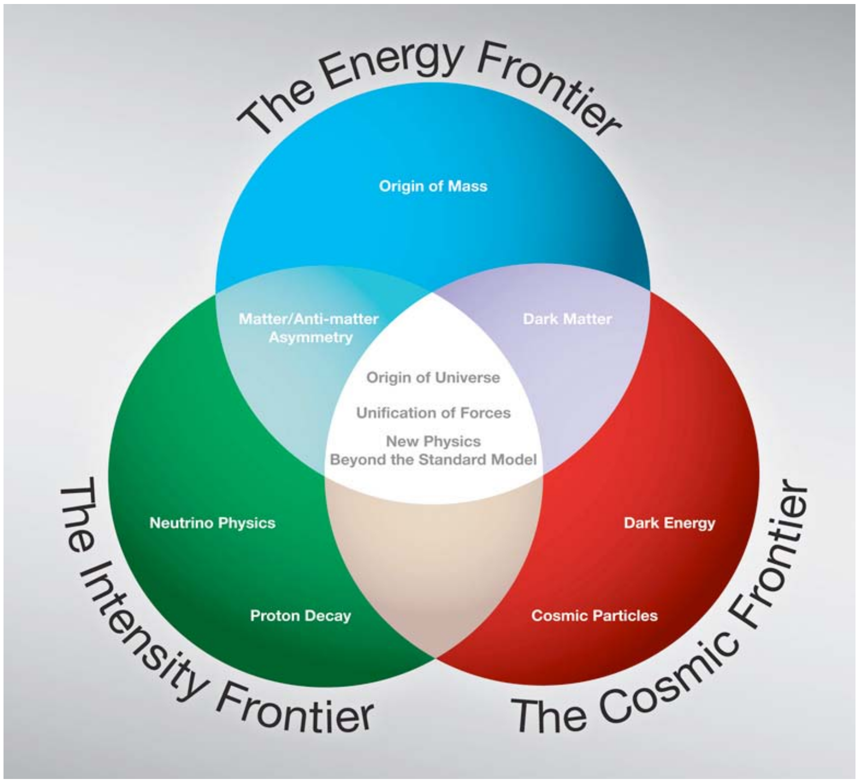
Major High Energy Physics Facilities
2014-2024

Input to the prioritization of proposed scientific user facilities for the Office of Science



HEPAP Facilities Subpanel

March 22, 2013

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Dr. W. F. Brinkman
Director, Office of Science
Department of Energy
Washington, DC 20585

Dear Dr. Brinkman:

This letter is in response to your letter to the Chairs of the Office of Science Federal Advisory Committees, dated Dec. 20, 2012, (Appendix A) requesting help with the important task of prioritization of proposed scientific user facilities. In particular, this letter reports categorization of facilities in two areas, the ability of the facility to contribute to world-leading science in the next decade and the readiness of the facility for construction.

As suggested in your letter, I empanelled a special subpanel of HEPAP to collect input, assess facilities, and prepare this report. The Subpanel was broadly composed of accomplished physicists from a variety of backgrounds, representative of the demography of the field of high energy physics. It included physicists whose primary funding is provided by NSF, as well as those who are DOE funded. Appendix B lists the members of the Subpanel.

The Subpanel received an initial list of facilities to consider from the Office of High Energy Physics. It met to review this list and to organize its activities at the end of January, and since that time has held eight additional meetings. It collected written input from contacts established for each of the listed facilities. The input requested was in the form of a one to two page summary, addressing the facility's expected scientific impact and its construction readiness. An optional supporting note of less than ten pages, which could contain references to other material, was also provided by nearly all facilities. One of the Subpanel's meetings, held on February 13, 2013 at Fermilab, was a meeting open to the particle physics community and had the primary purpose of allowing the Subpanel to have questions addressed by the facility contacts. Accordingly, its agenda was organized as a very brief introduction of each facility followed by questions and answers regarding that facility. The agenda of this meeting is listed in Appendix C. (The Subpanel greatly appreciates the input and presentations prepared by the facilities contacts and their collaborators.) The open meeting was followed the next day by a face-to-face meeting of the Subpanel. The other subpanel meetings were held as teleconferences, which were supplemented by extensive email exchange.

