processed. The selected proposals include dark matter, nuclear astrophysics, detector R&D, electronics and triggering, and common tools for underground physics. For dark matter, support of R&D allows preparation for the G2 down-select.

The DOE FOA for the second generation of dark-matter experiments (G2) has been published; the proposal review will be in September. It calls for 1 year of R&D support followed by a down-select for construction. The Division can co-fund more than one. G2 construction proposals are to be submitted to the agencies in 2013. NSF and DOE will discuss and, as warranted, coordinate the funding for G2 construction awards. Award decisions will be made independently by each agency.

During FY12, the Division operated under a flat strategy. The LHC, IceCube, and NSCL were flat, and LIGO was up $100,000 in FY12, a 3% decrease. It will be another 3% decrease next year. Investments will be made in Biological, Mathematical, and Physical Sciences (BioMaPS), Cyberinfrastructure Framework for 21st Century Science and Engineering (CIF21), and Science Across Virtual Institutes (SAVI). Fourth-round-solicitation (S4) funding was redirected to underground science. Midscale physics instrumentation is a priority for future budget cycles (FY14), and some funds are being applied to seed the activity. Also being discussed is accelerator physics research at universities for possible investment in FY14. These actions express the Accelerator Physics and Physics Instrumentation (APPI) concept and should benefit work at the three frontiers of particle.

Kim asked what process will be used to make decisions about unsolicited proposals. Dehmer said that it will be competed openly across the country and be announced in a dear-colleague letter. It is hoped that sufficient funding will be available. The program will be there.

Steinhardt asked how physics has suffered more than other fields. Dehmer replied that, over time, physics has done well. It peaked a couple of years ago. Greater priority has been given to (for example) engineering for sustainability. Physics has done well in cyber and other multidisciplinary programs. Physics is not well aligned with the priorities of the past few years. DOE and the National Institute of Standards and Technology (NIST) are doing well. Today, flat is good. Science R&D and education are widely seen as important for the future of the country. The scientific opportunities are fantastic. Particle physics is in its first swoon. Others have come out of swoons like gangbusters.

Glenzinski pointed out that Higgs and θ_{13} were off-shored and asked how that affects the nation's standing. Siegrist said that they were viewed as a victory. Dehmer replied that the U.S.

effort is appreciated and understood. θ_{13} has not gotten the same amount of press but *is* a big discovery. The center of gravity *has* moved offshore.

A break was declared at 10:15 a.m. The meeting was called back into session at 10:30 a.m.

Fabiola Gianotti was asked to review the status of the Standard Model Higgs searches in ATLAS.

July 4, 2012, was a historic day: the announcement of the discovery of a Higgs-like particle.

The first studies for a high-energy proton-proton collider in the Large Electron-Positron (LEP) collider were conducted in 1984. The LHC was approved by the CERN Council in 1994. Construction started in 1996, and the first collisions occurred at 7 TeV in 2010. The LHC required innovative technologies, concepts, a lot of ingenuity, and huge efforts from the worldwide community. Higgs searches have been one of the primary LHC goals, among the most challenging processes to be investigated. There is no unique answer to these challenges, so ATLAS and CMS took different paths. CMS has excellent muon momentum resolution, but the B = 4T solenoid constrains the hadron calorimeter (HCAL) radius. ATLAS has an excellent HCAL for jets and E_T^{miss}.

The ATLAS Higgs-discovery paper was submitted for publication in *Physics Letters B* along with that from CMS. Those papers presented results from several channels totaling about 10.7 fb^{-1}. These results were made possible by the superb performance of the LHC (delivering a maximum luminosity of 7.7×10^{33} cm^{-2} s^{-1}); excellent ATLAS detector performance; experience gained with the 2011 data; the huge amount of work to understand and mitigate the impact of pileup; detailed studies of Standard Model processes and control of the backgrounds; and the improvement in the sensitivity of the analyses of the Higgs channels. All in all, a huge amount of painstaking foundation work.

As of this meeting, ATLAS' total luminosity delivered was 10.61 fb^{-1}, and the total luminosity recorded was 11.81 fb^{-1}. The fraction of non-operational detector channels ranges from a few per million to 4%. The data-taking efficiency was about 93.7%. The good-quality data fraction that was used for analysis was about 93%. About 90% of the delivered luminosity was used to produce the results reported.

The big challenge in 2012 is pileup; that is to say, the simultaneous production of data. The team is now working beyond the design plan. Pileup-robust, fast-trigger, and off-line algorithms were developed. Reconstruction and identification of physics objects were optimized to be independent of pileup. In-time and out-of-time pileup was precisely modeled in simulation. A flexible computing model was developed to accommodate 2-times-higher trigger rates and event sizes. Efficiency is now high, and the number of reconstructed primary vertices is about 60% the number of interactions per crossings. Results of 2012 operation show that the trigger is coping very well with harsh conditions while meeting the physics requirements because of the optimization of selections and the pileup-robust algorithms developed.

The LHC performance and high pileup conditions also stressed computing. It would have been impossible to release physics results so quickly without the outstanding performance of the Grid at all levels. More than 1500 distinct ATLAS users do analysis on the Grid.

The electroweak and top cross-section measurements are important on their own and as a foundation for Higgs searches. Most of these processes are reducible or irreducible backgrounds to the Higgs. Reconstruction and measurement of challenging processes are good training for some complex Higgs final states. There is very good agreement with the Standard Model.

The Higgs cross-section increases by about 1.3 for the Higgs mass of about 125 GEV. There is a similar increase for several irreducible backgrounds; reducible backgrounds increase more; reduction of these backgrounds is expected to increase the Higgs sensitivity by 10 to 15%. The most sensitive channels for the mass of the Higgs are H → ZZ^* → 4|, H → w, and H → WW^* → |v|v.

Before July 4, a large area had been excluded. The results on the full 7-TeV data set had a combination of 12 channels. A 2.9 σ access at 126 GeV was observed. To increase sensitivity, events were divided into 10 categories based on photon identification, and a two-jet category was introduced. Crucial experimental aspects were excellent γγ mass resolution and powerful γ identification that increased the signal-to-background ratio.

Mass resolution was a huge component. It is not affected by pileup. The mass resolution of the inclusive sample was 1.6 GEV. The fraction of events in ±2 σ was about 90%.

The γ/jet separation was aided by separation into compartments. The choice of fine lateral segmentation of the first compartment the ATLAS electromagnetic (EM) calorimeter was determined. It was found that γγ comprised about 75 to 80% of the signal.

After selections, the total was 59,059 events. The spectrum was fitted with Crystal Ball plus Gaussian for signal plus background, and the model was optimized with Monte Carlo to minimize biases.

The new data allowed exclusion of 112 to 122.5 GeV and 132 to 143 GeV. The best-fit value at 126.5 GeV was significant at 4.5 σ.

The H → ZZ^* → 4| channel showed a signal of 2.5 fb at 126 GEV. This is a tiny rate, but the mass can be fully reconstructed; it is pure; four leptons are involved; and the main backgrounds can be suppressed with isolation and impact parameter cuts on two of the softest leptons. The crucial experimental aspects are the high lepton acceptance, reconstruction, and identification efficiency; good lepton energy/momentum resolution; and good control of reducible backgrounds. Kinematic cuts and increased $e^{\pm}$ reconstruction and identification efficiency led to a gain of 20 to 30% in sensitivity compared to previous analyses.

Muons were reconstructed with an efficiency of about 97% for a total acceptance × efficiency for the H → 4μ channel of about 40%. The resulting spectrum validated the Monte Carlo simulation.

After all selections, the mass spectrum for the H → 4| channel was in good agreement with expectations.

With the H → ZZ^* → 4| channel, exclusion at the 95% confidence level (CL) was expanded to include from 131 to 162 GeV and from 172 to 460 GeV.

Over the full mass range, there is only one sharp deviation at 126 GEV at 6 σ. This result is a little high in comparison to the Standard Model, but it is within 1 σ. The best-fit value at 126 GeV was $\mu = 1.4 \pm 0.3$. This is in good agreement with the expectation for a Standard Model Higgs within the present statistical uncertainty. The estimated mass is 126 ± 0.4 (stat) ± 0.4 (syst) GeV. Fitting γγ data in various categories to constrain different production modes gives results that are consistent with Standard Model expectations to about 1.5 σ. Additional data gained since July 4 pushes that value to 6 σ. We are sure that all backgrounds were carefully looked at.

More data will be essential to establish the observation in more channels, measure the nature and properties of the new particle, determine why it is so light, and determine whether this "Higgs" does the job of regularizing the $V_L V_L$ scattering at high mass. We are currently limited by our knowledge of the mass of *W*. The present plan is to install a new pixel B-layer; employ consolidation; install new muon small wheels and Fast TracK trigger (FTK) and Level-1 trigger; and installing a new tracker to achieve about 3000 fb^{-1}.

In summary, the superb performance and accomplishments of the LHC accelerator, the experiments, and the computing Grid were accomplished in less than 3 years of operation. ATLAS recorded about 5.2 fb^{-1} of proto-proton data at 7 TeV in 2011 and about 12 fb^{-1} at 8 TeV in 2012. The whole experiment works very well, as do all its components, from smooth and efficient operation of the detector, trigger, and computing to the fast delivery of physics results. ATLAS has produced a huge physics output covered in 185 papers published or submitted. In July 2012, ATLAS reported the discovery of a new Higgs-like boson with a significance of about 6 σ, a signal strength of 1.4 ± 0.3 of the Standard Model Higgs expectation, and a mass of 126 ± 0.4 (stat) ± 0.4 (syst) GeV. If it is a Standard Model Higgs boson, it is very kind of nature to have chosen this accessible mass. The era of precise Higgs measurements has started.

Daniel Marlow was asked to review the CMS results, status, and prospects.

The CMS collaboration was a large undertaking. The CMS emphasizes the measurement of particles inside a 3.8-T superconducting solenoid. It also has the Pixels, Tracker, electromagnetic calorimeter (ECAL), HCAL, and Muons detectors. CMS gave similar data to those of ATLAS. The amount of data taken has more than doubled since the July 4 announcement. It has a good operational efficiency. Thus far in 2012, CMS has recorded 93% of the luminosity delivered by the LHC. Of that, 85% is certified as "golden." The fraction of working channels is greater than 98%.

Studies at the LHC build on a beautiful series of previous electroweak symmetry-breaking (EWSB) measurements at the Tevatron, LEP, and Stanford Linear Accelerator Center (SLAC). These measurements provide a lot of guidance of where and how to look. In early 2012, there was an exquisitely precise measurement of the mass of W as 80.390 ± 0.016 GeV that was driven mainly by the Tevatron.

Higgs production could happen by three or four processes: at a cross-section of about 20 pb, dominated by gluon-gluon fusion, at 8-TeV with cross-sections 25 to 30% higher, or with all production modes used.

