Report of the Committee of Visitors

Office of High Energy Physics

to the

High Energy Physics Advisory Panel

Review of Fiscal Years 2016, 2017, 2018, and 2019

Germantown, Maryland (Virtual Meeting)

October 1, 13, and 21-22, 2020

Executive Summary

At the request of the High Energy Physics Advisory Panel (HEPAP), a Committee of Visitors (CoV) conducted a review of the DOE Office of High Energy Physics (HEP) Research and Technology program during the fiscal years 2016 – 2019. The review was conducted via remote conference on October 1, 13, 21 and 22, 2020.

During the period under review, HEP has attentively managed Research and Technology proposals, has strengthened communication with the community, and has engaged the community in reviews of programs and operations, targeted workshops, and roadmap study groups. It is an impressive record, and the resulting program is of high quality.

Since its release in 2014, the report of the Particle Physics Project Prioritization Panel (P5) has provided a roadmap for High Energy Physics. HEP has largely adhered to the report's guidance, and today, nearly all of the exciting new projects envisioned by P5 are complete or under construction. At the Energy Frontier, ATLAS and CMS implemented their Phase I upgrades and construction of the High Luminosity upgrades is underway. At the Intensity Frontier, Muon g-2 expects initial results soon and Mu2e is under construction. The Long Baseline Neutrino Facility (LBNF) is being excavated for the flagship DUNE experiment and PIP II is finalizing costs. On the Cosmic Frontier, the LSST camera at the Rubin Observatory will soon see first light and begin its survey of the universe, DESI has been commissioned and will begin its studies of dark energy, and plans for CMB-S4 are beginning to take shape. LZ is preparing to begin its search for massive dark matter and SuperCMDS at SNOLAB will follow with sensitivity to low mass. These experiments address some of humankind's deepest questions about nature and each is unique in the world; the ensemble comprises a world-leading program.

High Energy Physics is a global science, and its experiments depend on international collaboration for success. International partnership brings both shared technical know-how and the financial support needed to mount experiments whose extraordinary scale and complexity often put them out of reach for any individual nation. The need for international partnership in HEP will continue into the future, but in an evolving global context that places heightened attention on national security and the ownership of ideas. HEP will be in the vanguard in adopting new practices that respond to this context, while fostering the prudent exchange of ideas and international cooperation that are required to realize some of humankind's most ambitious endeavors.

The suite of experiments now under construction will rely on the Research and Technology program in order to realize its science, and it is fitting that this program was the focus of the COV charge. Students, postdocs and senior investigators in the Experimental Programs will operate the experiments, calibrate the detectors, and analyze the data. Theoretical physicists will interpret the experimental results, translating them into new understanding of nature. At the same time, scientists in the Technology Programs will begin to prepare for the next round of experiments by developing the knowledge needed to increase their performance and reduce cost.

Because of the importance of the Research and Technology program for translating the experiments into new understanding of nature and preparing for the future, P5 cautioned against reductions in level of effort (See P5 Recommendation 7.) and adopted an internal guideline of greater than 40% of the HEP budget to be allocated to the Research and Technology program.. Since the last COV, support has fallen below that level and at the same time, the program has expanded to encompass new research into Quantum Information Science (QIS) and Artificial Intelligence & Machine Learning (AI/ML). COVID-19 has exacerbated the strain on the research and technology budget largely by delaying several large projects that had recently transitioned to operations. In coming years, the pressure on the Research and Technology program is likely to increase because of new operations expenses as additional experiments come online. The result is that the ability of the university and laboratory groups to design and build, operate and analyze, and theoretically interpret the experimental data is at risk, and the accelerator and detector R&D needed to enable the next generation of experiments has been sharply curtailed. If allowed to continue, the consequences will become severe at a time when the Research and Technology program is increasingly central to realizing the P5 program.

Recommendation 1: Increase effort in the Experimental, Theoretical, Accelerator R&D and Detector R&D research programs in order to realize the promise of the portfolio of current and new experiments and to prepare for future endeavors. In the next year HEP should present a strategy to HEPAP for increasing the allocation to these programs by at least 4-5% per year until effort returns to the pre-P5 level, and should strive to return to 40% of HEP expenditures.

Table of Contents

A. Introduction

This report documents the findings from a Committee of Visitors (COV) that was assembled under the auspices of the High Energy Physics Advisory Panel (HEPAP) to evaluate the processes and programs in the Office of High Energy Physics (HEP) during the fiscal years 2016-2019. The COV met through virtual meetings on October 1, 13, and 21-22, 2020. This was the sixth in the series of COV reviews in the Office of High Energy Physics; the previous review was in 2016.

B. The Charge to the Committee of Visitors

The charge to the COV was established in a letter from the Chair of HEPAP, Prof. JoAnne Hewett, to Dr. Ritchie Patterson, who had agreed to chair the COV. The letter is attached as Appendix I. The charge was to address the operations of the Office of High Energy Physics during the fiscal years 2016, 2017, 2018, and 2019, in accordance with the Guidance for COV Reviews.

The main elements of the charge were as follows:

> The subpanel should assess: (1) the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document funding actions; and (2) the quality of the resulting portfolio, including its breadth and depth of portfolio elements, its national and international standing, and the progress HEP has made toward its long-term program goals since the last review of these milestones by HEPAP. The COV should comment on the effectiveness of the DOE implementation of the long-term goals and priorities as reflected in the HEP research program according to the 2014 report of the Particle Physics Project Prioritization Panel (P5). Are the actions of HEP maintaining the capabilities needed for healthy laboratory and university programs? Is the balance of research funding optimal – both overall and between the program components? Comments and suggestions for improving HEP processes and their implementation, as well as on the observed strengths or weaknesses in any component or sub-component of the HEP portfolio would be appreciated. The COV should assess progress in addressing the recommendations of the previous (2016) COV. It should also identify any significant issues that the COV is not able to appropriately consider within the limited timespan of this review, but which deserve subsequent consideration.

C. The Committee Membership

The COV membership was selected by the COV chair, Dr. J. Ritchie Patterson, in consultation with the chair of HEPAP and the HEP Associate Director leadership. The members were chosen to represent a cross-section of experts in scientific fields relevant to the activities supported by the Office of High Energy Physics. A balance was achieved between researchers who currently receive funding from HEP and those that do not (16 and 6 respectively), and between academic institutions (14) and national laboratories (8).

The COV consisted of a total of 21 members, plus the chair, and were divided between 4 panels for the first reading of the grant and FWP folders, and 3 panels for the second reading of the folders. The panels were:

1. Experiment (Energy, Intensity and Cosmic Frontiers)
2. Theory
3. Accelerator R&D and Accelerator Stewardship
4. Quantum Information Science
5. Detector R&D
6. Artificial Intelligence, Machine Learning and Computational HEP
7. Diversity

The following COV members served as the leaders for the Panels: Prof. Meenakshi Narain (Experimental), Prof. Timothy Tait (Theory), Dr. Sergei Nagaitsev (Accelerator R&D and Accelerator Stewardship), Prof. Ron Walsworth (QIS), Dr. Marcel Demarteau (Detector R&D), Prof. Kyle Cramner (Computatonal HEP and AI/ML), Dr. Hirohisa Tanaka (Diversity).

A full list of the COV members and their panel assignments for the first and second readings of the folders is given in Appendix II and Appendix III, respectively.