The Subpanel's discussions were informed by previous reports of various advisory committees. Principal among these is:

US Particle Physics: Scientific Opportunities
A Strategic Plan for the Next Ten Years
Report of the Particle Physics Project Prioritization Panel;
29 May 2008

which has guided the US HEP program for the last five years. Other important reports and studies that bear upon the facilities considered in this letter report include:

- High-Energy Physics Facilities for the DOE Office of Science Twenty-Year Roadmap (2003);
- Report of the HEPAP Particle Astrophysics Scientific Assessment Group (PASAG) (2009);
- An Assessment of the Science Proposed for the Deep Underground Science and Engineering Laboratory (DUSEL); Ad Hoc Committee to Assess the Science Proposed for the Deep Underground Science and Engineering Laboratory (DUSEL); Board on Physics and Astronomy; Division on Engineering and Physical Sciences; National Research Council of the National Academies (2011);
- New Worlds, New Horizons in Astronomy and Astrophysics; Committee for a Decadal Survey of Astronomy and Astrophysics; Board on Physics and Astronomy; Space Studies Board; Division on Engineering and Physical Sciences; National Research Council of the National Academies (2010);
- LBNE Reconfiguration; Steering Committee Report (2012); and
- Proposed Update of the European Strategy for Particle Physics; Erice (2013).

Preliminary conclusions of the Subpanel's assessments were presented to HEPAP at its meeting on March 11, 2013. Since that meeting, the Subpanel completed drafting of the letter report, and the report was approved by HEPAP.

The main body of our letter report starts in the next sections with the list of the fundamental questions that drive the field of particle physics, remarks upon the HEP roadmap process, list of the facilities considered, and remarks upon the categories used. The main body of the report, the description of the outcome of the categorization process for each facility considered, follows. As directed by the charge, no rank ordering of the facilities is provided. For each facility, a one-page description of the facility and its science goals is provided in Appendix D.

Science questions that drive the field of particle physics

Particle physics strives to discover the answers to fundamental questions about nature and the Universe by probing the smallest and largest scales. In 2008, a HEPAP subpanel, the Particle Physics Project Prioritization Panel (P5), outlined a strategic plan, a "roadmap", for U.S. particle physics growing out of nine questions set forth by "The Quantum Universe: The Revolution in 21st Century Particle Physics; DOE/NSF High Energy Physics Advisory Panel Quantum Universe Committee" and taking them as a mission statement for the field:

1. Are there undiscovered principles of nature: new symmetries, new physical laws?
2. How can we solve the mystery of dark energy?
3. Are there extra dimensions of space?
4. Do all the forces become one?
5. Why are there so many kinds of particles?
6. What is dark matter? How can we make it in the laboratory?
7. What are neutrinos telling us?
8. How did the universe come to be?
9. What happened to the antimatter?

In the course of developing the roadmap for a leadership role for the U.S. in world-wide particle physics, P5 created a view centered around three differing approaches in particle physics, labeling them as *frontiers*. The questions above and the intellectual framework of particle physics flow across the frontiers, and this division recognizes the strength of different perspectives on the same problems. The Energy Frontier seeks understanding of known phenomena and searches for new phenomena through particle collisions at the highest technically achievable energies. The Intensity Frontier makes precision measurements of known processes seeking a discrepancy with precise calculations and seeks to produce rare events not predicted by current theory. The Intensity Frontier also allows the study of neutrino oscillations and other neutrino properties. The Cosmic Frontier uses the techniques of astronomy and astrophysics to observe processes in conditions not possible on Earth, as well as particle and other techniques in underground and surface facilities, and seeks to interpret these observations in terms of new particles and/or new interactions. The P5 roadmap and frontier configuration was endorsed by HEPAP and has guided the thinking of the community. Recent years have seen important progress in each of the three frontiers: observation of a particle likely to be the Higgs boson at the LHC, measurement of $sin^2 2\theta_{13}$ in neutrino oscillation experiments, and important new limits on dark matter and on neutrino-less double beta decay.