Five modes of Higgs decay were studied: $\gamma\gamma$, ZZ, WW, $\tau^+\tau^-$, and $b\bar{b}$. The branching ratio plot, however, tells only part of the story (i.e., it is quality, not quantity).

Most of the heavy lifting is done by $\gamma\gamma$ and ZZ, because those modes exploit the excellent mass resolution (about 1%) of CMS.

In event reconstruction, CMS has used particle flow. Stable particles in the event are reconstructed by a sophisticated algorithm that combines information from all sub-detectors. This technique exploits the fine-grained nature of CMS. The particles thus reconstructed are then combined into jets or other objects.

Photons are of interest and are measured with EM calorimetry. Calibration is a key issue for Higgs to gamma-gamma ($H \rightarrow \gamma\gamma$).

The energy/momentum ratio is not 1; light-monitoring corrections are needed to greatly improve the temporal stability.

Plots of the production of electrons and muons show that the efficiency is stable even in a high-pileup environment. In addition, CMS and LHC are good enough to allow for the search (and discovery) of rare Z decays.

The H → $\gamma\gamma$ strategy uses multivariate analysis (MVA) for photon identification and event classification that divides events into non-overlapping samples of varying signal-to-background ratio (S/B) on the basis of the properties of the reconstructed photons and the presence of di-jets from the vector boson fusion (VBF) process. This result is cross-checked with cut-based analysis. The trackers are used for primary vertex selection, which is needed for $M\gamma\gamma$ calculation. It is based on consistency with di-photon kinematics. It achieved the correct assignment 83% of the time.

Event selection uses a boosted decision tree to classify events based on photon quality (shape and isolation), expected mass resolution, probability of correct vertex assignment, and kinematic characteristics of photons (excluding the invariant mass). Events are divided into five categories, dropping those in the lowest category. An additional category is created for di-jet tagged events, and then a table is drawn up.

In general, the number of events is smaller for the rarer events, but the background is also smaller. The local p values show a peak at 125 GeV at 4.1 σ. The "old-fashioned" spectrum has a peak at 125 GeV, also.

In the H → ZZ* selection, the 4e, 4μ, and 2e2μ cases are handled separately. The direct ZZ-production background is irreducible. The Z + bb and Z + $\tau\tau$ backgrounds are real leptons. In the Z + jets and WZ + jets, the jet can be misidentified as a lepton. The dilepton mass is quite loose: the closest match is $40 < M_{||} < 120$ GeV. The other pair is $12 < M_{||} < 120$ GeV.

Matrix element likelihood analysis (MELA) uses kinematic inputs for signal-to-background discrimination. In general, the distributions of these quantities will look very different, lending discriminating power to the result.

The 4| mass spectrum gives an excess of 3.2σ at 125.6 GeV vs. the 3.8σ expected.

For the H → ZZ signal and background, one would expect to see 7.54 ± 0.78 for the signal and 3.8 ± 0.5 for all backgrounds. What was observed in the signal region was 9. The data for the dilepton mass for the WW mode are consistent with a Higgs but not conclusive. The same is true for the $\tau\tau$ mode. The $\tau\tau$ and *bb* modes did not produce evidence of penguins. However, the combined results for all decay modes give dataset and mode results that are very similar; both produce 5σ significance at the same mass range. The signal strengths for some modes are a bit high and for others are a bit low. Taken together, one gets the feeling that this scheme is working.

The properties of the new particle are $M = 125.3 \pm 0.4 \pm 0.5$ GeV. The best-fit signal strength to combined data is 0.87. In spin-parity, spin one is ruled out by double-gamma decay. If one assumes the spin is zero, one can use H → ZZ to distinguish between parity states.

With MELA, which uses kinematic inputs to form likelihood, the separation is at 1.6σ with the current sample; 3.1σ is expected with a 5+30 fb^{-1} sample.

For the future, a general need for an upgrade has been understood for some time now, given the excellent performance of the LHC. The recent discovery has brought a new focus to plans for the near- and long-term future. The studies are rapidly advancing, and one can expect significant improvements over the snapshot to be presented. There are, of course, other topics of interest that can be studied at the energy frontier.

Benchmark data sets would be the LHC with a luminosity of 300 fb^{-1}, the high-luminosity LHC with 3000, and the high-energy LHC with 300. In terms of parton luminosities, the higher energy (33 TeV) is worth about a factor of 2 for the creation of 100-GeV objects and a factor of 10 for objects of mass 1 TeV One assumption is that the trigger and reconstruction performance are similar to what CMS currently has at 8 TeV. This is superficially conservative, but will, in fact, require significant detector upgrades to offset effects of radiation damage and higher pileup.

The team has started to measure the signal-strength precision. It is also considering the scenario where the Standard Model is extended through an effective-theory approach, wherein modified *couplings to vector bosons* and *fermions* are obtained. These couplings are referred to as CV and CF, respectively, and are nominally equal to 1 in the Standard Model (although uncertainties exist). One can go a step further and introduce additional couplings. One would like to see the Higgs go to the second generation ($H \rightarrow \mu\mu$). Enhancement relative to the Standard Model is needed to make a persuasive measurement. The most straightforward approach uses gluon-gluon to the Higgs, but this runs out of gas for masses greater than 140 GeV. For lower masses, one needs a high background and low signal ratio and likely needs the 33-TeV machine.

In summary, a new boson with Higgs-like properties has been discovered at 125 GeV, a major accomplishment for the field. Much remains to be done to confirm (or refute) the Standard Model Higgs interpretation. An upgraded LHC will play a key role in elucidating the nature of this new particle.

Ramond asked Gianotti to comment on the ability to distinguish between spin 1 and spin 0. Gianotti replied that ATLAS is limited only to 1 to 3 σ.

Fisher asked if one needed 33 TeV to turn on the unitarity of bosons pairs. Gianotti replied, no, but it will be difficult to distinguish the signal. A beam upgrade is needed to distinguish several channels from the background. Even then, it will be difficult if the Higgs suppresses the divergence. Subtracting the divergence will be required. Marlow said that the same is true with CMS.

Kim asked how to improve the theoretical uncertainty in Higgs couplings. Marlow suggested that looking at ratios would be more effective.

A break for lunch was declared at 12:19 p.m.

Afternoon Session

The meeting was called back into session at 1:56 p.m.

Stephen Parke was asked to give an overview of current neutrino physics.

Researchers at Daya Bay have discovered that $\sin^2 \theta_{13}$ is nonzero. The results really pinned this down; the experiments found something that was 10 times larger than what they were designed to detect. But there are still unanswered questions in the neutrino Standard Model, where there are three active flavors and they mix. What is the nature of the neutrino? Are they two-component Majorana fermions or four-component Dirac fermions? Is there CP violation in the neutrino sector in the mixing matrix? What is the order of the masses of the neutrinos? Is the ν_3 mass eigenstate more ν_μ or more ν_τ? If the neutrino is a Majorana particle, there should be two additional phases. What is the mass of the lightest one? Beyond the Standard Model, what is the mass of the sterile neutrinos, light or superheavy? What is the size of nonstandard interactions in neutrino physics? And where are the true surprises?

In the neutrino Standard Model, oscillations and flavor conversions are a fact. Two different L/E scales have been observed: atmospheric L/E (which has a velocity of 500 km/GeV and is ν_e

poor) and solar L/E (which has a velocity of 15,000 km/GeV and is ν_e rich). The simplest way to explain this is that neutrinos have mass and they mix. The flavor eigenstates and mass eigenstates can be ordered by ν_e content. The top two mass eigenstates were separated at SNO in 2003–2004. The ordering of the third mass eigenstate is still unknown. In the mixing angles, ν_1 is known to be about 1/6 μ, 1/6 τ, and 2/3 ν_e; ν_2 is known to be about 1/3, 1/3, and 1/3; and ν_3 has just been measured as about 0.02 ν_e with the rest being μ and τ neutrinos. The sum of the masses of these neutrinos has to be greater than the atmospheric mass splitting of 50 MeV and is shown by cosmology to be about 500 meV. The solar δm^2 is 30 times smaller than the atmospheric δm^2. There is a phase that varies from 0 to 2π but is unknown. It affects the ν_e contribution to ν_1 and ν_2.

The big questions are: What is the neutrino mass hierarchy? Is ν_3 mostly muon neutrino or tau neutrino? And is CP violated in the neutrino sector?

Some of the results from Daya Bay are very strange on $\sin^2 \theta_{23}$, where muon neutrinos or tau neutrinos dominate ν_3 and push one into a strange portion of the parameter space for δ. Some of the fits are not global fits for the $\sin^2 \theta_{23}$ data.

So, what has been measured? Actually, not much of the matrix has been measured. Three elements are known quite well: μ_{e2}, μ_{e3}, and $\mu_{\mu 3}$. The mass-squared splitting of solar neutrinos has been measured with a sign by KamLAND. The mass-squared splitting of atmospheric neutrinos has been measured as an absolute value with no sign by MINOS. Measurements of mass eigenstates have been made by Charge-Current-SNO, Neutral-Current-SNO, KamLAND, K2K, MINOS, Double Chooz, Daya Bay, and RENO.

In the quark sector, there is the unitarity triangle. A lot of experiments have been done to determine that the equivalent matrix in the quark sector is unitary. The same thing has to be done for the lepton sector. The triangle is not a squashed triangle because $\sin^2 \theta_{13}$ is now known. It is not inconceivable that future experiments will allow seeing this triangle. Leptons and quarks have very different mixing matrices. Different models predict different values for $\sin^2 \theta_{13}$. Seven models satisfy the results of Daya Bay and RENO. What do they say about the other mixing angles? The matrices exhibit relationships under certain assumptions for θ_{13} and θ_{23}. There are models that predict patterns of masses and mixings, and it would be good to validate these models with experimental data.

Where can this information come from? Nature has given us a wonderful set of processes: basically, ν_μ going to ν_e and its relatives, the charge conjugation, the T conjugation, and BCP conjugation. The first row can be explored with superbeam experiments. θ_{13} is large, so the beam contamination of the electron neutrinos is about 1% and not very important. The oscillation probability of the muon neutrino to electron neutrino in the three-flavor case is simple; one just needs to add the amplitude for a two-flavor oscillation for the 31 sector and a two-flavor oscillation for the 21 sector, and there is a phase between them that causes CP violation. When these factors are multiplied out, one gets a path that is CP conserving and an interference term. For large θ_{13}, the atmospheric neutrino has a large amplitude and high frequency; the solar neutrino grows very slowly to 15,000 km/GeV and then drops down; an interference term flips between neutrinos and antineutrinos. Because one cannot do experiments in vacuo, there is a matter effect that changes the amplitudes and produces a complicated structure that allows many things to be measured.

How can θ_{23} the measured accurately? MINOS results have indicated that θ_{23} is not maximal; their $\sin^2 2\theta$ is about 0.96. In long-baseline experiments, if the neutrino probability is added to the antineutrino probability, one gets something that depends only on $\sin^2 \theta_{13}$ and $\sin^2 \theta_{23}$. When the probabilities are added in, there are two regions where these two should be able to be separated.