D. The COV Process

The COV assembled on Tuesday, October 1, 2020 from 1:00-3:15pm Eastern Time, on Tuesday, October 13, 2020 from 1:00-4:40pm Eastern Time, on Wednesday, October 21, 2020 from 10:00am-4:30pm Eastern Time, and on Thursday, October 22, 2020 from 1:00 pm-6:15pm. All meetings were virtual, conducted using DOE Zoom. The agenda for the COV is attached as Appendix IV.

Prior to convening, each COV member was supplied with access to the COV module in PAMS. Within PAMS was a comprehensive set of information pertaining to: the COV process, the report template, the core research activities, the procedures used by HEP in reviewing both university and national laboratory applications, and a copy of the 2016 HEP COV report together with the response from HEP. This comprehensive documentation set the stage for the COV meetings and served as a valuable resource for the panel members throughout the process.

The October 1st meeting began with an overview of the COV process and a reiteration of the charge from HEPAP by COV Chair Patterson. This was followed by an overview of Research and Technology Division by Dr. Glen Crawford, and overview of Operations and Projects by the Dr. Michael Procario.

The October 13th meeting consisted of presentations about each of the programs under review by its program manager. These were Energy Frontier (Dr. Abid Patwa), Intensity Frontier (presented by Dr. Glen Crawford), Cosmic Frontier (Dr. Kathleen Turner), Theory (Dr. William Kilgore), Detector R&D (Dr. Helmut Marsiske), General Accelerator R&D (Dr. L.K. Len), HEP Computing and AI/ML (Dr. Lali Chatterjee), and Accelerator Stewardship and Traineeship (Dr. Eric Colby).

The reading of the folders began on October 21st. Each panel was supplied with electronic proposal folders to evaluate the Research and Technology Division award/decline/monitor process. The first two folder sessions addressed the Experimental Program, Theory Program, Quantum Information Science, and Accelerator Programs. A third session addressed Computational HEP and Machine Learning, Detector R&D and Diversity. During all sessions, the relevant program managers were available to the subcommittees to respond to questions. The program also included a presentation and discussion of Diversity led by Dr. Alan Stone and Dr. Julie Carruthers of the Office of Science. At the end of the day, the committee convened for a preliminary discussion of their findings and potential recommendations.

The provided grant proposals were distributed among four types of programmatic decisions: big awards, small awards, strong awards, weak awards, and proposals rated near and far from the threshold for funding. The total was no more than ten proposals per panel. In general, the number of proposals reviewed reflected the budget and numbers of applications for the subprograms. The panels were free to request any additional materials (including folders for other projects) and information that they felt would help them in their evaluation process.

For laboratory-based field work proposals (FWPs), the panels reviewed laboratory triennial reviews for renewals of projects plus mail reviews for new projects.

The October 22nd meeting included further folder review as well as extensive discussion within the subcommittees where they refined their findings based on further review and prepared material for the report. The entire COV then met in executive session to discuss and reach consensus on the major findings and recommendations. In the late afternoon the COV Chair and panel leads met and presented the major findings and recommendations to HEP management, and then to all of HEP staff.

The HEP staff provided extensive written comments in response to questions from the COV on October 13, October 16 and October 21. This documentation included descriptions of the responses to the 2016 COV report and to targeted questions addressing each of the programs and crosscuts.

The written reports from the panels (Appendix V - Appendix X) and the conclusions and recommendations drawn from the executive session provided the basis for this report.

E. Major Findings, Comments and Recommendations

The COV compliments HEP for its excellent organization of the review. The presentations were clear and well-focused, documentation was extensive, and the staff responded with thought and detail to the committee’s many questions.

The following sections address the main components of the committee's charge as follows: 1) Proposal solicitation, review and implementation; 2) Diversity, Equity and Inclusion; 3) Portfolio quality; 4) Consistency with P5 recommendations; and 5) Response to the recommendations of the 2016 COV.

1. Proposal procedures

a) Proposal Solicitation and pre-proposal communication

Finding: In the last few years, HEP has made strides in communicating its expectations to PIs, largely through its series of PI meetings, where program managers explain program goals, funding criteria, advice on proposal structure, and the review process.

Comments: This process has helped increase proposal quality and reduce the incidence of non-compliant proposals. Furthermore, by increasing the transparency of the process, these meetings have increased the equity of the proposal process and lowered the barriers to entry for new PIs. We commend HEP staff for this success.

The COV identified additional topics that could be added to those presentations, including HEP perspective on Detector R&D and GARD proposals that are not project-driven, increased guidance for PIs seeking to migrate between programs, and the opportunity for supplements for those in demanding leadership positions. The COV encourages HEP to continue to define its expectations for proposals and communicate them to the community.

b) Proposal review

Findings: HEP has continued comparative reviews for university and laboratory programs. The university comparative reviews begin with mail-in reviews followed by a panel primarily composed of mail-in reviewers, which assesses all proposals in the same program and assigns them to tiers based on their priority for funding.

Laboratory comparative reviews during the period under review have addressed the Experimental Frontiers, Detector R&D, Theory, and GARD, on a cycle of approximately 4 years. A panel assesses the activities at each laboratory based on team presentations and, in some cases, a written report summarizing achievements and plans.

In addition to the comparative reviews, HEP carries out many other reviews. Laboratory institutional reviews address one laboratory each year on a rotating basis. To distinguish them from the comparative reviews, these have been reformatted to address the five science drivers identified by P5 and other topics that cut across laboratory divisions and departments. Since the last COV, HEP has also conducted a Portfolio Review (2018), Laboratory Optimization reviews (2016-18), regularized optimization reviews, and small laboratory institutional reviews.

Comments: HEP's processes for proposal and laboratory review are thorough and have increased the quality of the program. This COV, like the last one, commends HEP for its continuation of this important process.

In spite of considerable effort by the Program Managers to solicit mail-in reviews, the COV observed proposals that received no written reviews in advance of the panel. The COV echoes Recommendation 9 of the 2016 COV.

Recommendation 2: Ensure that an adequate number (at least 3) of written reviews is in hand for each PI in advance of the panel review.

Finding: The laboratory reviews consist only of a panel review, without mail-in reviews.

Comment: The mail reviews are a notable strength of the university comparative reviews because they ensure that each proposal is reviewed by at least two experts in the proposed topic areas. The mail reviewers provide a broader, deeper pool of expertise than a committee alone can offer, and could enhance the quality and thoroughness of the laboratory reviews.

Mail review of laboratory programs would increase parity between the laboratory and university comparative review procedures. We note that this issue was also raised by the prior COV, which included the following recommendation:

> COV 2016 Recommendation 8: Encourage HEPAP to form a study group to consider whether the agencies should convene a subpanel to evaluate different roles and responsibilities in university and laboratory research and the ways in which this research is evaluated.

The COV recognizes that adding mail-in reviews to the laboratory comparative reviews adds work for an already busy staff. To contain this, HEP could consider using the same page limits for laboratory proposals as for those from universities and relaxing the interval between laboratory comparative reviews to five years.

Recommendation 3: Solicit mail reviews as part of the laboratory comparative reviews. The mail reviewers should include university scientists.

Finding: HEP provides merit criteria questions in Section V of the Funding Opportunity Announcement (FOA) and to merit reviewers and panelists. The merit criteria categories are 1) Scientific and/or Technical Merit of the Proposed Research; 2) Appropriateness of the Proposed Method or Approach; 3) Competency of Research Team and Adequacy of Available Resources; 4) Reasonableness and Appropriateness of the Proposed Budget; and, 5) Alignment of Proposed Research to the Priorities Established in the P5 Strategic Plan. HEP provides a series of questions for each category that fleshes out the intent.