HEP roadmap

These and other important experimental results have inspired new experiments as well as refined approaches by current and proposed experiments. This report of the present subpanel on facilities, in response to your charge, will be part of an overall prioritization in the DOE Office of Science and represents a snapshot of the major facilities of the field of particle physics. Following the charge, we considered only experiments and facilities that are within a ten-year time horizon and are expected to cost over $100M; consequently, this report is necessarily incomplete. The main planning effort for the field lies in the coming months. The particle physics community, led by the APS Division of Particles and Fields, initiated a community planning process in 2012 that involves a nearly year-long series of workshops and that will culminate in a report of its study of scientific opportunities in the coming 10-20 years. This community planning and report will lay the foundations for an update of the HEP roadmap via a new project prioritization process, with which DOE and NSF are anticipated to charge a HEPAP P5 subpanel in the second half of 2013.

List of facilities considered

As directed by the charge, we considered only those facilities that require a minimum investment of $100 million, where we have treated this minimum as the Office of Science investment in cases of interagency or international facilities. In light of the 10-year horizon of this assessment, we considered only those facilities that would initiate construction (applied as being ready for consideration for CD-1 approval) by 2024. We did not include a number of other facilities that we discussed, including a circular electron-positron collider for precision studies of the Higgs boson and other phenomena, for one or the other of the above criteria.

The list of facilities considered is:

- Facilities with CD-1 approval:
    - Mu2e (IF)
    - LBNE (IF)
    - LSST (CF)
- Facilities in an advanced stage of development:
    - High-Luminosity upgrade of LHC (EF)
        - Accelerator upgrade for the HL-LHC
        - ATLAS upgrade for the HL-LHC
        - CMS upgrade for the HL-LHC
    - International Linear Collider (hosted in Japan) (EF)
        - ILC accelerator
        - ILC detectors
    - Project X accelerator (IF)
- Facilities in conceptual development & next-generation facilities:
    - New Project X experiments (IF)
    - nuSTORM (IF)
    - Third generation direct detection dark matter experiment(s) (CF)
    - Next generation dark energy experiment (CF)

For purposes of presentation, the facilities are listed above in categories that crudely characterize the facility's phase of development. The experimental frontier to which each facility belongs is denoted by the designations: [CF] Cosmic Frontier, [EF] Energy Frontier, [IF] Intensity Frontier. An additional facility that is of great scientific interest to the particle physics community, a ton-scale neutrino-less double beta decay experiment, is being considered as part of the NSAC facilities assessment because NP is its steward; consequently, this facility is not considered in this report.

HEP facilities are of two basic types, accelerator facilities and detector facilities. Accelerator facilities provide particle beams for multiple experiments, big and/or small. The present Fermilab accelerator complex and the LHC are examples of accelerator facilities. The accelerator facilities on the list considered are the accelerator upgrade for the HL-LHC, the ILC accelerator, and the Project X accelerator.

Detector facilities are used to perform experiments, *i.e.*, to conduct a research program. Detector facilities are built, and maintained and operated, by collaborations of scientists involved in the research program. These collaborations can consist of hundreds or even thousands of scientists. Large detector facilities are typically built using resources from multiple and international funding agencies. The CDF and D0 detectors that operated at the Fermilab Tevatron and the ATLAS and CMS detectors that presently operate at the CERN LHC are examples of detector facilities. They are facilities in the sense that they serve many users and typically address multiple science questions.

The accelerator and detector facilities funded by the Office of High Energy Physics generally serve a large community of both DOE and NSF supported particle physicists, as well as scientists from other nations. Some of these facilities also serve significant numbers of scientists from other fields, most notably from nuclear physics and from astrophysics.

The scale and technical challenges of the accelerators and detectors to probe deeper and deeper into the particle world and further and further into the Universe increasingly demand international, or even global, collaboration. For instance, the LHC accelerator and detectors were built at CERN by its many member states with substantial, and critical, contributions from Japan, Russia, and the U.S. The technical development of the ILC accelerator and detectors has been conducted as a global initiative.