What about the mass hierarchy? Probability plots can be constructed with the Daya Bay value for $\sin^2 \theta_{13}$ and 0.97 for $\sin^2 \theta_{23}$, allowing two values for $\sin^2 \theta_{23}$, one for the normal hierarchy and one for the inverted hierarchy. One should be able to determine the hierarchy with NOvA. There are two plots of the significance of the mass-ordering resolution for NOvA; one is the right one, and the other is irrelevant.

What about LBNE? The full LBNE is 1300 km; with its wideband beam, using the NUMI beam at 700 kW or the Project X beam at 2.3 MW, it would separate the two hierarchies and increase the probability of determining the mass hierarchy.

In reactor experiments, flux times cross-section at 60 km vs. L/E is plotted. Low energy is at high L/E, and high energy is at low L/E with a perfect resolution of the detector. Other resolutions show slight differences between the normal and inverted hierarchies, but only one is correct. McKeown and Vogel have noted that, for such a measurement to succeed, one must understand the nonlinearity of the detector energy scale at the level of a few tenths of a percent (i.e., the linear energy resolution of the reactor has to be a few tenths of 1%). The best that KamLAND has achieved is 1.9%. So an improvement of an order of magnitude in the linearity of the energy resolution scale must be achieved. This is hard.

What about CP violation? In vacuo, at the first oscillation maximum, the neutrino/antineutrino asymmetry for ν_μ going to ν_e is 0.3 sin δ, so it can be as large as 30%. This means that the probability of $P(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$ is ½ to 2 times $P(\nu_\mu \rightarrow \nu_e)$. That is an enormous asymmetry. Because θ_{13} is large, there will be lots of events.

What can NOvA say about CP violation? NOvA is limited by statistics. If one is in a favorable region, one can get some information; if not, life gets complicated. To nail it, one needs a new experiment, LBNE, which could show whether there is CP violation vs. δ_{CP} in the neutrino sector at greater than 3σ. There is a connection between these phases and leptogenesis. The observation of CP violation in neutrino oscillations would enhance the credibility of leptogenesis.

Beyond the neutrino standard model, in sterile neutrinos, LSND and MiniBooNE see oscillations that do not fit into this three-flavor pattern that has been seen; the δm^2 is wrong. There is a reactor anomaly, a deficit in the neutrinos coming from a reactor in comparison to what is measured at nearby detectors. It could be nonstandard interactions. When the LHC discovers new vector bosons, it is not surprising that neutrinos are not involved. The neutrino oscillations depend on the coherence of the mass eigenstates; there could be premature discoherence. In the standard neutrino model, neutrinos decay; but they do so on a timescale longer than the age of the universe. It could be that the heavier neutrinos decay more rapidly than do the light ones. That would indicate new physics. There are also effects of extra dimensions and surprises. With extra dimensions, one sees wiggles in the probability of νμ going to νe for both normal and inverted hierarchies. The extra-dimensions curve has a slight shift from the standard oscillation curve. From these wiggles and shifting, one can learn about other exotic phenomena in long-beamline experiments.

In summary, the sizable ν_e fraction of ν_3 is a wonderful opportunity to answer the question whether there is CP violation in the neutrino sector; what the mass ordering of neutrinos is; and which flavor dominates ν_3, μ or τ. Knowing these three will allow testing of neutrino-mass models, enhance the credibility of leptogenesis, and give some information beyond the Standard

Model of neutrino physics. Neutrinos have surprised us in the past and will continue to surprise us.

Steinhardt asked Parke if he could say something about the impact of sterile neutrinos on the cosmic frontier and warm dark matter. Parke replied that the sum of the masses of the neutrinos can be measured from cosmology. The sum of the masses of the neutrinos in normal hierarchy must be greater than 60 meV; in the inverted hierarchy it must be greater than 110 meV. If one can show the sum to be less than 110 meV, then the mass hierarchy can be determined. However, the mass is known to be greater than 60 meV from the atmospheric δm^2. To show that it is less than 110 meV is going to be a challenge. It will not happen soon.

Bassler asked if the experiments dealing with sterile neutrinos were compatible with each other. Parke replied, no. Some experiments may be right, and some not so right.

Ramond asked about the role of hierarchy vs. inverse hierarchy in determining neutrinoless double-beta decay. Parke responded that , if neutrinos are inverted, neutrinoless double-beta decay will be seen in the next round of experiments if neutrinos are Majorana. However, in the normal hierarchy, effective mass could be much lower. In the inverted hierarchy, there is a lower limit on the effective mass from double-beta decay. If the hierarchy were inverted, that would be great to show and would be a violation of lepton number.

Cvetic asked if bonds can be stronger in extra dimensions. Parke replied, yes and no, depending on the model used.

Young-Kee Kim was asked to report on the Long-Baseline Neutrino Experiment Reconfiguration Steering Committee's activities.

The 2008 P5 report has as a central pillar of the future U.S. HEP program, a long-baseline neutrino program driven by a high-intensity beam from Fermilab because it would address a number of important physics questions:

- Is there CP violation in the neutrino sector?
- What is the ordering of the neutrino states?
- Is the proton stable?
- What physics and astrophysics can be learned from the neutrinos emitted in supernova explosions?

In conjunction with the consideration of the Tevatron extension, P5 reaffirmed the 2008 plan in October 2010. The Committee confirmed that plan.

The large value of θ_{13} found in March 2012 mitigated the physics risk.

Fermilab was executing the P5 plan. Critical Decision-0 (CD-0) was approval in January 2010 for the full LBNE; DOE CD-1 review is scheduled on Oct. 30–Nov. 1, 2012, for LBNE Phase 1. The Fermilab accelerator complex continues to run for neutrino and antiproton experiments. It has the world's most powerful neutrino beam. The recycler is coming back, and the muon complex will come online. The Fermilab accelerator front end is 40 years old. It needs to be updated. There are a lot of opportunities for collaboration at Fermilab.

The evolution of the U.S. LBNE started with MINOS in 2005; NOvA is currently under construction; and the LBNE is envisioned to start running in 2022. The MicroBooNE detector is also under construction. There has been a remarkable improvement in technology with electronic efficiency going from 4 to 80%.

The detector technology choice was made in January 2012. The liquid argon time projection chamber (TPC) was chosen because of its extremely high performance and particle identification and the uniqueness of the technology. A large θ_{13} value has been found (about 9°). A larger baseline separates hierarchies and makes CP violation measurements easier. About 1300 km is nearly optimal for a combined sensitivity of CP and mass-hierarchy measurements.

However, Dr. Brinkman's charge on March 19, 2012, asked Fermilab to find a path forward to reach the goals of the LBNE in a phased approach or with alternative options. His letter notes that this decision is not a negative judgment about the importance of the science but rather a recognition that the peak cost of the project cannot be accommodated in the current budget climate. A steering committee and two working groups (physics and engineering/cost) were formed in April to identify viable options and to write the report to DOE.

The process included a kickoff meeting in April, an interim report in June with briefings to DOE and NSF, a response letter from DOE to prepare CD-1, and a final report in August. This is a very open process with all documentation on a website.

A guideline LBNE Phase 1 budget calls for about $700 million to $800 million, about half of the full LBNE cost. The main issues for Phase 1 are: What physics are to be compromised to make it affordable? What long-term physics limitations are imposed by the different Phase-1 options? One practical issue was whether to use the existing NuMI beamline to Soudan/Ash River or to develop a new beamline to Homestake. A new beamline would include a target hall with remote handling and a high-radiation environment; beam extraction and transport from the Main Injector to the target; focusing horns for secondary particles; the beamline to Homestake; and a large underground decay pipe. A Homestake beamline would provide much better aquifer protection than the NuMI beamline.

The options that were considered included, for Homestake, (1) a new beamline plus a small detector for long-baseline neutrino physics or (2) no beamline plus a large detector for non-accelerator-based physics. For long-baseline accelerator-based neutrino physics, Homestake and other sites were considered. The conclusion was that other sites are not cheaper than the Homestake option, thus there would be no gain. Rather, there would be a loss of the significant investments already made at Homestake. Therefore, Homestake was chosen as the site. Overall, the longest baseline is best. A shorter baseline (to Canada) is not viable because the beam would be 21 mrad off axis and the neutrino flux would be too low for CP studies. The far detector chosen is a liquid argon TPC. It was assumed that Phase 1 running would use a 120-GeV proton beam at 700 kW for 10 years.

The Committee looked at low and medium energy and wide and narrow beams for the different sites and calculated the neutron appearance probability. It then calculated the mass-hierarchy reach for the different sites; by adding NOvA and T2K, advantages were obtained for certain parameters. Such calculations were also conducted for CP-violation reach; again, adding NOvA and T2K gained advantages. The resolution of δ_{CP} measurements was also considered. Other mixing parameters were also looked at.

Regarding new physics, a wideband beam and long baseline can be used to look for a breakdown of the third-generation mixing model in terms of neutral-current non-standard matter effects, long-range interactions between neutrinos and background sources, and active-sterile neutrino mixing from the neutral-current event rate.

Proton decay is distinctive in liquid argon and is the favorite mode for supersymmetry-inspired grand unified theories (GUTs). The detector must be underground and at least 10 kt to be competitive. Studies of proton decay are complementary to those being performed with existing water Cerenkov detectors. Atmospheric neutrino events are similar to accelerator neutrino events. They also must be underground to detect the mass-hierarchy sensitivity.

In summary, the neutrino hierarchy and the CP phase angle are accessible with the options being considered. A longer baseline allows complete separation between matter and CP effects. A longer baseline and a wide-band beam allow observation of multiple oscillation peaks and the valleys between them in the long term, providing broader sensitivity to neutrino oscillation physics beyond that described by the standard 3 × 3 matrix. The search for proton decay and the study of atmospheric and supernova-burst neutrinos require the detector to be underground. Homestake is at a 4850-ft depth and affords excellent opportunities. The Soudan laboratory at a 2340-ft depth produces a modest compromise in the physics reach.

Moving to the engineering/cost studies, LBNE has developed a CD-1-level conceptual design and cost estimate for the full project, which has been reviewed and found to be sound. This exercise became the baseline for all cost estimates. Value engineering during the reconfiguration process lowered the cost estimate for the full LBNE to less than $1.5 billion. This reduction was accomplished by simplifying designs to a minimal configuration while maintaining the same scientific capability. A lot of comparisons have been done between the Homestake cost estimates and operational methods, and actual experience at Soudan and Ash River was very helpful in this process.

The engineering/cost studies found a difference of $130 million between the surface vs. the at-depth options. For all options, the project management would be about 10% of the project. Homestake would require a new beamline. Soudan's underground detector would require two new shafts and a beamline upgrade. An Ash River or Soudan surface detector would require surface infrastructure and a beamline upgrade. Even though Homestake is more expensive, it allows a small detector that offsets the more expensive large detectors required at Soudan and Ash River.