Program managers highlight the criteria at the start of panel deliberations. The program managers also discuss topics such as program alignment with the P5 plan, the development of a diverse group of supported researchers, and opportunities for early-stage scientists.

Comment: In spite of this effort, reviewers vary in their application of the criteria, with some reviewers rating all proposals in the top echelon and others using the full range of ratings. There also appears to be considerable variation in the weightings that the reviewers give to the various criteria.

Inconsistency in the ratings reduces the utility of the reviews and increases the burden on the HEP staff, who are stuck trying to discern reviewer intentions. The variability also hampers cross-program comparisons that could assist HEP in planning. For these reasons, the COV encourages HEP to provide reviewers with guidance on the meanings of each rating. This guidance could be as simple as providing the typical proportion of proposals in each level.

Recommendation 4: Develop guidance for mail-in and panel reviewers about proposal ratings in order to improve consistency.

Comment: Reviewer assessments are often based on their experience or impressions, in addition to information contained in the proposal; consequently, these assessments tend to be subjective and anecdotal. This issue is particularly concerning for the question on the competency of the team because it has the potential to hinder some underrepresented groups, either because of unintended biases or because of practical barriers that could reduce PI visibility. While the program managers actively try to prevent inequities of this type, the COV believes that the emphasis of the reviews should be on information contained directly in the proposal. The COV believes that the current proposal elements, which include both recent achievements and clear research plans, should be sufficient for robust merit review.

Recommendation 5: Inform review panels and mail-in reviewers about the impact of biases regarding gender, race, age, and institution.

Recommendation 6: Set clear expectations for mail-in and panel reviewers that proposal evaluation should be based on proposal content and documented information, rather than on impressions or anecdotal information about prior performance by the PI(s).

Finding: HEP increasingly emphasizes quality mentorship in its proposal processes. It identifies quality mentorship as a sign of leadership in presentations at PI meetings and the FY21 FOA lists it among the Program Policy Factors, which Program Managers consider in making award decisions. To date, however, proposals need not include a mentorship plan and the quality of mentorship is absent from the merit review criteria.

Comment: Effective mentorship for students and postdocs has lasting benefits for their careers and earnings, and is therefore a mechanism for amplifying the impact of HEP student and postdoc support on future advancement of US science and technology. Formal mentorship is particularly valuable for students and postdocs from underrepresented groups, who may have limited access to informal advice from other scientists. For these reasons, the COV welcomes the addition of mentorship and other diversity considerations into the Program Policy Factors.

Mentorship quality would be further enhanced if mentorship planning were incorporated into the proposal review process. The COV believes that mentorship is sufficiently important that it warrants its own merit review category, perhaps following an initial step of including mentorship quality among the questions that define one of the existing merit review categories. Appropriate policies would emphasize the quality of the plan for mentorship and avoid penalizing early career PIs without a mentorship track-record.

Recommendation 7: Promote the importance of effective mentorship as a consideration in the proposal review process.

c) Award implementation and feedback to PIs

Finding: The interval between issuing of FOAs and the proposal deadline can be as short as six weeks, and award notification sometimes takes place after the start of the funding period. Moreover, the COV heard that sometimes late FOAs result in a review period for Early Career awards that is insufficient to accommodate both mini-panel and super-panel reviews.

Comment: Given the amount of work for PIs to assemble a compelling proposal, deadlines should not be allowed to decrease to fewer than eight weeks from the release date of the FOA. Short deadlines particularly disadvantage PIs who are not "in the know" about pending FOAs, perhaps because they are junior or have a weaker support network. Underrepresented minorities disproportionately fall into this group.

Both the 2016 COV and HEP staff have highlighted the benefits of conducting both mini-panel and super-panel reviews for the Early Career program.

Notifications to PIs of proposal decisions should be timely, since prompt knowledge of the outcome, whether positive or negative, allows the PI to plan appropriately for students and postdocs.

Recommendation 8: Work with SC for more timely release of FOAs in order to allow adequate time for proposal preparation and review and PI notification before the start of the award period. In the case of the Early Career awards, the timeline should accommodate both mini-panel and super-panel reviews.

Recommendation 9: Notify PIs of award decisions promptly, whether positive or negative.

Finding: The COV observed that some proposals are declined without explanation to the PI.

Comment: Useful feedback about the review process allows PIs to improve future proposals and is particularly valuable to PIs whose proposals were declined. Comparative review results should contain a clear summary that explains the panel's reasoning, including comments on the strengths and weaknesses and tier assignment. A panel member could be designated to write this summary for each task reviewed, including the task's tier level. Program Managers should provide an additional summary that (a) explains the final decision if it differs from the mail-in and panel reviews, (b) informs PIs about the opportunity for verbal feedback at their "office hours", and (c) for positive decisions, gives the details of the final award decision and budget guidance.

While making sure that funded groups have adequate support to carry out their approved scope is important, the precision of the recommended individual award funding levels is less important than overall fairness and balance of the funding decisions.

Recommendation 10: Provide an explanation of funding decisions to PIs, particularly in the case of declined proposals or those with significant weaknesses.

Recommendation 11: Advise panelists to prioritize feedback to PIs through written reviews and/or summaries of panel discussions over detailed rankings of PIs and proposals.

Finding: The PAMS system is capable of storing extensive information about each proposal, including the proposal text, budgets, reviews, and correspondence. Because the COV meeting was conducted via videoconference, the COV depended on PAMS in order to access all proposal-related information.

Comment: The COV found PAMS cumbersome, and a large fraction of the folder review sessions were spent learning how to navigate it. This issue noticeably reduced the committee's ability to review HEP proposal processes, in spite of considerable effort by individual committee members outside the scheduled hours. One complication is that each Program Manager appears to have developed his or her own methods for using PAMS, so that the location of proposal reviews, for example, varies from program to program. This means that a single instruction manual would not address the problem; instead, separate instructions are required for each program.

The committee advises HEP to provide written instructions to the next COV for accessing: 1) proposals; 2) mail-in reviews; 3) panel reports and panelist names; 4) final award decision by task and associated justification, and 5) feedback to PIs. Alternatively, HEP could provide pdf files that include this information. If possible, all programs should use the same practices for storing proposal related information, and persistent differences should be clearly documented for the next COV.

The committee is grateful to Christie Ashton for her tireless assistance with PAMS, without which the committee would have been lost.

2. Diversity, Equity and Inclusion

Finding: While HEP currently offers PIs an opportunity to provide demographic information, many PIs do not respond. Demographic information presented to the COV, for instance on gender of PIs, was generally based upon the assessment of program managers rather than on self-identification by PIs.

Comments: An essential part of a plan to address diversity, equity and inclusion is documenting the demographics of PIs, their groups, and reviewers. While such information cannot be required, the response rate could be increased by requiring a response to diversity questions. PIs preferring not to provide such information could be accommodated by including a "prefer not to respond" option for each question.

Recommendation 12: Implement measures to improve the collection of demographic data for participants in HEP processes (PIs, personnel supported by grants, reviewers, etc.).

Finding: HEP is coordinating with the Office of Science initiative to address diversity, equity and inclusion (DEI). Following SC guidance, the laboratories collect demographic data and have developed DEI strategies, addressing leadership and accountability, recruiting and hiring practices, professional and leadership development opportunities for employees, and fostering inclusive research environments. SC has commenced an external review of the laboratory strategies. To address SC business practices, it convened a D&I working group that generated 15 recommendations, which are under review by SC leadership, and with their approval, an implementation working group will be convened. In the meantime, DOE has policies prohibiting discrimination and harassment, in accordance with federal civil rights laws, and these are posted on its public website.