The facilities on the above list reflect a number of characteristics of experimental particle physics. They reflect the diversity of tools and techniques, including the three frontiers but also a variety of techniques within each frontier, that are required to address the challenging central science questions of the field. They reflect the extensive time from conception through construction demanded to address the scale and challenge of the detectors required by the science; all but one of the facilities listed above are part of the 2008 P5 roadmap, and nearly all were included in the 2003 HEP facilities 20-year roadmap (reported in response to a similar charge from the Office of Science). They also reflect the multi-generational approach to addressing the most profound questions of the field by reaching further and probing deeper on each frontier, where each generation is based upon the progress and results of its predecessors. Indeed, within the field, a number of high-energy physics facilities have ceased operation in the last decade as more capable facilities have been brought online. Finally, the list of facilities reflects the fact that some large facilities are based in the U.S. and some involve U.S. participation in facilities abroad.

Scientific progress in particle physics requires access to and intellectual contributions by U.S. scientists to central science facilities abroad, as well as offering facilities in the U.S. that fit the global program and that serve the worldwide scientific community, while providing intellectual opportunity within the U.S. This model of access and contribution has worked well in the past, although it is becoming more challenging as the size of facilities grows and the number of facilities shrinks; nevertheless, the LHC demonstrates the success of this model.

Categorization of facilities

We assess "the ability of the facility to contribute to world-leading science" and we place each facility in one of four categories provided by the charge: (a) *absolutely central*; (b) *important*; (c) *lower priority*; and (d) *don't know enough yet.* In order to be categorized as *absolutely central*, we require that: (1) the science question or questions to be addressed by the facility must be among the questions of very great scientific importance for the field of particle physics, questions whose answers have the potential to change our view of the; (2) the facility must very significantly improve upon the capabilities of existing facilities to address the scientific questions; and (3) the facility must be unique in its capabilities. In order to be categorized as *important,* we continue to require that question(s) to be addressed are of very great scientific importance; and we require that the facility must significantly improve upon the capabilities of existing facilities.

We assess "the readiness of the facility for construction" and we place each facility in one of three categories provided by the charge: (a) *ready to initiate construction*; (b) *significant scientific/engineering challenges to resolve before initiating construction*; and (c) *mission and technical requirements not yet fully defined*. In order to be categorized as *ready to initiate construction*, we require that a facility must be at a level of technical maturity to allow proceeding to the project engineering and design stage, which, in terms of the critical decision process, means ready to proceed to CD-1 approval. Because of the coarseness of the available categories, we categorize facilities that are not yet ready to initiate construction and whose mission and essential technical requirements are fully defined as *significant scientific/engineering challenges to resolve before initiating construction* regardless of how significant or how challenging the remaining research and/or development is.

Energy Frontier facilities

Accelerator upgrade for the HL-LHC
ATLAS upgrade for the HL-LHC
CMS upgrade for the HL-LHC