The conclusions of the Steering Committee are as follows. The three options are (1) using the existing NuMI beamline in the low-energy configuration with a 30-kt liquid-argon-TPC surface detector 14 mrad off-axis at Ash River, 810 km from Fermilab ($684M); (2) using the existing NuMI beamline in the low-energy configuration with a 15-kt liquid-argon-TPC underground (at the 2340-ft level) detector on-axis at the Soudan Lab, 735 km from Fermilab ($675M); and (3) constructing a new low-energy LBNE beamline with a 10-kt liquid-argon-TPC surface detector on-axis at Homestake, 1300 km from Fermilab ($789M). The Committee looked at possibilities of projects with significantly lower costs and concluded that the science reach for such projects becomes marginal.

In terms of the mass hierarchy, Homestake does much better than the other options. In the CP reach, Ash River does the best if the mass hierarchy is not resolved. In terms of δ_{CP} measurements, the three sites are comparable.

The 30-kt detector at Ash River (810 km; surface) gives the best Phase 1 CP-violation sensitivity in combination with NOvA and T2K results for the current value of θ_{13}. The sensitivity would be enhanced if the mass ordering were known from other experiments. It also has an excellent mass-ordering reach in nearly half of the δ_{CP} range. However, the narrow-band beam does not allow measurement of an oscillatory signature. Shorter baseline risks have fundamental ambiguities in interpreting results. The sensitivity decreases if θ_{13} is smaller than the current experimental value. Cosmic-ray backgrounds are not a big issue. This facility accommodates only accelerator-based physics, and it has a limited Phase 2 path. The beam is limited to 1.1 MW; Phase 2 could be a 15- to 20-kt underground detector at Soudan.

The 15-kt detector at Soudan (735 km; 2340 ft) has the broadest Phase 1 physics program. Its accelerator-based physics include good mass ordering and good CP-violation reach in half of the δ_{CP} range. CP-violation reach would be enhanced if the mass ordering were known from other experiments. Non-accelerator physics include proton decay, atmospheric neutrinos, and supernova neutrinos. Cosmic-ray background risks are mitigated by the underground location. However, there is a mismatch between the beam spectrum and the shorter baseline that does not allow full measurement of an oscillatory signature. Using a shorter baseline risks fundamental ambiguities in interpreting results. This risk is greater than for the Ash River option. Also, sensitivity decreases if θ_{13} is smaller than the current experimental value. It has a limited Phase 2 path. The beam is limited to 1.1 MW. Phase 2 could be a 30-kt surface detector at Ash River or an additional 25- to 30-kt underground detector at Soudan.

The 10-kt detector at Homestake (1300 km; surface) would have an excellent mass-ordering reach in the full δ_{CP} range. It would have a good CP-violation reach that would not be dependent on an *a priori* knowledge of the mass ordering. The longer baseline and broad-band beam would allow explicit reconstruction of oscillations in the energy spectrum. Self-consistent standard neutrino measurements can be done; it has the best sensitivity to Standard Model tests and non-standard neutrino physics. There is a clear Phase 2 path: a 20- to 25-kt underground detector at the Homestake mine. This covers the full capability of the original LBNE physics program. This option takes full advantage of Project X beam power increases. However, cosmic-ray backgrounds' impact and mitigation need to be determined. It accommodates only accelerator-based physics. Proton-decay, supernova-neutrino, and atmospheric-neutrino research are delayed to Phase 2. It is about 15% more expensive than the other two options; cost evaluations and value engineering exercises are in progress. A complete LBNE near-detector system will be required in a later stage to achieve the full precision of the experiment.

While each Phase-1 option is more sensitive than the others in some particular physics domain, the Steering Committee strongly favored the Homestake option (a new beamline and a 10-kt liquid-argon-TPC detector on the surface). The physics reach of this first phase is very strong. Moreover, this option is seen by the Steering Committee as the start of a long-term world-leading program that would achieve the full goals of LBNE in time and allow probing the Standard Model most incisively beyond its current state.

Placing a 10-kt detector underground in the first phase would allow for a rich physics program (including proton decay, supernova, and atmospheric neutrinos), support a broader community, and increase the cost by about $135 million. Having additional national or international collaborators would increase the scope of the first phase and accelerate the implementation of subsequent phases.

In summary, the Committee identified three viable options for the first phase of LBNE: (1) using the existing NuMI beamline in the low-energy configuration with a 30-kt liquid-argon-TPC surface detector 14 mrad off-axis at Ash River, 810 km from Fermilab; (2) using the existing NuMI beamline in the low-energy configuration with a 15-kt liquid-argon-TPC detector underground (at the 2340-ft level) on-axis at the Soudan Lab, 735 km from Fermilab; and (3) constructing a new low-energy LBNE beamline with a 10-kt liquid-argon-TPC surface detector on-axis at Homestake in South Dakota, 1300 km from Fermilab. The last is the preferred option.

Its physics reach is very strong; it has a clear Phase 2 path; and it takes full advantage of Project X beam-power increases.

The Committee produced an interim report and presented it to Dr. Brinkman on June 6. On June 29, Dr. Brinkman wrote a letter to Pier Oddone, asking the Laboratory to proceed with planning a CD-1 review later this year on the basis of the reconfigured LBNE options. The CD-1 review is scheduled on October 30 – November 1, 2012, with the Homestake option as the baseline. Additional national or international collaborators have the opportunity to increase the scope of the first phase of LBNE and accelerate the implementation of subsequent phases. On July 17, 2011, the U.S. DOE and India's Department of Atomic Energy (DAE) signed an Implementing Agreement on Discovery Science that provides the framework for India's participation in the next-generation particle accelerator facility at Fermilab. The DAE has "in principle" recommended making significant "in-kind" contributions to Project X and LBNE construction. The DOE-DAE Project Annex (I and II) is awaiting Indian Government approval and signing, which is expected before the end of 2012.

Bassler asked what the effect was of the preferred option on the cost of Phase 2. Kim replied that the preferred Phase 1 configurations would be a 10-kt detector above ground at Homestake, and the Phase 2 configuration would expand that to a 20- to 25-kt underground detector. Phase 2 would be optimized according to what Phase 1 was.

Byrum asked what the community was supposed to do at Snowmass. Lankford suggested saving that question for later.

Brinkman asked if it saved money in Phase 2 to do Phase 1 underground at Homestake. Kim replied, yes; there are two options: underground at Homestake or at the surface elsewhere. One might save $135 million or less. Strait added that there is an investment to 10s of millions of dollars that would not have to be paid again if Phase 1 were constructed underground at the Homestake Mine. But the biggest savings is that one gets the beam and baseline that is desired.

Dehmer asked if the near detector had been thrown out. Kim replied that the cost of the near detector was saved. Dehmer asked if there were a gain in physics benefit by starting underground. Kim responded, yes; the scientific program becomes much richer.

Honscheid asked why there was a $135 million difference in the report to go to Homestake. Kim answered that the whole new beamline costs $150 million. There is a large detector required at the surface, also.

Fisher noted that one learns a lot about underground detectors by doing a smaller facility first. With proton decay in the $K + \mu$ mode, one is giving up a little on proton decay. Kim agreed.

Roe asked how confident and certain the Steering Committee was about limits placed on surface detectors by cosmic rays etc. Kim said that that topic is being studied. A relatively simple cut on given angles etc. has shown a manageable background. Strait added that, without a photon system, the kinematics indicate that the soft component will be filtered out. Also, discriminators get the background down to a couple of percent. There will be space-charge distortions. It will be small and can be calibrated out. The issue is not being ignored.

Hartill asked what the timescale for Phase 2 was. Brinkman replied, later. Kim replied it will need to be seen what happens with Phase 1 and the success in forming international collaborations.

Lankford asked what Fermilab thought about the relative phasing of Project X and the LBNE. Kim replied that they are interleafed. It depends on how much Bill [Brinkman] loves Fermilab. There are a lot of interconnections in the plan.

Byrum asked if there were other collaborators beside India. Kim replied, yes: the United Kingdom, Italy, and CERN; they are waiting for the European Strategy outcome. Byrum asked about China. Kim said that they are interested in Project X. They have an interest in LBNE but feel stretched by Daya Bay and other experiments. They do not have enough personnel.

Bassler asked how Fermilab sees the role of Japan. Kim replied that discussions are being held with Japan, also. Fermilab has had a collaborative effort with them for more than 30 years. There is a continuing dialogue with them about their planning. For them, there are other interests, and they need to figure out their priorities.

A break was declared at 4:02 p.m. The meeting was reconvened at 4:21 p.m.

Milind Diwan was asked to talk about the LBNE Collaboration.

The LBNE Collaboration is planning for an experiment with these elements:

- A long-baseline to allow full exploration of neutrino oscillations, in particular, mass hierarchy, CP violation, and precision measurements that might lead to new physics and non-standard interactions;
- A capable large detector located deep to obtain statistics and explore rare physics of proton decay and supernova; and
- An advanced near detector for precision measurements of oscillations and other precision measurements.

This effort represents a broad and rich program of science.

The Collaboration recognizes that all of the above are not currently planned in Phase 1 because of the cost constraint, but the reconfiguration choice allows the best path to achieve it over time. Several meetings have been held. The LBNE design and organization are ready, and, most importantly, the science is timely. The Collaboration and the project are well organized and want to get construction started rapidly to maintain leadership in this science.

Daya Bay was an extremely precise experiment. This is the last missing angle in the neutrino flavor: $\sin^2 2\theta_{13} = 0.089 \pm 0.010$ (stat) ± 0.005 (syst). Both the ratio of δm^2 and the mixing angles are fortunately just right for a practical laboratory experiment. These values lead to the conclusion that a neutrino will turn into a tau particle as a result of mass effects. The neutrino oscillation model is based on a limited dataset. With very precise predictions, it is desired to determine the large matter effects with potentially large CP violation. LBNE will test this picture with a detailed spectrum.

The design for a U.S.-based CP-violation program started 10 years ago before the solar large-mixing-angle solution and θ_{13} were known. The argument was made that the scale of the program needed is only weakly dependent on θ_{13} because the CP asymmetry is smaller for larger θ_{13}. Looking back, the scientific choices and the design could not have been any better. The investment requested by P5 and carried out by the DOE/NSF was timely and has paid off. The U.S. program is now in the best position to investigate CP violation in neutrinos.

Phase I would allow the measurement of ν_e (anti-ν_e) at the rate of about 50 (about 20) events per year with >50% modulation. With a smaller detector, one does not do as well. LBNE will have a definitive determination of the mass hierarchy. LBNE will produce a measurement of the phase and θ13 with no ambiguities. The phase measurement will range from ±20 to ±30 deg for Phase I when combined with reactor data. Parameter measurement will continue to improve with statistics.

The LBNE Collaboration has 347 members, 59 institutions, 25 U.S. states, and 5 countries.