Comments: The COV commends the HEP staff for their considerable effort to address diversity, equity and inclusion (DEI) since the prior COV. They express significant awareness of the issues and their importance, and in addition to enforcing the general DOE practices, they have taken the initiative in several instances to address DEI. For example, HEP now informs panels about special considerations for proposals from non-traditional institutions, and a few have been funded.

Nevertheless, clear DEI policies are absent in the HEP office, and need to be developed and implemented. These should address topics such as steps to mitigate bias in the review process, consequences for PIs found by their institution to have violated Title IX regulations, and policies for managing work-life balance for supported researchers. While developing such policies will be demanding in the short-term, they will lead to more consistent and sustainable practices.

Recommendation 13: In consultation with SC, develop and implement strategies and policies to foster diversity, equity and inclusion in supported university groups as well as at the laboratories. The policies should be widely publicized to the community, for example through presentations to HEPAP and at PI meetings.

3. Portfolio Quality

Finding: The Research and Technology Division in the Office of High Energy Physics consists of Physics Research in Experiment (Energy Frontier, Intensity Frontier and Cosmic Frontier) and Theory, General Accelerator R&D and Accelerator Stewardship, Detector R&D, Artificial Intelligence/Machine Learning (AI/ML), Computational HEP, and Quantum Information Science. It includes both research and university-based operational activities. Facilities Operations, Instrumentation and Major Systems, and Projects were outside the COV charge.

Comment: HEP has managed the Research and Technology program with care and has adhered closely to the P5 plan and the P5 Science Drivers. The resulting program is of high quality with world stature.

The program takes advantage of data from experiments at each of the three frontiers: The Large Hadron Collider at the Energy Frontier, a powerful program in neutrino physics and rare processes at the Intensity Frontier, and telescopes and detectors targeting dark matter, dark energy and cosmic inflation at the Cosmic Frontier. Accelerator and detector R&D enable these, and Theory interprets the results and guides the path forward. Thanks to vigorous construction spurred by the P5 report, the array of experiments is expanding with exciting opportunities ahead.

During the last five years, HEP funding has been redirected from research into construction. This has been appropriate and in spite of the strain on university and laboratory research and technology development, it has had the support of the community. This support was affirmed in the recent "HEPAP Assessment of Progress on 2014 P5 Report" (March 2020).

Now, with the new experiments coming online, it is necessary to redirect effort into research and technology in order to take full advantage of the current and new experiments and prepare for the future. This urgent need drives **Recommendation 1**.

Finding: Award decisions are based both on the merit of the proposal and program priorities. Since the last COV, HEP has taken steps to clarify these priorities in several areas. It has conducted workshops on Basic Research Needs in Light Dark Matter (2018), Compact Accelerator Technology (2019) and Detector R&D (2019). In addition, it has fostered the development of roadmaps for accelerator R&D in three of its five thrusts (Advanced Accelerator Concepts, RF Acceleration Technology, and Superconducting Magnets & Materials) and the fourth is underway (Accelerator and Beam Physics).

Comment: The Basic Research Needs and Roadmap initiatives have resulted in critical community-driven guidance for HEP.

Findings: Since the last COV, five new elements have been added to the research program, each with their own Funding Opportunity Announcement (FOA). The HEP-QIS (QuantISED) program is aligned with the QIS initiative in the Office of Science and seeks to exploit and develop QIS technology in pursuit of discovery aligned with the P5 science drivers, as well as to build a foundational QIS program and contribute to the national QIS enterprise. New initiatives in Dark Matter seeks to complement large-scale dark matter searches with small-scale experiments that use existing beam facilities and advanced ultrasensitive detectors to search a wider dark-matter parameter space. The US-Japan Science and Technology Cooperation program enhances collaboration between US and Japanese scientists working on accelerator R&D, detector R&D and R&D to enhance the physics of current or future HEP experiments. Accelerator Traineeships support early-stage graduate students interested in accelerator science and feature laboratory internships. An initiative in Artificial Intelligence & Machine Learning (AI/ML), which was added in 2018, was incorporated into ongoing activities.

Comments: A side effect of the thorough review processes and new program elements is that the burden on the HEP staff has increased to worrisome levels. The COV heard, for example, that because of workload, HEP is considering the option of ending support for small multi-laboratory, multi-agency and multi-partner experiments not led by HEP and reducing the number of international activities.

P5 noted that experiments hosted by agencies other than DOE-HEP sometimes provide information essential to particle physics, and it recommended:

> P5 Recommendation 9: Funding for participation of U.S. particle physicists in experiments hosted by other agencies and other countries is appropriate and important but should be evaluated in the context of the Drivers and the P5 Criteria and should not compromise the success of prioritized and approved particle physics experiments.

The COV supports this P5 recommendation, and it would regret to see workload/staff issues at HEP prevent its implementation.

Findings: HEP recently hired Dr. Brian Beckford as the new program manager for the Intensity Frontier. The theory IPA position, which was open at the time of the last COV and was identified in the 2016 COV report as a priority, remains unfilled. SC has approved a search for a program manager for AI/ML and HEP computing.

Comments: Hiring Dr. Beckford as the new Intensity Frontier program manager is an important step toward addressing the staffing shortfall. Dr. Beckford brings significant expertise in intensity frontier physics, most recently on K0T0, and he has worked to increase diversity in physics. The COV is delighted by this development.

The COV is concerned about the long-unfilled theory IPA, who would strengthen the management of the theory program. The COV notes, for example, that obtaining sufficient mail reviews is essential, but has been difficult to achieve with the current staffing level. A university scientist would be particularly beneficial in this position.

The COV welcomes SC approval of a hire in AI/ML and HEP Computing. The computing program has grown substantially and requires dedicated planning, including an assessment of software and computing needs of the evolving operations program and forthcoming experiments. A crosscutting strategy for AI/ML and HEP Computing is also a high-priority need.

Recommendation 14: Fill the open positions for a program manager for the AI/ML and HEP computing program and for a Theory IPA as soon as possible.

Finding: The program has recently seen an increase in cross-cutting efforts, especially with the recently created quantum information science program. There is an increasing recognition of the value of multi-disciplinary research and cross-collaboration within the Office of Science to deliver and advance on the P5 science goals.

Comment: The value of interdisciplinarity to innovation is unquestioned. Yet as much as there is agreement that this is a good thing, realizing interdisciplinary work is not trivial. HEP should be commended for starting not only the coordination of cross-cutting efforts within the office, but also for reaching out to other offices within the Office of Science. The COV stresses the importance of continuing and strengthening this dialogue. There are several areas that have been identified where these discussions need to be strengthened. At the individual PI level, the office should evaluate lowering the barriers to move between projects and frontiers. At a programmatic level it was observed that there are multiple efforts under various programs that could benefit from increased coordination. In the area of computing, for example, there are efforts being supported under the operations program that are not well connected to the research program. In the area of Quantum Information Science it seems that the clear and significant synergies between the theory and detector R&D programs with the QIS program are not leveraged as best as can be. The collaboration with other offices, such as ASCR, BES and NP, should be leveraged more to address technical barriers that HEP faces in computing and accelerator technology. The COV understands the challenges of overcoming the "no-man's-land of interdisciplinarity" but encourages the office to vigorously continue on the current path to bridge this divide.