The Large Hadron Collider (LHC) provides the world's highest center-of-mass energy collisions. The facility just completed a successful first run, providing approximately 5 fb^{-1} and 25 fb^{-1} of luminosity at center-of-mass energies of 7 TeV and 8 TeV, respectively, to each of the two general purpose detectors, ATLAS and CMS. The next LHC run is scheduled to begin in 2015 and is projected to deliver center-of-mass energies in excess of 13 TeV, with a delivered luminosity of 300 fb^{-1} by early 2022. Another shutdown is scheduled for 2022-23, during which time substantial upgrades to the LHC and to both experiments, ATLAS and CMS, will be installed. U.S. participation in three facilities is associated with the upgrade: accelerator upgrades for the High-Luminosity LHC (HL-LHC); the ATLAS upgrade to operate at HL-LHC; and the CMS upgrade to operate at HL-LHC. The accelerator upgrade will increase integrated luminosity to the experiments by a factor of ten with respect to the integrated luminosity anticipated before the upgrade (a factor of 100 with respect to present). The associated large data sample and the ATLAS and CMS upgrades will support a diverse particle physics program. Measurements of the properties of the Higgs boson will be substantially improved, and the data sample will enable the study of rare decays of the Higgs as well as of the top quark. If new physics is discovered in the period before the upgrade, the samples available to explore that physics will be greatly enhanced at the HL-LHC. The reach for new physics will also be increased, both by probing higher mass scales and by exploring processes with smaller production cross sections. U.S. scientists will contribute critical expertise and experience to the accelerator upgrade and to the upgrade of both ATLAS and CMS, and to the ensuing research program, as they have for the current facilities. U.S. participation in all three upgrades is almost certain to be required for continued participation of U.S. scientists in the international experiment collaborations. In this era, the LHC, and the ATLAS and CMS upgrades, will also serve a significant number of scientists from the U.S. nuclear physics community who study relativistic heavy ion collisions at the LHC. The accelerator upgrade for the HL-LHC will deliver the large data samples that fuel the HL-LHC research program; it is *absolutely central*. Although the technologies needed for the accelerator upgrade have been proven, there remain *significant scientific/engineering challenges to resolve before initiating construction*. The ATLAS and CMS upgrades are required to maintain the present capabilities of the detectors in the high luminosity environment of the HL-LHC, and thus to enable the HL-LHC research program. The two experiments complement and reinforce each other, and the results of the two experiments can be combined to improve statistically limited measurements. Both the ATLAS upgrade for the HL-LHC and the CMS upgrade for the HL-LHC are *absolutely central*. The detector technologies required for the ATLAS and CMS upgrades exist; however, designs are not yet ready to initiate construction, and for this reason the readiness classification *significant scientific/engineering challenges to resolve before initiating construction* is assigned to both ATLAS and CMS upgrades.

International Linear Collider (hosted in Japan) - Accelerator
International Linear Collider (hosted in Japan) - Detectors

The discovery of the Higgs boson reinforces the strong scientific case for the International Linear Collider (ILC). The ILC research program will be complementary to the research program of the LHC (and HL-LHC), in that it can deliver measurements that are complementary, as well as enable searches for new physics that are complementary to those performed at the LHC. For instance, the ILC enables high precision measurements of Higgs boson properties in a program complementary to the LHC. Beginning at energy above the threshold for production of pairs of top quarks, the ILC will allow a detailed study of top physics, which is closely connected to the phenomenon of electroweak symmetry breaking. Through precision measurements, the ILC will be a sensitive probe of new physics, such as that from additional gauge bosons and extra dimensions at high mass scales. The ILC accelerator and detectors enable a research program that will address questions of very great scientific importance, and both the accelerator and the detectors are *absolutely central*. The initiative from the Japanese particle physics community to host the ILC in Japan is very welcome, and the U.S. particle physics community looks forward to a proposal from Japan to discuss possible participation. The ILC accelerator has been the subject of a comprehensive international development program with significant U.S. contributions and leadership roles. A technical design report for the accelerator facility was recently completed; the ILC accelerator is technically *ready to initiate construction* once agreements are reached in Japan and internationally. Detailed baseline designs for the detectors have been completed; however, engineering remains before the ILC detectors are ready to initiate construction, and for this reason the readiness classification *significant scientific/engineering challenges to resolve before initiating construction* is assigned.

Intensity Frontier facilities

Mu2e

Understanding the source of lepton flavor violation is a question of very great scientific importance. The discovery of neutrino mixing established that lepton flavor is not conserved; however, flavor violation in the charged lepton sector has not yet been observed. The Mu2e experiment will search for the conversion of a muon to an electron in the field of a nucleus and will improve the limits on flavor violation in muon interactions by four orders of magnitude and reach a sensitivity where a positive signal would be expected in many models. The Mu2e experiment is *absolutely central*. The project has CD-1 approval and is therefore classified as *ready to initiate construction*.