There are about 15 working groups. The project costed personnel at about 30 to 50 full-time equivalents. Projections indicate a need for about 500 members. Future growth is planned to be international.

The Collaboration has an institutional board that sets policy, elected bodies, and appointed working groups and committees. The project organization is different. Fermilab is the lead laboratory. The Brookhaven National Laboratory (BNL), Fermilab, and Los Alamos National Laboratory project leadership is well integrated. There is substantial university participation. It has a good working relationship with the Sanford Underground Research Facility (SURF); a memorandum of understanding is expected soon.

The important events have been

- December 2010, when the National Science Board (NSB) turned off NSF consideration for DUSEL; the 2011 review from the NRC/BPA committee reaffirmed the science for LBNE and DUSEL
- July 2011 when the Marx/Reichanadter committee reviewed the costs and technologies for DOE; the costs for LBNE had been roughly known since the summer of 2011; it became clear that one could not afford both a water and a liquid argon detector
- Fall of 2011 when extensive internal reviews for the detector technology choice were completed
- December 2011 when the LBNE Exec Board/Fermilab/DOE held extensive negotiations over the far detector technology; the Collaboration board preferred the water detector because of the cost/schedule certainties; however, the final decision was for a 34-kt liquid argon detector based on the better performance for higher energies and uniqueness of the technology and had complementarity for proton decay and supernova physics to existing water detectors
- March 2012 when the project was deemed ready for CD-1 review when the Daya Bay result was announced and DOE asked that LBNE be structured in phases leading to the reconfiguration panel

The Collaboration's effort has a level and quality of effort that is very high. The physics working group has produced numerous reports. The reconfiguration panel relied on the Collaboration for physics input. There is active collaboration with > 6000 documents in the document database so far. The Collaboration has grown since Dec. 2010 by about five institutions. The Collaboration remains committed and strong and will seek expansion of the science program.

A technically driven Phase 1 schedule has been developed. It runs from 2010 to 2022. The current funding profile is expected to cause an 11-month delay. The period up to the far-detector construction start offers a good opportunity to seek major non-DOE and international partners. Deep placement of the far detector as well as a near detector expansion can be accommodated in the current plan by CD-2.

A full-scope LBNE (34 kt at the 4850-foot level and a near detector) would cost $1.440 billion. LBNE Phase I (10 kt at the surface) would cost $0.789 billion. If one added in underground option, it would cost $0.924 billion. With an added near detector, it would cost $1.054 billion.

Locating the detector underground will cost $135 million (or 15% of the LBNE Phase I total) and enable the physics of proton decay and supernova neutrinos. Similarly, a full capability near detector needs about $130 million, including civil construction. The Collaboration has started conversations to consider various non-DOE proposals/avenues to enable underground placement of the detector for a substantial broadening of the program. There will be conversations with European physicists at the European Strategy Preparatory Group (ESPG) on Sep. 10–12, 2012. There are technical collaborations with United Kingdom/Rutherford-Appleton Laboratory already. High-level agreements with India are proceeding regarding a substantial contribution for the near detector.

In conclusion, the goal of finding the phenomenon of CP violation in the neutrino sector is extraordinary and has been strongly endorsed. There may be CP violations beyond the third-generation model. Our accelerator/detector technological capability and the geographical situation could not be better matched to the science of neutrino oscillations. The LBNE Collaboration and project are well organized and ready to construct and operate LBNE. The Steering Committee report is a culmination of a very long process of design, costing, and planning by a broad section of the community. It puts the United States on a track to a massive detector for CP violation and proton decay. The Collaboration (with FNAL and DOE) will work toward strong international investment and expansion of the science program.

Fisher asked if all of the costs included the beamline. Diwan replied, yes.

Honscheid pointed out that, by 2022, we are all getting old. He asked if there are other options. Diwan replied that the scale of funding is the thing.

William Brinkman was asked to review the activities of the DOE Office of Science (SC).

He prefaced his remarks by saying that the people involved in the LBNE had done a terrific job breaking it up into pieces and that he hoped that DOE could make it happen.

There will probably be a continuing resolution based on the FY12 budget and lasting through March 2013. The extension of tax cuts, the FY13 budget and its associated sequestration of funds, and the debt ceiling that will be reached in February will be the focus of Congress and will lend uncertainty to DOE's budget planning.

The Office of High Energy Physics (HEP) seems to have the sympathy of Congress; the President's request was for $776.5 million, and the House mark was for that same amount, and the Senate mark was for $781.5 million. The HEP budget was stretched by construction funding for the Thomas Jefferson National Accelerator Laboratory (JLab), the Relativistic Heavy Ion Collider (RHIC), and the Radioactive Ion Beam (RIB) facility. In any FY13 budget, the appropriation probably will not vary more than $7 million if all goes well. However, the budget climate is very uncertain.

The world is getting hotter. Something needs to be done about this problem. A 250-megawatt coal plant produces 250 tons of CO_2 per hour. This issue is a priority in budget decisions. There is a little good news, however. For the first time, the Energy Information Administration (EIA) has said that the amount of CO_2 being produced in the United States is going down a little bit. It needs to go further and further. The Arctic is really heating up. Old ice is melting before new ice is made each winter; this is a new cycle. Glaciers have receded, one more than 100 m. There is a belt in North America that is getting hotter, but warming is not uniform. Sea level is rising.

New technology on the market to shift energy use from petroleum to electricity includes the Tesla automobile, which can travel 300 miles on a single charge. It runs on batteries and goes from 0 to 60 mph in 4.4 s. Our country is making progress. Hybrid-car sales have taken off in terms of percent of all vehicles sold: from 0% in 1999 to 3% in 2012. Supporting this revolutionary technology is very important. Discovering the Higgs is also important. A balance has to be figured out for future budgets.

The floor was opened for public and general discussion. Cohen noted that no one seems to be happy with an aboveground LBNE; everyone would like to have it underground. Brinkman agreed; the Office would like to see it underground. Siegrist noted that the Europeans are in the planning stage of establishing an underground facility. The United States has a facility that could accomplish this science. If the United States could get a proper target and beamline, international collaborators should be attracted, and the enterprise should be of interest to our European and Japanese colleagues. A capped, phased approach is needed with the hope of getting it underground.

Lankford asked if the agency would send a companion message to Ramond's invitations for international collaboration. Siegrist replied, yes. Lankford said that he had not divined how committed the agencies were. The Committee had heard the logic behind the LBNE and that there is a good compromise and that the Collaboration accepts the compromise plan. The agencies seem to be uncertain. Are they going to go forward with this? Neutrino physicists in other sections of the world have the sense that it will not go forward. The Siegrist replied that the Department has a process for getting a project funded. That process has to be conducted. It will take some time to do the technical and cost reviews, and DOE cannot commit itself until those reviews are completed.

Fisher asked what the current funding was for liquid argon R&D. Siegrist said that he did not know. Kim said that the MicroBooNE experiment adds some technology development: a few million dollars a year in R&D. Oddone said that, in addition, there is $26 million for the preparation of the LBNE project as modified by Congress for FY13 (e.g., $16 million for project engineering upon a successful CD-1 decision). There is a slow ramp-up. It does not ramp up rapidly until 2017. There is a forward commitment of $100 million; that is reassuring. MicroBooNE is trying out some of the new technologies (e.g., cold electronics).

Honscheid asked what was wanted from Snowmass in the next year, a broad endorsement of the P5 plan? Siegrist answered that the community should agree on how to measure this matrix. How does one measure the success of the neutrino experiments? This needs to be discussed at Snowmass. What does a comprehensive evaluation look like? Do we need a neutrino factory? That goes beyond the scope the LBNE. Honscheid asked if the community as a whole has to say that it is the most important question. Siegrist replied that P5 says that it is. The community has to reassess whether the Department's direction is correct and the balance among the three frontiers is proper so a compelling program results.

Ramond pointed out that the Snowmass process responded to angst in the community. DPF is independent of the national laboratories and represents the field. It has identified conveners and will have a meeting at Fermilab to determine from all of the physics the questions about where we are going. He pointed out that the physics payoff from an underground detector at Homestake is extremely good and a very important issue. There is an opportunity to set up the United States neutrino sector as a world leader.

Roe noted that Siegrist had made the point that a science plan not grounded in reality is not useful and cuts are coming. Snowmass's making its input would be good if some budgetary guidance were provided to Snowmass so it can assess the aspirations of the community. Siegrist replied that that is a good idea. Projects are also needed in the pipeline. The Office of Basic Energy Sciences (BES) has done this very well. The construction process dovetails their construction projects very well.

Lankford asked what the definition of success was. Siegrist replied that an OMB review had said 20% of the budget should go to construction of large projects. Oddone stated that the reality is that BES has grown tremendously, but HEP has shrunk. Unless more of SC's budget is spent on particle physics, life will be very difficult.

There being no additional comments, the meeting was adjourned for the day at 5:26 p.m.

Tuesday, August 28, 2012

The meeting reconvened at 9:09 a.m., and **Marjorie Corcoran** was asked to report on the DPF Committee on DOE Comparative Reviews.

At the April APS meeting in Atlanta, the DPF Executive Committee was approached by several people who had concerns about DOE's comparative review process. The DPF chair decided to have an independent look at the process. The Committee of Visitors to the DOE had recommended comparative reviews for DOE university grants to mitigate longstanding inertia in funding. NSF and the National Aeronautics and Space Administration (NASA) have done comparative reviews for many years. The goal is to provide feedback to DOE, to be a communication link between DOE and the HEP community, and to improve the comparative review process going forward. There is strong support on all sides for comparative reviews but some concern over their implementation.

The charge to the DPF Committee was to consider the review process and its methodology and the changes it has produced and to write a report to be sent to the DOE through the DPF on behalf of the community. The Committee (1) distributed an early working draft of the report to the community, (2) set up a web page for community input, (3) consulted with the community, (4) met with the DOE to be briefed, and (5) requested from DOE information not already in the public domain.

A long list of questions was sent to DOE, inquiring about

- The proposals funded in FY12, the history of university grants in terms of the number of grants and total funding, funding trends, and declinations
- The review process strategy
- Guidance given to the applicants
- The charge given to the reviewers and any guidance given about expected outcomes
- Specific instructions given to reviewers regarding Senior Research Scientists
- Provisions for reviewing grants or PIs that have multiple activities that cross the energy/intensity/cosmic boundaries
- Funding of students and post docs under a PI who was not funded
- The evaluation of shared resources and infrastructure

A lengthy conference call was held with HEP staff, and supplementary material has been received. Four public comments and about twice as many private comments have been received, most from those who have lost funding.

There is strong support in the community for such a process, although several respondents expressed concerns that:

- Scoring of proposals tended to have a small spread, requiring program managers to make sharper distinctions than the reviewers.
- Some individuals and grants span different frontiers, and the full range of a contribution may not be taken into account.