Recommendation 15: Strengthen existing and explore new collaborative, multi-disciplinary efforts that could advance the P5 science goals and increase the science productivity of the field.

Finding: The Accelerator Stewardship program is moving to a new office in SC, Accelerator R&D and Production (ARDAP).

Comments: The COV expresses its strong interest in the outcomes of the new ARDAP office and advises HEPAP to work with HEP and other Offices of Science to ensure a strong accelerator technology basis for its current and future facilities, and also advises HEPAP to actively follow the establishment of ARDAP and to robustly participate in the future advisory process for the new office.

Recommendation 16: Seek an appropriate role for HEPAP in the future advisory processes for ARDAP.

Finding: Detector R&D is currently directed by the needs of current projects and is largely concentrated at the laboratories. A study of Basic Research Needs in Detector R&D was completed in 2020.

Comment: The COV commends the excellent BRN in Detector R&D. This should be the basis to define, together with the high energy physics community, the future roadmap for Detector R&D promoting mid-term and long-term research and development. The roadmap should include a plan for increased participation at Universities.

Recommendation 17: Generate a roadmap for investments in detector R&D based on future research needs of the field, with emphasis on innovation, including a substantial role for university-based R&D.

Finding: Following exploratory workshops in 2014 and 2015, HEP initiated the new QuantISED program in 2018 as part of the wider SC initiative in quantum information science. Under QuantiISED, there were 32 and 21 awards in 2018 and 2019 respectively, primarily in the "Pioneering Pilots" track.

Comments: The COV commends HEP's proactive engagement with the DOE initiative in QIS, which has led to a substantial program. The COV looks forward to its continued development, for example through support for successful pilots that were launched under the QuantISED program and are synergistic with elementary particle physics.

Areas of QIS synergy with traditional particle physics research include theory, sensor technology, and superconducting cavity technology, and the long-term success of the program depends on successfully leveraging these synergies. Indeed, many particle physicists have the expertise needed to advance both QIS and HEP. Communicating clearly to PIs the broad definition of QIS as it is relevant to HEP would facilitate the participation of traditional HEP PIs with suitable expertise and foster the best and most appropriate proposals.

Reommendation 18: Strengthen the HEP QIS program through 1) greater integration of traditional HEP research efforts with the QIS program; 2) clear articulation of QIS goals that capitalize on and advance HEP expertise; and 3) advancing QuantISED pilots that promise to address the P5 science drivers.

Finding: The P5 report, the 2016 COV recommendations, and the LHC Subpanel Report from the 2018 Portfolio Review all emphasize that computing and software are a significant fraction of the cost of projects (roughly 50% of operations in some experimental areas) and that it is imperative that the large experiments in all frontiers develop new computing models that can better exploit high-performance computing (HPC) resources. Furthermore, they have all recommended strengthening cooperation and to seek synergies across experiments in an effort to reduce costs and to develop workforce expertise in the field.

In 2017, HEP collected information from the laboratories and large experiments, which revealed that 'business as usual' would be unaffordable. A second call for information from the laboratories and large experiments culminated in an Inventory of Computing Needs Roundtable in 2018. Various pilot projects were identified to explore more efficient use of HPC resources. In addition, the Center for Computational Excellence received renewed funding and the SciDAC4 program funded projects partially addressing these issues.

Comment: While these are all laudable steps, the challenges of computing and software continue to be of critical importance and should be addressed with dedication and urgency. A clear plan would facilitate not only the next COV, but also the Program Managers in navigating the complex computing landscape of the program. Under the circumstances, hiring a dedicated Program Manager is urgent.

Recommendation 19: Develop a cross cutting view of the allocations in computing, software, and AI/ML broken down by program and type of cost (e.g., computing facilities, FTE, operations, R&D).

Finding: The Early Career Research program, which was launched in FY 2010, provides important funding to early career scientists at the laboratories and universities. HEP has awarded a total of 120 ECAs since its inception and has increasingly prioritized them. In 2020, HEP made 15 awards, 10 to university scientists and 5 to laboratory scientists.

Comment: The COV is pleased to see this support of early career scientists. The awarded proposals are impressive, and the COV looks forward to their being carried out.

4. Consistency with P5 and the Accelerator R&D Panel recommendations

Finding: In response to the P5 report, HEP has built or is now constructing an exciting suite of experiments addressing the science drivers. HEP has closely adhered to the guidance of P5 report in selecting these.

Comment: Rich opportunities lie ahead for both experiment and theory as a result of the new experiments coming online.

The P5 report was based on projections suitable at the time of writing. Since its release, some of the conditions that affect planning have evolved: project costs have been refined and most have increased, budgets have changed, and the international landscape has moved forward, affecting assumptions about international financial investment in domestic projects and the outlook of global projects sited elsewhere in the world. As a result of this natural evolution, decisions must be made about how best to adapt the P5 plan, and the community should have a voice in these decisions. Community involvement becomes essential when the scale of the decision is sufficiently large that it will have ripple effects on other activities. With this in mind, the 2016 COV recommended:

> COV 2016 Recommendation 2: Adopt, in consultation with HEPAP, an annual mechanism to determine the best plan of action to implement the P5 vision. In such cases where HEP deviates from the strategic advice, the case should be clearly explained to the community through discussion with HEPAP.

HEP has responded with regular budget and status updates at HEPAP meetings describing actions that are complete or already planned. While these updates are useful and widely appreciated, they have not resulted in the active community involvement in the decision-making that the previous COV envisioned.

Several mechanisms could provide effective community involvement in decisions. As examples: a specially convened HEPAP subpanel could be charged to evaluate the options in a specific case; a standing national particle physics advisory committee could address issues as they arise; or the P5 subpanel could continue after the release of its report and meet as needed when significant unanticipated programmatic choices or conditions arise.

Recommendation 20: Establish a mechanism in consultation with HEPAP to advise HEP when a programmatic choice must be made that significantly deviates from the P5 plan or when the context for that choice has evolved significantly from P5 expectations.

Finding: The P5 report included a series of recommendations related to specific Research and Technology activities. The report predates the initiatives in AI/ML and QIS, so its recommendations applied specifically to the three frontiers, theory, and the Accelerator and Detector R&D programs, which the COV refers to as the "core" Research and Technology programs. P5 offered the following broad recommendations regarding core Research and Technology:

> **P5 Recommendation 6:** In addition to reaping timely science from projects, the research program should provide the flexibility to support new ideas and developments.
>
> **P5 Recommendation 7:** Any further reduction in level of effort for research should be planned with care, including assessment of potential damage in addition to alignment with the P5 vision.
>
> **P5 Recommendation 26:** Pursue accelerator R&D with high priority at levels consistent with budget constraints. Align the present R&D program with the P5 priorities and long-term vision, with an appropriate balance among general R&D, directed R&D, and accelerator test facilities and among short-, medium-, and long- term efforts. Focus on outcomes and capabilities that will dramatically improve cost effectiveness for mid-term and far-term accelerators.
>
> **P5 Recommendation 27:** Focus resources toward directed instrumentation R&D in the near-term for high-priority projects. As the technical challenges of current high-priority projects are met, restore to the extent possible a balanced mix of short-term and long-term R&D.
>
> **P5 Recommendation 28:** Strengthen university-national laboratory partnerships in instrumentation R&D through investment in instrumentation at universities. Encourage graduate programs with a focus on instrumentation education at HEP supported universities and laboratories, and fully exploit the unique capabilities and facilities offered at each.