LBNE

The 2008 P5 report recommended a world-class neutrino program as a core component of the US HEP program. This report envisioned a large detector underground targeted by a high intensity neutrino beam and that would be capable of a broad physics program including the study of neutrino oscillations in order to resolve the neutrino mass hierarchy, to search for CP violation in the neutrino sector, and to search for new physics in neutrino oscillations, while contributing also to the search for proton decay and to measurements of neutrinos from galactic supernovae. The 2010 NRC assessment of the Deep Underground Science and Engineering Laboratory (DUSEL) characterized the neutrino experiment as “an exceptional opportunity to address scientific questions of paramount importance”, and characterized its sensitivity to the study of proton decay and to detection of supernova neutrinos as “of great scientific interest”. The first stage of the Long Baseline Neutrino Experiment (LBNE) initiates the program toward that long term goal. In this stage, a new neutrino beam line, initially to be operated at 700 kW, but capable of 2.3 MW, will be constructed at Fermilab and directed towards a new massive high-sensitivity neutrino detector at the Homestake mine. LBNE will bring several unique features to the future study of neutrino oscillations; its baseline will be the longest in the world, it will study oscillations over the broadest range of neutrino energies, and it will advance the technology of neutrino detection. This stage of LBNE will make significant advances in the measurement of the neutrino mass hierarchy and begin the search for CP violation in neutrinos. Additional participation from international collaborators could significantly extend the science program of this first stage. The first stage of LBNE is *important* and it lays the foundations for the *absolutely central* world-class neutrino program envisioned by P5. The first stage has CD-1 approval and is therefore classified as *ready to initiate construction*.

PROJECT X accelerator
PROJECT X experiments

The Project X accelerator facility is an evolution of the Fermilab accelerator complex that can simultaneously produce high-intensity beams of various particle species (*e.g.,* neutrinos, muons, kaons) to support a suite of Project X experiments studying a broad range of science questions. The Project X accelerator would be a world-leading facility for supporting a broad Intensity Frontier research program, and would be capable of providing beams with unique characteristics required by specific experiments. In addition to enabling new experiments, the Project X accelerator facility would dramatically enhance the physics capabilities of some existing and proposed experiments, including the Mu2e and LBNE facilities. The full Project X research program is currently in the planning stage, and includes a spallation target optimized for particle physics applications.

The Project X accelerator facility can be deployed in stages, with each successive stage introducing new world-class research capability and each stage retiring significant legacy elements of the Fermilab accelerator complex. The Project X accelerator facility and the associated spallation target have potentially broader impacts beyond particle physics as a resource to the nuclear physics, material science, and fusion energy communities. The fusion energy community for instance identified a “Materials Facilities Initiative” utilizing a spallation target as absolutely central to Fusion Energy Science.

The development of Project X was endorsed by the 2008 P5 report, which recommended an R&D program in the immediate future to design a multi-megawatt proton source at Fermilab. The importance and breadth of the research program that it enables and enhances, leads the Project X accelerator facility to be classified as *absolutely central*. Although R&D is still required for the spallation target needed by some experiments, all stages of the Project X accelerator facility are *ready to initiate construction.*

Project X experiments that compose the research program range from important to absolutely central, but scientifically the Project X research program as a whole is classified as *absolutely central*. Being in the planning phase, the construction readiness of the Project X research program is classified as *mission and technical requirements not yet fully defined*, although some experiments are beyond this phase.

nuSTORM

nuSTORM would be a unique neutrino facility based on a muon storage ring that would provide neutrino beams with well-defined flavor composition and spectrum. It would also serve as a valuable platform for developing muon storage ring technology. nuSTORM would be superb for measuring neutrino cross sections and for exploring anomalies observed in prior short baseline neutrino experiments. nuSTORM is still in the early stages of planning, and while a proposal is planned for June 2013, neither a proposal nor a design report is currently available. At this time, we classify the scientific capabilities of nuSTORM as *don’t know enough yet.* While we are not aware of significant technical challenges facing nuSTORM, we are unable to evaluate construction readiness based on the currently available information and classify it as *mission and technical requirements not yet fully defined*.