- Some funding changes were significant and abrupt.
- Funding decisions were not always aligned with the needs of ongoing experiments.
- No systematic attempt was made to gather this information.
- Cutting funding for graduate students who are then picked up by the department has a negative impact on the department's and university's view of the group.
- Funding cuts may impact future faculty hires.
- Faculty reapplying in later years may lose favorable agreements that had been previously negotiated.

Possible additional input from DOE may be received within a few weeks. After a few more weeks for community comments, a consensus of the Committee will be sought, and a final report will be issued by the end of September.

Alan Stone presented the HEP update on comparative reviews for Glen Crawford.

The current DOE funding opportunity announcements are

- General Office of Science FOA: DE-FOA-0000600. It closes Sept. 30; it will be renewed. It provides for the renewal proposals, supplemental funding, conferences. It has rolling start dates.
- HEP Comparative Review FOA: DE-FOA-0000733. It closes Sept. 10. It is for new research proposals only; awards will start in April 2013.
- Office of Science Early Career FOA: DE-FOA-0000751; there is a parallel national laboratory funding announcement LAB-12-751. Mandatory pre-applications are due Sept. 6; full applications are due Nov. 26. It is for eligible junior investigators only; awards start during the summer of 2013.
- Small Business Innovative Research/ Small Business Technology Transfer (SBIR/STTR) Phase I: Letters of intent are due Sept. 4; applications are due Oct. 16.

No additional FOAs are planned for FY13.

PIs with expiring grants need to submit a final report within 90 days of the end of the grant. Note that all grants with prior (FY11) DOE funding that underwent comparative review in 2012 are now expired. Per order of DOE Deputy Secretary, all conferences and workshops exceeding $100,000 in cost to DOE (including DOE lab travelers) must obtain prior approval before committing any funding.

A Joint HEP–Office of Advanced Scientific Computing Research (ASCR) funding opportunity announcement for Scientific Discovery through Advanced Computing (SciDAC) was posted in Sept. 2011 and closed Jan. 2012. It was for research to advance the HEP mission by fully exploiting DOE/SC leadership-class computing resources and bringing together researchers working in topical areas with computer scientists. It provides 3-year awards; progress against milestones will be reviewed in 2014.

Research funding will decrease about 2% a year for the next several years. Program priorities and comparative reviews will be used to implement the cuts. Both the universities and the laboratories will be affected. Comparative laboratory reviews in the energy frontier and detector R&D will be conducted this year; cosmic and intensity frontiers will be conducted next year; accelerator science is to be determined.

Operations funding is approximately flat-flat. The Office is seeking approval of CD-0 for mid-scale dark matter and dark energy; ATLAS and CMS upgrades; and muon g-2 this fall. It is investing in the cosmic, energy, and intensity frontiers. CD-1 has been approved for LSST, Belle-II and Mu2e; the CD-1 review for the LBNE will be in October. The Office is embarking on a community planning process. The APS DPF is organizing it.

Laboratory Research Reviews were held during the month before this meeting. Not all of the reports and comments are in, yet. They held external, comparative peer reviews of HEP national-laboratory programs in July on Detector R&D and the Energy Frontier. In general, the comments were positive; some review letters are still being awaited. Review reports are due in October. Lessons learned include:

- More time for executive sessions and more structured agendas are needed.
- Clearer instructions for the national laboratories are needed.
- A more-structured closeout would be appreciated

The process for the 2013 HEP university comparative reviews is well under way. Alan Stone is the HEP point of contact. A revised and updated frequently asked questions (FAQ) page is available. Prospective PIs are urged to read the FOA and FAQ carefully. Panel reviews will be held in November, internal decisions are due in December, negotiation/revised budgets will be held in December and January, and awards will be made in April 2013.

Shipsey asked what he meant by "negotiations." Stone said that, typically, there are no negotiations; the program manager tells the recipient what money is available, but is open to changes.

Stone continued: This past year, there were 121 proposals (47 of which were new proposals), 36 of them were declined (26 of which were new proposals), 49 of them were from junior faculty (34 of which were new proposals), and 27 junior-faculty proposals were funded (16 of which were new proposals).

HEP staff members have met with the DPF Committee. The only strategy the Office had going into the process was to identify and support the best proposals and PIs. There were no targets for the number of new grants to be funded or for existing grants to be renewed. When the panels met, the reviewers were given the outlook of the HEP budget available to cover the research thrust in question and the total of the requests from all the proposals. In the energy frontier area, for example, the total requests were 70% higher than the available HEP budget. Theory was 2 to 3%.

The format of reviews and the uniformity of reviewers varied by thrust:

Mail only	Detector R&D
Panel only	Intensity frontier
Mail plus panel	Accelerator R&D, cosmic, energy, and theory

For the intensity frontier, all reviewers were panelists so they could speak to and discuss their reviews in real time. Mail and panel reviews were very uniform for cosmic and theory; less so for accelerator and energy. Any conflicts/outliers in reviewer ratings were generally resolved via a thorough panel discussion about the proposal. For the energy and cosmic frontiers, notes summarizing the panel discussion were compiled by the chair and provided as part of the reviewer comments sent to the PIs.

Shipsey asked if the mail reviews were available to the panelists. Stone answered that the reviews were frozen one week ahead, and panels could summarize them. The panels were quite big. Shipsey asked if the same process was going to be used for the intensity frontier. Stone replied, no; the area is too big.

Stone continued: PIs with different areas of interest were evaluated by different panels of experts in that specific interest area. The final funding of the PI was then determined in accordance with the aggregate outcome of the individual reviews. Efforts that reviewed well were typically supported, and those that did not review well were not supported. Reviewers were also asked to comment on shared resources and infrastructure in their overall comments and rating of a given proposal. These elements were also discussed in the panel deliberations and folded into the HEP program-manager discussions and programmatic decisions for "umbrella" grants.

The Office considers that the 2012 comparative peer review process was successful in identifying the best research proposals in a generally strong pool of applications. There were serious discussions among program managers about the relative merits of proposals. Therefore, the external-peer-review elements of this process are being maintained for the 2013 review cycle. In addition, the following changes will be implemented in 2013 to help improve the process:

- The review process will be started earlier to allow more time for programmatic decisions.
- The panel review process will be made more uniform across all research thrusts.
- Panel chairs will be asked to write brief summaries of panel deliberations for all proposals and PIs (as appropriate).

The Office is continuing to communicate the process, outcomes, and impacts to the community. An updated FAQ has been developed for the HEP website. Talks at HEPAP, community meetings, and site visits have been held. Numerous phone calls have been responded to. Interactions have been held with the DPF. In 2013, the Office will be working to involve reviewers with experience from 2012 process as well as those who will be writing proposals in 2014. Questions are welcome and will be responded to.

Corcoran commented that what DOE has on the website about FAQs etc. is very clear. Stone replied that it was there last year but was harder to find.

Rameika noted that, on the statistics, one cannot tell what proposals had shared resources. Stone agreed. Rameika said that that information would be very helpful. This process will be ongoing, and having this information available to the Committee would be very helpful. The number of reviewers for each panel would be helpful, also. Stone noted that he had all of that information available. The review panels get to dig into all of that information.

Steinhardt asked what guidelines were given for the percentage of approvals. Stone said that the budget is the final arbiter. There is a ranking of the PIs and proposals, but not all can be funded. Each panel has different priorities. The panels are not given the responsibility of distributing funds. They review the science merit and financial reasonableness. They are asked for a list of the top proposals and who was *the* top proposer. Steinhardt asked if DOE was satisfied with the drawing of the line. Stone replied that this year would be different; 45 to 50% of the university grants are coming up for review and being looked at. It is not known where the line will have to be drawn.

Shipsey noted that there will be a 2% research reduction and asked how that will be applied to universities funded last year. Stone responded that the Office will be more selective in what it funds rather than taking back what was already funded. It will fund fewer PIs. There will be budget guidance for each program area. The process is not mechanical. An effort is made to put as much information into the system as possible.

Cohen asked how the funding varied by area last year. Stone said that detector R&D got new grants. The intensity frontier got fewer people, but the average funding went up. He did not know what happened with theory and the energy frontier. The cosmic frontier was close to a 5% increase. Cohen asked who decides what fraction goes to universities and what fraction goes to national laboratories. Procario answered that DOE is given guidance to carefully evaluate the laboratory–university balance.

Honscheid noted that individual PIs were looked at on the university side and asked whether the same was done on the national-laboratory side. Stone said that the national-laboratory side is more global and uses a research-program approach. National-laboratory staff members are employees of the laboratory. The Office does not make staff decisions. They are evaluated on the strength of their proposed efforts.

Cvetic asked if the same approach applied to theory in the national laboratories. Procario said that that is where the Office may go off-track. It is one of the most difficult reviews. National laboratories and universities are not compared directly. Steinhardt noted that the costs are quite different and asked about the Office's feelings about balance between national laboratory and university theory funding. Procario responded that many of the national laboratory theorists review very well and are reviewed by university personnel. They are closely tied to experiments, but produce fewer students. Byrum noted that having a theory group at a national laboratory is very effective and they support postdocs. Steinhardt replied that it is an expensive resource. The question is whether the balance is correct.

Cohen asked if DOE had any plans to consider whether the current balance is correct. Siegrist responded that a process to do that had not yet been figured out. It is believed that the national-laboratory theory programs give good value for the money. Stone commented that the Office comes up against this issue every year. A common ground must be found to make an unbiased decision on the process. Ramond said that the APS is seeking comments from the community, and that they may comment on this issue. Kim pointed out that another important role of the national laboratories is to serve users, and the users need theorists. That element should be taken into account.

A break was declared at 10:28 a.m. The meeting was called back into session at 10:45 a.m.

Richard Kron was asked to review the Dark Energy Survey (DES).

The DES will perform a 5000-square-degree, 5-band, ~24th-magnitude survey of the southern sky with the Blanco 4-m Telescope at the Cerro Tololo Interamerican Observatory (CTIO) and a new instrument with a 2.2-degree-field-of-view (FOV), 570-megapixel, red-sensitive charge-coupled-device (CCD) imager and optics. Project preparation and reviews were held in 2003–2008, instrument construction was done in 2008–2011, delivery to CTIO was made in 2011-2012, installation of the new cage was performed in February–August 2012, and commissioning was held in September 2012. The 5-year project will operate 105 nights per year. The facility will be available to the general community on other nights.

The project really measures the history of the rate of expansion of the universe. The Dark Energy Task Force (DETF) recommended four complementary probes of dark energy:

- Galaxy clusters, which is sensitive to the growth of structure and geometry (results can be compared with those from the South Pole Telescope).
- Weak lensing, which is sensitive to the growth of structure and geometry.
- Large-scale structure [baryon acoustic oscillations (BAO)], which observes a power spectrum of the clustering of galaxies and is sensitive to geometry
- Supernovae, which is sensitive to geometry

The claim is that there will be a factor of 3 to 5 improvement over previous experiments.

This is a rich collaboration with many universities, agencies, and countries involved.