Shortly after the release of the P5 report, an Accelerator R&D subpanel was charged by SC Acting Director Pat Dehmer and NSF Assistant Director for the Directorate for Mathematical and Physical Sciences Dr. F. Fleming Crim to "examine research in the current HEP accelerator R&D program and to identify the most promising research areas to support the advancement of high energy and particle physics." The subpanel made recommendations regarding specific thrust areas and facilities, as well as the following:

> **Accelerator Recommendation 15:** To ensure a healthy, broad program in accelerator research, allocate a fraction of the budget of the Accelerator Physics and Technology thrust to pursue fundamental accelerator research outside of the specific goals of the Next Steps and Further Future Goals. Research activities at universities should play a particularly important role.

> **Accelerator Recommendation B1.** Increase base GARD funding modestly in order to open numerous critical R&D opportunities that do not fit in the current base, as well as to invigorate fundamental accelerator science research, and to step up development of the national accelerator workforce.

Comments: HEP has prioritized project construction in recent years and the construction budget has grown impressively, while the budget for Research and Technology has declined below P5 expectations. This has resulted from underestimates of construction and operations costs at the time of P5, the addition of projects not on the P5 or Accelerator R&D Panel roster, and recently, from added expenses due to COVID-19.

The COV believes that the time has come to address the P5 recommendations related to the core research programs. In particular, research at the experimental frontiers and the theory program are required in order to reap the opportunities of the new and ongoing experiments in a timely fashion. The Accelerator and Detector R&D programs, which were redirected to further the P5 construction projects, now need to focus on the future, opening new opportunities and reducing the costs of the next generation of experiments.

HEP should renew its efforts to meet these P5 and Accelerator R&D subpanel recommendations regarding the core Research and Technology programs. This leads to the primary recommendation of this COV:

Recommendation 1: Increase effort in the Experimental, Theoretical, Accelerator R&D and Detector R&D research programs in order to realize the promise of the portfolio of current and new experiments and to prepare for future endeavors. In the next year HEP should present a strategy to HEPAP for increasing the allocation to these programs by at least 4-5% per year until effort returns to the pre-P5 level, and should strive to return to 40% of HEP expenditures.

5. Response to the recommendations of the 2016 COV

The COV commends HEP for its overall response to the recommendation in the 2016 COV report. It finds that HEP took notable steps to address them, through for example, the continuation of effective comparative reviews, establishment of informative PI meetings, commissioning several studies of Basic Research needs and roadmaps, and convening the Facilities panel. It is a long and impressive list of advances.

The following sections step through the recommendations of the 2016 COV and note the successes as well as areas requiring additional effort. These comments are confined to the recommendations in the 2016 COV Executive Summary and main report. Findings and comments related to the recommendations in the program sub-reports are provided in the corresponding appendices.

a) Primary recommendations

> COV 2016 Recommendation 1: Continue the comparative reviews of university and laboratory research proposals and activities.

Finding: HEP has continued comparative reviews.

Comment: This COV concurs with the 2016 COV that the "The review process, with its comparative nature, is an effective tool towards achieving optimal research programs within tightly constrained budgets," and urges HEP to continue the practice.

> COV 2016 Recommendation 2: Adopt, in consultation with HEPAP, an annual mechanism to determine the best plan of action to implement the P5 vision. In such cases where HEP deviates from the strategic advice, the case should be clearly explained to the community through discussion with HEPAP.

Finding: HEP regularly provides Budget and Program status briefings to HEPAP.

Comment: This COV commends HEP for the briefings, which update HEPAP on the status and health of the program. This COV believes that additional community input is needed in advance of decisions (**Recommendation 20**).

> COV 2016 Recommendation 3: Work closely with the Laboratories and with Project Management and Program Management teams to develop a comprehensive strategic plan, consistent with P5 guidance, that anticipates the needs for future operating funds that will arise from improvement, upgrade and MIE projects. The plan should account for the funding needs not only of accelerator and experimental operations, but also of software, computing, and technical support for the new experimental programs. Develop a similar comprehensive plan for future research program needs, once again taking into account the need for research efforts to maximize the scientific return on improved, upgraded, and new facilities and experiments.

Finding: HEP now folds experiment operating budgets into their projections and presents them to HEPAP.

Comments: The COV welcomes the budgetary information and the HEP planning for operational expenses; however, it notes that HEP generally does not provide forecasts that allow HEPAP to assess the impact of the operating costs on other HEP activities. Because of this omission, other components of HEP portfolio, notably core research, have diminished significantly with little discussion or opportunity for community input. **Recommendation 20 addresses** the need for community input at critical junctures in implementing the P5 plan.

b) P5 Alignment

> COV 2016 Recommendation 4: Augment discussion with HEPAP of budgets by annually presenting the disposition of reserves and explaining how the final HEP allocations to the research programs of the frontiers are consistent with P5 recommendations.

Finding: HEPAP now gives regular presentations on Budget and Program status at HEPAP meetings. These have not always included 'as spent" budgets and do not address the distribution of reserve funds.

Comment: The Budget and Program status presentations at HEPAP meetings are informative, and the COV congratulates HEP for them; however, this COV believes that HEP should expand them to fully address the 2016 COV recommendation and do more to solicit advance community input on potential deviations from the P5 plan and shifts that are under consideration in the balance among program elements. See **Recommendation 20**.

c) Comparative Review Process

> COV 2016 Recommendation 5: HEP should work to reduce barriers to migration of researchers from one frontier to another.

Finding: HEP now provides some guidance on migration at PI meetings, consults individually, and guides reviewers in their evaluation.

Comment: This COV appreciates this progress and suggests that HEP further expand on it by adding more advice on migration to their presentations at PI meetings.

> COV 2016 Recommendation 6: Deliver laboratory comparative review reports no later than six months after the review is held.

Finding: The laboratory comparative review reports are now more timely and are delivered six months after the review on average. While HEP has successfully eradicated very long delays, some reports continue to straggle beyond the six-month marker.

> COV 2016 Recommendation 7: Appoint members of recent university panels to the laboratory comparative review panels in each program area in order to help gauge the uniformity of quality between laboratory and university research.

Finding: Done.

Comment: This COV commends the improvements in connection with Recommendations 5-7 and urges HEP to continue its efforts in these areas.

> COV 2016 Recommendation 8: Encourage HEPAP to form a study group to consider whether the agencies should convene a subpanel to evaluate different roles and responsibilities in university and laboratory research and the ways in which this research is evaluated.

Finding: While there were discussions with the HEPAP chair of convening a subpanel to evaluate the roles and responsibilities of the laboratory and university research and methods for evaluation, a suitable charge was never developed.

Comment: This COV advises instead increased parallelism between the laboratory and university comparative reviews, with a recommendation that HEP solicit mail-in reviews for laboratory proposals, and that the reviewers should include university scientists (**Recommendation 3**.) It also advises that reviewers of both laboratory and university proposals be provided with guidance regarding any difference in criteria that arise from the difference in roles and responsibilities of laboratory and university groups and their personnel.

> COV 2016 Recommendation 9: Ensure an adequate number (at least 3) of reviewers for each PI.

Finding: HEP strives for three reviewers for each research task. However, typically fewer than half of the scientists contacted for a review respond, and the committee saw cases when the success rate was far lower. For example, in one case HEP solicited 14 reviews in order to receive three, and the COV saw proposals for which no mail reviews were received in advance of the panel. Finding reviewers becomes a time-consuming task for program managers.