Cosmic Frontier facilities

Third Generation Direct Detection Dark Matter Experiment(s) (DM-G3)

Detection of dark matter presents one of the greatest experimental challenges of all time, and definitive detection will rely in successful integration of results from nuclear recoil experiments (often referred to as direct detection), the LHC, as well as astrophysical and astronomical measurements (often referred to as indirect detection). The nuclear recoil technique for searching for dark matter has improved in sensitivity over the last twenty-five years by a factor of ten billion, about a decade of sensitivity every two and a half years. This technique, in which the recoil energy of a nucleus struck by a dark matter particle is measured two or more different ways, has been applied to gas, liquid, and solid target media, and it has currently achieved thresholds of a few keV, critical for high detection efficiency. Presently, DOE and NSF have a well defined roadmap of second followed by third generation detectors that will provide increasingly greater sensitivity in coupling over a wide range of possible dark matter masses. The second generation of detectors, which are presently under development, will probe couplings comparable to those accessible to the LHC. The third generation would improve sensitivity by an order of magnitude. Owing to the difficulty of the measurement, at least two detectors will be needed to establish a result. Third generation dark matter nuclear recoil detectors are *absolutely central*. The third generation of detectors has *significant scientific/engineering challenges to resolve before initiating construction*.

LSST

The Nobel Prize for Physics in 2011 was awarded for the discovery of the accelerating expansion of the Universe, but the basic question "Why is the expansion speeding up?" remains unanswered. The Large Synoptic Survey Telescope (LSST) is an 8.4-meter telescope with a 3-Gigapixel camera that, over 10 years starting early in the next decade, will carry out deep, wide imaging surveys of the southern sky. While of interest to a broad astronomy and astrophysics community, addressing the fundamental questions about cosmic acceleration is among the primary scientific objectives of the LSST. LSST is the central next-generation component in the DOE OHEP program to explore dark energy. It will measure the cosmic expansion history and growth of structure in the Universe through measurements of supernovae, weak and strong gravitational lensing, large-scale galaxy clustering, and clusters of galaxies. Its ability to contribute to world-leading science is *absolutely central*. The LSST telescope project has been approved by the National Science Board for MREFC funding at NSF, and the LSST camera project has been awarded CD-1 approval by DOE. LSST is therefore classified as *ready to initiate construction*.

Next Generation Dark Energy Experiment

The discovery that the expansion of the Universe is speeding up engendered a progressive program of U.S.-led Cosmic Frontier experiments that will probe dark energy and the physical origin of cosmic acceleration with increasing precision. Determining the ultimate nature and properties of dark energy and the physical cause of cosmic acceleration is challenging and requires multiple techniques and facilities. The Next Generation Dark Energy Experiment embodies the recognition that a future facility complementary to LSST will be necessary to more fully address these fundamental questions. Examples of such an experiment include: WFIRST (Wide-Field Infrared Space Telescope), a proposed NASA space mission; a large-aperture (8-10m) ground-based telescope that could carry out deep, wide spectroscopic redshift surveys of LSST targets; and 21-cm intensity mapping radio observations to measure baryon acoustic oscillations. A next-generation dark energy facility would be world-leading and, given the importance of the fundamental questions that it would address (such as the nature of 70% of the Universe) it is *absolutely central*. The readiness of the facility depends upon which facility concept is pursued; consequently, the construction readiness of the next generation dark energy experiment is classified as *mission and technical requirements are not yet fully defined*.

Conclusion

The facilities characterized above as *important* and as *absolutely central* are those facilities that are required in order to address the critical scientific questions of the field of particle physics. Together these facilities will constitute the integrated program on the three frontiers of the field, Energy, Intensity, and Cosmic, that will lead to the discoveries that will propel the field forward in its understanding of physics on both the smallest and largest scales. These facilities provide for a program that progressively reaches further and probes deeper, and where each subsequent step is informed by the progress of its predecessors. These facilities also reflect the international, and increasingly global, character of the field of particle physics, as they reflect U.S. facilities and participation in facilities outside the U.S. in the context of a worldwide program.

Respectfully,

Andrew J. Lankford

Andrew J. Lankford
Chair, HEPAP

cc: Patricia Dehmer
James L. Siegris