The Blanco Telescope primary mirror support has been upgraded. A new clean room and control room have been added. A new telescope control system has been installed. And a new data-transport system has been put in place.

Each night produces 300 gigabytes of data that are sent to the National Center for Supercomputer Applications at the University of Illinois at Champaign for processing. These data include galaxy colors (photometric redshifts), galaxy shapes (weak lensing), and identification of Type Ia supernovae (accurate fluxes). Pipelines have been tested with simulated data and data challenges.

The CCDs are thick, back-illuminated, fully depleted p-channel devices designed by LBNL and manufactured at Teledyne DALSA and Lawrence Berkeley National Laboratory (LBNL). A plot of the quantum efficiency of CCDs shows that the dark-energy-camera (DECam) CCD is hugely more sensitive than previous CCDs. About 500 CCDs were packaged and tested at Fermilab; of those, about 120 were judged to be science-grade devices; 62 are used in the imager (15-micron pixels producing 0.27 seconds of arc). The whole focal plane is read out in 17 seconds. All of this technology was made possible by the Fermilab silicon vertex detector construction for the collider programs. It took a few years.

A Telescope Simulator was constructed at Fermilab to model DECam systems integration (with no optics). This mockup was essential for testing and debugging all systems prior to shipping, and it was critical for DOE technical reviews. The facility was also used to devise and practice procedures for actual installation on the Blanco Telescope.

The old cage was removed and the new one installed in April and May. The primary mirror and the Cassegrain cage with additional counterweights were reinstalled in June. The cabling and cryogenic lines were very tricky. Installation of the imager is being done during this meeting. The first light for the imager should occur soon. Commissioning, science verification, and start of survey operations will occur during the last quarter of this year.

In summary, the DECam is complete, on budget, and on schedule. Data management will be ready for the first on-sky data; the architecture is being revamped for better operational Efficiency; and the upgrade will be phased in after the first season. This is a successful DOE–NSF partnership, with U.S. and foreign institutional support. The DES will use DECam to take the next step in constraining dark energy. The NSF Astronomy Portfolio Review supports DES and community access to DECam and Blanco.

Shipsey asked what was expected to be the limiting systematic. Kron replied that it would be a number of things: one is good control over redshift (biasing).

Byrum asked how many were in the collaboration. Kron answered, 130; two-thirds of those are from the United States.

Steinhardt asked how well W and W_a were known. Kron responded that W is known to about 20%; it is hoped to get that value to about 10%. W_a is about the same. The detector is run at 100°; it is cooled by nitrogen.

James Ulvestad was asked to review the status of the LSST.

The National Science Board (NSB) of the NSF has moved the LSST forward in the long line of approvals. It was the number-one recommendation in the 2010 Astronomy and Astrophysics Decadal Survey. It has an 8.4-m primary mirror with a 6.7-m effective aperture, a 3.3-gigapixel digital camera, a 3.5-degree field of view, an integration time of 15 seconds, and a readout time of 1.5 seconds. It produces 30 terabytes of data nightly and a complete coverage of the visible sky twice per week. It has a 10-year primary mission. It is to be located on Cerro Pachon in Chile. The current cost estimate is $665 million in as-spent, then-year dollars, assuming a start in late FY14. Of that cost, $466 million comes from NSF, $160 million from DOE, and $39 million from private donors.

This project is intended to be a 10-year experiment to reach specific scientific goals with well defined deliverables. It is not just another telescope. The LSST is a data-driven instrument with a prime mission of transformative discovery throughout astrophysics. It has four primary science goals:

- Probing dark matter and dark energy
- Mapping the Milky Way
- Inventorying the solar system
- Surveying the transient optical sky

It is optimized to perform all of these goals at once.

Site leveling has been completed. Fabrication of the primary and tertiary mirrors (final abrasive grinding and polishing) will be completed at the University of Arizona by end of CY12. The secondary mirror substrate is completed and in storage. Two vendors have fabricated fully operable prototype sensors that meet the major specifications: SLAC is the lead laboratory on the camera, and BNL is the lead laboratory on the detectors.

MREFC is a line item in President's budget request. Current MREFC projects include the Advanced Technology Solar Telescope, Advanced LIGO, Ocean Observatories Initiative, and National Ecological Observatory Network. Recent MREFC projects included Atacama Large Millimeter/Submillimeter Array and Ice Cube. Projects approved by the NSB advance to the "MREFC readiness" or "final design" stage, which gives the NSF Director approval to request funding for the project in a future budget request

The NSF Preliminary Design Review (PDR) considered the camera and interfaces from technical and managerial perspectives. It reported that "The Panel considers that the LSST project has met the requirements for PDR." The DOE CD-1 Lehman review of the Camera concluded that the project met all the CD-1 prerequisites "and in some areas has even significantly exceeded them." Both review panels made recommendations:

- NSF and DOE should align their funding profiles.
- An independent review of the interfaces between the camera and the other observatory systems should be conducted.
- Additional systems engineering analysis are needed.

All of these recommendations have been addressed.

The NSF MREFC Panel gave "unanimous recommendation of LSST as the highest priority major science facility opportunity that should be the next project to receive NSF MREFC funds for construction … conditional on completion of … NSF-DOE joint systems engineering review of the whole project." This positive report was complete on June 1, 2012. A cost update review was also completed May 16, 2012. An agreement or letter of intent with DOE, which addresses individual agency and joint interagency responsibilities for LSST in anticipation of the completion of a detailed interagency memorandum of understanding (MOU), was signed Apr. 17, 2012; the MOU was signed at both agencies on July 12, 2012. The NSF-DOE MOU provided a common project baseline definition of scope, budget, schedule, and risk; agency oversight roles and responsibilities; an integrated project office; a mutually agreed-upon data policy; operations contributions; and exit and termination criteria.

The current LSST annual operating costs were estimated at $37 million (in FY11 $). The MOU commits NSF and DOE to their respective levels that were recommended by the Decadal Survey, about $19 million and $9 million. $19 million per year is less than 0.3% of the NSF budget. NSF is presently at the low end of the 22 to 27% target range for Foundation-wide research infrastructure costs. The remaining $9 million is to be covered by international partners.

In summary, the LSST has been approved by the NSB and is slated to be included in the President's FY14 budget request. The Final Design Review is likely to occur in the summer of 2013. It is hoped that the LSST will be included in the FY14 Congressional appropriation for NSF. The earliest survey start would be October 2021.

Roe asked who was leading the negotiations on Euclid. Ulvestad replied that the NSF is not involved; NASA is talking with them. A decision will have to be made about how to negotiate with stakeholders. DOE is talking with Euclid program managers.

Edward (Rocky) Kolb was asked to review the Community Dark Energy Task Force (DETF) Report, which was completed just a couple of weeks before this meeting. The purpose of the report is to provide an overview of the current dark-energy science reach and to identify opportunities and key missing components in the current program. The intent was to produce a report that was independent of other agencies and scientific communities (just DOE researchers on dark energy) and that was not project- or facility-specific.

Dark-energy science is recognized as important. Dark energy is the dominant component of the present mass-energy. DOE has provided leadership in the field from the beginning as part of the Cosmic Frontiers Program. The nature of dark energy is unknown; it is 120 orders of magnitude larger than naïve estimates. It represents an area that is beyond the Standard Model of particle physics. It is not known if it is Einstein's cosmological constant or proof of a multiverse, an evolving ultralight scalar field, or modified gravity. The acceleration of the universe is, along with dark matter, the observed phenomenon that most directly demonstrates that the fundamental theories of particles and gravity are either incorrect or incomplete.

The goal of the investigation is to determine the nature of the dark energy that causes the universe to accelerate and seems to comprise most of the mass-energy of the universe. It is desirable to exclude the Lambda-Cold Dark Matter (ΛCDM) model, the standard explanation of the universe's expansion that employs a cosmological constant (Λ); to probe the expansion dynamics by measuring as well as possible the time evolution of dark energy; and to search for a possible failure of general relativity through the comparison of cosmic expansion with growth of structure. What is needed is a cross-braced latticework of observation; drawing upon different techniques is crucial to reach the goal.

The DETF identified four stages (Stages I, II, III, and IV) of dark-energy research. Stage I is the discovery phase, which includes the Supernova Cosmology Project, Hi-*z*, etc. Stage II is largely completed, and included the Sloan Digital Sky Survey, Supernovae Legacy Survey, Essence, etc. Stage III is the ongoing program, which includes BOSS, DES, various supernovae projects, etc. Stage IV is the taking of ground- and space-based measurements with the LSST, Euclid, Wide-Field Infrared Survey Telescope (WFIRST), etc.

No single technique can tell one everything about dark energy; one needs to use multiple techniques. The different techniques have different strengths and weaknesses, different systematic uncertainties, and different sensitivities to new physics.

Dark energy changes the history of the expansion rate of the universe. One can discern this change by measuring distances as a function of redshift and measuring the growth rate of structure as a function of redshift. One also has to be aware of the possibility that the acceleration may be caused by modified gravity; this case can be proven or disproven by measuring the growth rate of structure and the infall of galaxies.

The simple description of dark energy's effect on expansion is made up of w_0, the present value of the dark-energy equation of state, and w_a, the time change in the dark-energy equation of state.

Multicolor photometric surveys look at the sky with different filters (colors). They can give redshift interferometry. Multiobject spectroscopic surveys use many filters to take the spectrum of hundreds of galaxies at one time.

There are different techniques to study dark energy:

- The supernova technique measures the luminosity and redshift of Type Ia supernovae; it is sensitive to apparent magnitude and the redshifts of supernovae, $d_L(z)$, and geometry. It does not probe modified gravity. It is done by photometric surveys with targeted spectrometric follow-up.
- The weak-lensing technique measures the small distortion of shapes by large-scale structures. It is sensitive to distance, growth of structure, geometry, and dynamics. It can probe modified gravity. It is done by photometric surveys with spectroscopic information for training sets.
- The clusters technique measures the number and masses of galaxy clusters as a function of redshift. It is sensitive to the angular size and redshift, the growth of structure, geometry, and dynamics. It can probe modified gravity. It is done with photometric surveys with spectroscopic information for velocity dispersions.
- Baryon acoustic oscillations (BAO) measure the three-dimensional spatial distribution of galaxies. It is sensitive to angular size and stature history as a function of redshift and geometry. It does not probe modified gravity. It uses spectroscopic surveys.
- Redshift space distortions (RSD) measure the infall of galaxies as the three-dimensional velocity distribution of those galaxies. It is sensitive to galaxy infall, geometry, and dynamics. It can probe modified gravity. It is done by spectroscopic surveys.

The current dark-energy projects that have major DOE support are as follows: The BAO and RSD project is the spectroscopic BOSS. For supernova, there are the Supernova Cosmology Project, Supernova Factory, Palomar Transient Factory, and Quest; these projects will continue through about 2018 to reach a needed sample of about 500 nearby supernovae. For weak lensing, supernova, clusters, and BAO/RSD, there are the photometric Dark-Energy Survey and the photometric LSST, which has DOE and NSB approval.