Comment: Successful comparative review depends on the critiques of expert reviewers, and a panel often lacks the breadth to adequately review all tasks. This COV echoes this recommendation (**Recommendation 2**). It hopes that the members of the research community will understand that a quality HEP program depends upon their willingness to provide thoughtful review of proposals. Indeed, HEP could take advantage of community events such as PI meetings to explain the importance of responding to review requests.

> COV 2016 Recommendation 10: Inform review panels about special information obtained by DOE program managers concerning project operational or infrastructure responsibilities and experiment leadership roles.

Finding: HEP solicits this information from experiment leadership and shares it with panels when available and relevant.

Comment: HEP collection of this information has reduced dependence on hearsay information at panel reviews, and the COV urges HEP to keep up the practice.

> COV 2016 Recommendation 11: Include more information about why proposals were declined in both the declination letters and the folders.

Finding: Program managers informed the COV that additional information is now included in the reviews and transmitted to PIs.

Comment: The COV appreciates the increase in information. It noted some cases, however, in which proposals were declined with minimal explanation to the PI, for example, in cases where reviews were strong, but the proposal was misaligned with HEP priorities. This COV recommends that HEP do more in this area (**Recommendation 10** and **Recommendation 11**.)

> COV 2016 Recommendation 12: Seek ways to mitigate the load arising from repeated submissions of rejected proposals.

Finding: HEP now requires "substantial revision" before resubmission and reports that this works well.

> COV 2016 Recommendation 13: Form mini-panels to review Early Career proposals in related fields. At least one member from each mini-panel should be a member of the larger super-panel deciding Early Career Awards.

Finding: HEP implemented this practice starting in 2015 and finds it effective. Since 2018, delays in issuing the ECRP FOA have left too little time to convene both the mini-panel and the super-panel, and in that case HEP has found that the best option is to drop the mini-panel.

HEP notes that even in years when the mini-panels take place, they are often conducted via videoconference with no record PAMS.

Comment: The COV encourages HEP to continue to strive for the mini-panel as well as the super-panel. See **Recommendation 8** regarding the timely release of FOAs. The COV urges keeping a record of mini-panels.

> COV 2016 Recommendation 14: Ensure that the review process recognizes the potential contributions to the DOE mission from qualified applicants at a wide range of institutions, including non-Ph.D. granting colleges.

Finding: HEP now informs panels about special considerations for proposals from non-traditional institutions, and a few have been funded.

Comment: The COV celebrates HEP success in making awards of this type and encourages continued effort in this direction. See the section of this report on Diversity, Equity and Inclusion.

> COV 2016 Recommendation 15: Change the organization of future CoVs to amalgamate the review of the three experimental frontiers into one subpanel that is smaller than the sum of the three current subpanels

Finding: In response to this recommendation, the 2020 COV formed a single subcommittee addressing the experimental frontiers.

Comment: This worked well and should be continued in future years. The 2020 COV notes, however, that realizing the benefits of this approach requires that the COV allocate dedicated time for the discussion of the issues that are common across the frontiers.

d) General Detector R&D

> COV 2016 Recommendation 16: Restore a balanced generic detector R&D program as soon as possible after the technical challenges of current high-priority P5 projects are met.

> COV 2016 Recommendation 17: Work with the high energy physics community to generate a roadmap for investments in detector R&D based on future research needs of the field.

Finding: The balanced generic detector R&D program has yet to be restored. A study of Basic Research Needs in Detector R&D was recently completed.

Comment: This COV commends the BRN and concurs with the 2016 COV on the importance of these recommendations. See **Recommendation 1** and **Recommendation 17**.

e) Computing

> Recommendation 18: Include planning for computing and software development into the planning for projects and new initiatives.

Finding: Since 2016 HEP has taken various actions to address this recommendation including data calls to the laboratories and large experiments in 2017, which revealed that 'business as usual 'would be unaffordable. A second data call to the laboratories and large experiments culminated in an Inventory of Computing Needs Roundtable in 2018. In addition, ATLAS and CMS received Performance Evaluation and Measurement Plan (PEMP) Notables, and submitted plans for High-Luminosity LHC software & computing R&D activities planned for the next 2-3 years with specific milestones for deliverables under the U.S. Subsequently, various pilot projects were identified to explore more efficient use of HPC resources. In addition, the Center for Computational Excellence received renewed funding and the SciDAC4 funded projects partially addressing these issues.

Comment: While these are substantive steps, the challenges of computing and software continue to be of critical importance and should be addressed with dedication and urgency. See **Recommendation 19**.

f) Diversity

> COV 2016 Recommendation 19: Develop a plan for increasing diversity in the programs HEP supports.

Finding: HEP is coordinating with the Office of Science initiative to address diversity, equity and inclusion.

Comment: This COV concurs that the development and implementation of a plan for diversity, equity and inclusion is high priority (**Recommendation 13**).

g) Communication

> COV 2016 Recommendation 20: Continue and enlarge the effort by HEP staff to make presentations about program priorities and to have PI meetings at major conferences.

Finding: HEP has initiated a series of PI meetings at which it communicates to PIs its expectations and guidance for proposals. These address program priorities, share advice for successful proposals, and provide guidance on topics such as PI migration among frontiers and the incorporation of Research Scientists into proposals.

Comments: The PI meetings are very effective, and the COV enthusiastically encourages HEP to keep them up as well as to continue the practice of meeting with PIs at conferences.

h) Research Scientists

> Recommendation 21: Continue to require appendices describing the work of each university research scientist in proposals.

> Recommendation 22: Consider for support, through research and operations funding, research scientists making clear and critical contributions to cosmic frontier experiments and construction projects

Finding: HEP continues to require the appendices about Research Scientist activities and now provides guidance to PIs and panels on policies for Research Scientists. For funding outside operations and project budgets, HEP encourages physics-research related activities, including 1) algorithm development, performance studies, data collection and analysis, mentorship of students and PDs and 2) activities in support of detector R&D. Some are university Research Scientists are supported.

Comment: Scientists play an important role in some university groups by supporting activities such as computing and detector R&D and guiding students and postdocs. They may contribute significantly to an experiment in a variety of ways over its life cycle in a manner that does not fit neatly into other funding mechanisms, such as operations programs. They also can provide continuity to an experimental effort in a way that postdocs cannot. The COV welcomes the clear guidance on funding practices regarding Research Scientists and encourages HEP to continue to support them when appropriate.

Appendix I: Charge from the Chair of HEPAP, Professor JoAnne Hewett to the Chair of the COV, Professor J. Ritchie Patterson.