The current dark-energy projects that do not have major DOE support are as follows. HETDEX is a U.S. spectroscopic BAO project. The Panoramic Survey Telescope and Rapid Response System (Pan-STARRS) and SkyMapper are U.S. imaging supernovae primary probes. WFIRST is a U.S. space-based project with NASA support. The polarization sensitive receiver for the Atacama Cosmology Telescope (ACTpol) and polarimeter for the South Pole Telescope (SPT-pol) are U.S. millimeter surveys of clusters. The BAO Broadband and Broad-beam array (BAOBAB), Precision Array to Probe Epoch of Re-ionization (PAPER), and Murchison Widefield Array (MWA) are U.S. 21-cm surveys for signal detection and then dark energy. Subaru Prime Focus Spectrograph (PFS), Physics of the Accelerating Universe (PAU) survey, Javalambre Physics of the Accelerating Universe Astrophysical Survey (J-PAS), and 4-meter

Multi-Object Spectroscopic Telescope (4MOST) are non-U.S. spectroscopic projects mostly targeted at BAO. The Kilo-Degree Survey (KIDS) and Subaru Hyper-Suprime Cam (HSC) are non-U.S. imaging projects mostly targeted at weak lensing. Euclid is a non-U.S. space-based project that has some DOE scientist support. The Canadian Hydrogen Intensity Mapping Experiment (CHIME) is a non-U.S. 21-cm project that is primarily aimed at other topics than dark energy. The extended ROentgen Survey with an Imaging Telescope Array (eROSITA) is a non-U.S. space-based project for looking at galaxy clusters via X-rays.

Future possible dark-energy projects include the spectroscopic surveys eBOSS (a follow-on to BOSS), BigBOSS (proposed for Kitt Peak), and Dark Energy Survey Spectroscope (DESpec, proposed for Cerro Tololo).

What is the status and progress? To achieve the goal of determining the nature of dark energy, Stage IV information is needed in all techniques. The progress in individual techniques is detailed in the current report. Overall, much progress has been made in 14 years, and DOE has played a leadership role. Stage III is in progress for clusters from DES, for weak lensing from DES, for baryon acoustic oscillations from BOSS, and for supernova from several projects. In the foreseeable future, there will be Stage IV for weak lensing from the LSST (LSST will also contribute to other techniques). In the far future there will be Stage IV for clusters, BAO/RSD, and weak lensing.

One missing ingredient is an advanced wide-field spectroscopic survey in the time frame roughly between DES and LSST. It would provide Stage IV BAO and RSD information and calibration data for systematic error mitigation. Another missing ingredient is advancing the supernova technique to Stage IV. The clearest path would be DOE participation in supernova studies at high-redshift from space (e.g., a DOE-led modest upgrade to WFIRST). In the meantime, there could be a pilot project to explore vigorously ground-based alternatives (it could use an R&D effort for near-IR technology and skyline suppression). Pilot studies are also needed to generate new ideas for the future. Deep spectroscopic calibration data are needed for the LSST. A pilot study could determine the exact needs and how to meet them. Pilot studies combining theory and targeted observations could also chart an effective modified gravity program to study the transition to modified gravity.

Glenzinski asked which bullet points under opportunities and missing ingredients do the future spectroscopic surveys address. Kolb replied, Bullet 1, which would occur after the DES but before the LSST.

Bassler asked whether it should be located in the north or south. Kolb said one or the other or maybe both; the Subcommittee looked at various tradeoffs but did not want to weigh in on that issue.

Glenzinski asked if the same stretch of sky had to be surveyed to produce calibration data for the specific surveys. Kolb responded that the answer to that question was unclear to him; for redshifts, LSST would go very deep and would have to have some handle on photometric redshifts. DES would use photometric redshifts. For clusters, one needs spectroscopic information to determine the velocity-dispersion of the cluster, which gives a good indication of the mass of the cluster. Some overlap is wanted, but not 100%.

Shipsey asked whether Subaru would not provide enough information. Kolb replied that a future for the DOE program was being charted.

Steinhardt asked how much improvement was expected in the spectrum and whether it was a continuous scale. Kolb said that the Subcommittee did not look at this issue at this time. An earlier task force addressed it. It is unclear how to proceed to do it. The common figure of merit does not capture all aspects of dark energy. A crude estimate is an improvement by a factor of 10. How the different techniques play off against each other is complicated.

Turner thanked the team for laying out a path for the high-energy-physics community. Siegrist also thanked them and noted that this report can be used as a model for Snowmass; it will also be useful in defending the program. He noted that the sponsors appreciate the risk involved.

Ramond asked why there would need to be a modified gravity. Kolb answered that there could be an ultralight scalar field that would not require modified gravity.

Lankford initiated a discussion of what needed to be put into the Chairman's letter to the agencies.

Blucher said that the possible cuts in funding reopened the competition between universities and laboratories. The community's reconsideration of balance is appropriate. Steinhardt said that universities' vision for the future of the field (i.e., young people) plays into that. The universities have to make decisions. There could be cuts in staff. They need to plan.

McBride pointed out that the operations funding is expected to be flat-flat. The nation needs to honor its international commitments.

Bassler asked what the impacts were of the discoveries at the LHC. A position and plan will need to be consolidated. Shipsey said that the LHC has excited public interest in high-energy physics and in all the physical sciences. Congressmen are hearing about this excitement and wondering why the discovery was not made here. This is an opportunity to develop a compelling narrative to sell a unified vision for the future. The physics community needs to get it right so the United States will play an important role in the exploration of fundamental physics. Lankford asked how long Congress's memory was. Steinhardt was confident that the memory is there. Siegrist said that there has to be a vision from the community; it needs to figure out what the feedback should be. Ramond said that there was a community report that looked at the relevance of particle physics; maybe this is the time for a similar report. Yamamoto said that this was a good time to look at the possible options. The emphasis of discussions is on the energy frontier. Ramond stated that the purpose is to range from the P5 frontiers, to facilities, to elsewhere. No stone should be left unturned. Byrum pointed out that there is an urgency; this is something to capitalize on; that window will close.

Lankford pointed out that there are immediate problems (cuts in the research program) and longer-term problems (new programs). One could ask what this Committee could do to help these agencies in the short term while Snowmass addresses the long-term possibilities. Siegrist replied that nothing came to mind. Lankford suggested that the advances in θ_{13} and the Higgs be used to promote high-energy-physics funding. Siegrist pointed out that the Office used θ_{13} in this year's budget discussions. It would be helpful if a consensus by the community existed. Oddone said that there is a consensus to continue the LHC. The question is whether to plan for a follow-up facility. The physics community should be responsible in support of the LHC. Shipsey pointed out that this is a singular event and that a hundred universities could be brought to the House and hold a reception to celebrate the Higgs and talk about what should be done next.

Siegrist pointed out that the Sensenbrenner agreement expires in 2017. A lasting agreement with CERN needs to be established. Steinhardt said that the new theories and experimental results that are possible in light of the Higgs discovery should be pointed out. Ramond cautioned that, when the top quark was discovered, it was cast as the *last* quark, implying that the field was dead. This is the beginning of a new era. That point has to be made emphatically and soon.

Goldberg said that the NSF response would be, "What do you want to do now?" Ramond replied that peoples' minds have to be elevated to great questions (e.g., dark energy) and show it to be part of an integrated reality.

Byrum suggested going to Congress and thanking them for their support for the Higgs. Oddone confirmed that there is a lot of interest in Congress and among the congressional staffers. Such a thankful gesture would be a good thing to do. Rameika suggested trying to share the excitement with Congress and not ask for the next money but point out that the community is going to continue evaluating what these discoveries mean through a long planning process and is going to continue the discovery process.

Lankford pointed out that the LBNE being looked at today is different from that envisioned earlier. He asked if the planners were on the right path. Glenzinski replied that it depends on whether there will be a Phase 2 where important science would be done. Bassler pointed out the need to pursue international collaboration.

Honscheid asked whether DOE should be encouraged to pursue funding for the longer-term goals. Hartill stated that the need for the accelerator upgrade needs to be emphasized. That is where the future lies. Siegrist pointed out that the Office has been trying to protect the core R&D to that end. Oddone said that Project X can contribute to the R&D and is collaborating with Sweden, Korea, and others. Kim added that the scale of that foreign support is substantial, on the order of hundreds of millions of dollars.

Lankford said that, on the cosmic frontier, the white paper from the DETF is a good model for Snowmass. The dark-energy area is moving forward. Kathy Turner said that the APS has taken the report and is moving forward on a spectroscopic experiment. If it can be gotten into the FY14 budget, exactly what that experiment should be will be clearer. If funding is sought for 5 years out, a wider range of experiments would be in the running.

Lankford asked if there were any thoughts on comparative reviews. Community concerns were expressed at the previous meeting. It was good that DPF took up the question. For years, there have been questions about the funding profiles. The guidance provided to reviewers might discuss the different roles of universities and national laboratories. Would it be worthwhile (and doable) to develop such guidance? Steinhardt replied that it would be important because universities will have to adjust to these changes. McBride said that articulating these roles would be helpful to the reviewers. Blucher added that this is a tremendous change and a good time to reassess the situation, given that two-thirds of the community has not undergone such comparative review. Lankford pointed out that there had always been a review process, but not a *comparative* review process. He asked whether a lot of senior researchers had not been re-funded. Stone said, no; there were just a few, maybe five. Many senior scientists *were* re-funded. Lankford asked whether some of the inertia had been removed. Stone answered, yes; but it was done in a consistent way. Turner pointed out that the requests that NSF got in the cosmic frontier were twice what could be funded. The review was not only of groups but of individual PIs. The panel looked at details of what each person was doing because of the pressure on the funding. Stone said that, when it was just one proposal, the panel could be more generous. Now, the potential performance can be evaluated up and down. Turner pointed out that there is no policy on salary caps, but the NSF said that a certain amount could be given for salaries. Steinhardt said that this is a profound change, and the results of something that universities need to know about in order to plan.

Ramond noted that the Snowmass process had changed. On October 11–13, there would be a meeting at Fermilab where the Snowmass conveners will report on input from the community.

At that meeting, the standards and scope of the process will become known. It will be followed in 2013 by the Snowmass meeting at the University of Minnesota, which will last for 2 weeks. That meeting will bring some clarity on where theory is and where the community wants to go. There will be no prioritization. P5 should be reconvened in the following year to set those priorities. McBride suggested that the timeframe for that prioritization should be discussed at the next meeting of HEPAP. Roe suggested that the P5 and Snowmass processes should occur in parallel.

Siegrist stated that the practical step would be to draft a charge.

There being no further comment, the meeting was adjourned at 1:29 p.m.

Respectfully submitted,
Frederick M. O'Hara, Jr.
HEPAP Recording Secretary
November 1, 2012

Andrew J. Lankford
3/11/13