SLAC NATIONAL ACCELERATOR LABORATORY

FUNDAMENTAL PHYISCS DIRECTORATE

STANFORD UNIVERSITY

JoAnne Hewett
Associate Laboratory Director of Fundamental Physics
Chief Research Officer

2575 Sand Hill Road, MS 81
Menlo Park, California 94025
650-926-4424
hewett@slac.stanford.edu

August 2, 2020

Subject: DOE Office of High Energy Physics Committee of Visitors

Dear Ritchie,

Thank you for agreeing to chair the 2020 Committee of Visitors (COV) review of the Department of Energy (DOE) Office of High Energy Physics (HEP). The review should be conducted in accordance with the Guidance for DOE Office of Science Committee of Visitors Reviews, found at the following url: https://science.osti.gov/sc-2/Committees-of-Visitors

The COV subpanel is asked to assess the operations of HEP during the fiscal years 2016, 2017, 2018, and 2019. In particular, as indicated in the Guidance for COV Reviews, the subpanel should assess: (1) the efficacy and quality of the processes used to solicit, review, recommend, monitor, and document funding actions; and (2) the quality of the resulting portfolio, including its breadth and depth of portfolio elements, its national and international standing, and the progress HEP has made toward its long-term program goals since the last review of these milestones by HEPAP. The COV should comment on the effectiveness of the DOE implementation of the long-term goals and priorities as reflected in the HEP research program according to the 2014 report of the Particle Physics Project Prioritization Panel (P5). Are the actions of HEP maintaining the capabilities needed for healthy laboratory and university programs? Is the balance of research funding optimal – both overall and between the program components? Comments and suggestions for improving HEP processes and their implementation, as well as on the observed strengths or weaknesses in any component or sub-component of the HEP portfolio would be appreciated. The COV should assess progress in addressing the recommendations of the previous (2016) COV. It should also identify any significant issues that the COV is not able to appropriately consider within the limited timespan of this review but which deserve subsequent consideration.

The results of this review should be documented in a report with findings, comments, and recommendations clearly articulated. The report should be completed for consideration by HEPAP at its December 2020 meeting and submitted to the agency shortly thereafter. I appreciate the COV's willingness to take on this important activity and look forward to its final report.

Sincerely,

JoAnne L. Hewett

JoAnne L. Hewett
HEPAP, Chair
Professor of Particle Physics and Astrophysics, Stanford University
Associate Laboratory Director of Fundamental Physics, SLAC
Chief Research Officer, SLAC

A U.S. Department of Energy Research Facility Operated Under Contract by Stanford University

Appendix II: COV Members and Contact Information

First Name	Last Name	Institution	COV Role	Email Address
J. Ritchie	Patterson	Cornell	Chair	jrp3@cornell.edu
Petra	Merkel	FNAL	Member	petra@fnal.gov
Meenakshi	Narain	Brown	Member	meenakshi_narain@brown.edu
Andy	Lankford	UC Irvine	Member	andrew.lankford@uci.edu
Hirohisa	Tanaka	SLAC	Member	tanaka@slac.stanford.edu
Mark	Messier	Indiana	Member	messier@indiana.edu
David	Hertzog	U Washington	Member	hertzog@uw.edu
Katrin	Heitmann	ANL	Member	heitmann@anl.gov
Dan	Akerib	SLAC	Member	akerib@slac.stanford.edu
John	Ruhl	Case Western	Member	john.ruhl@case.edu
Hiroshi	Ooguri	Caltech	Member	ooguri.caltech.edu
James	Wells	U Michigan	Member	jwells@umich.edu
Tim	Tait	UC Irvine	Member	ttait@uci.edu
Reina	Maruyama	Yale	Member	reina.maruyama@yale.edu
Ron	Walsworth	U Maryland	Member	walsworth@umd.edu
Kyle	Cranmer	NYU	Member	kyle.cranmer@nyu.edu
Elizabeth	Simmons	UC San Diego	Member	evc@ucsd.edu
Marcel	Demarteau	ORNL	Member	demarteau@ornl.gov
Maria	Chamizo-Llatas	BNL	Member	mchamizo@bnl.gov
Jamie	Rosenzweig	UCLA	Member	rosen@physics.ucla.edu
Marc	Ross	SLAC	Member	mcrec@SLAC.Stanford.EDU
Sergei	Nagaitsev	FNAL	Member	nsergei@fnal.gov

Appendix III: COV Panel Assignments

Breakout Group 1	**Experimental Program** Narain* Akerib Chamizo-Llatas Heitmann Hertzog Lankford Merkel Messier Ruhl Tanaka	**Theory Program** Tait* Ooguri Simmons Wells	**Quantum Information Science Program** Walsworth* Demarteau Maruyama	**Accelerator Program** Nagaitsev* Ross Rosenzweig
Breakout Group 2	**Detector R&D Program** Demarteau* Akerib Chamizo-Llatas Hertzog Merkel Ruhl	**Computational HEP, Artificial Intelligence and Machine Learning** Cranmer* Heitmann Narain Rosenzweig Wells	**Diversity, Equity and Inclusion** Tanaka* Maruyama Messier Patterson Simmons Tait	

*Sub-panel chair

Appendix IV: COV Agenda

Tuesday - 10/1/2020 - Pre-Meeting		
13:00	COV Chair - Orientation Presentation	Ritchie Patterson
13:30	Overview of PAMS	Christie Ashton
14:00	Questions from COV Members on logistics	COV Members
14:30	Research and Tech. Overview and 2016 action items	Glen Crawford
15:00	Operations and Projects	Mike Procario
15:15	Budget and Planning	Alan Stone
Tuesday - 10/13/20 - Day 0 - PM Presentations		
13:00	Welcome & Organization	Ritchie Patterson
13:15	Energy Frontier	Abid Patwa
13:35	Intensity Frontier	Glen Crawford
13:55	Cosmic Frontier	Kathy Turner
14:15	Lunch break	
15:00	Theory	Bill Kilgore
15:20	QIS, Computational HEP and ML	Lali Chatterjee
15:40	Detector R&D	Helmut Marsiske
16:00	Accelerator R&D	LK Len
16:20	Accelerator Stewardship	Eric Colby
16:40	Executive Session (Focusing on Folders)	Ritchie Patterson
Wednesday - 10/21/20 - Day 1 - Breakout Sessions - Folder Reviews and Formulate Questions		

10:00	Break out Session 1: Initial folder review (Exp, Theory, GARD & Acc. St., QIS)	COV Members
11:30	Break	
12:00	Breakout Session 2: Folder review & formulate questions (Exp, Theory, GARD & Acc. St., QIS)	COV Members
13:30	Breakout Session 3: Folder review & formulate questions (Detector R&D, Computational HEP & ML, Diversity)	COV Members
15:00	Executive Session	COV Chair and COV Members
15:30	Questions for HEP Staff	COV Chair, COV Members and HEP Staff
16:00	COV Chair and Panel Chairs	COV Chair and Panel Chairs
16:30	Adjourn	
Thursday - 10/22/20 - Day 2 - Folder Review & Formulate Comments; Findings and Recommendations		
10:00	OHEP staff responses to questions	COV Chair, COV Members and HEP Staff
10:30	Breakout Session 4: Folder review & Formulate comments (Exp, Th, Acc, QIS)	COV Members
12:00	Executive Session	COV Chair and COV members
12:30	Breakout Session 5: Folder review & Formulate comments (Det R&D, Comput, Diversity)	COV Members
14:00	Lunch break	
14:30	Breakout Session 6: Draft of Findings & recommendations	COV Chair and COV Members
16:00	Break	
16:15	Meet with Management (Siegrist, Crawford)	COV Chair and COV Members

17:00	Discussion of Findings & Recommendations	COV Chair, COV Members, and HEP Staff
18:00	Adjourn	

Appendix V: Experimental Frontiers Summary Report

This appendix addresses the Energy Frontier (EF), Intensity Frontier (IF) and Cosmic Frontier (CF).

1. Efficacy and Quality of the Program's Processes

Below we include our findings and comments on the aspect of the programs' processes and management used to solicit, review, recommend, document and act on proposals.

Finding: The Program Managers of the three frontiers should be commended for the quality and clarity of the review process and the documentation provided during solicitation, evaluation and award steps of the proposal review.

a) Review Process

Finding: The review process of proposals for each of the three frontiers is similar. This includes the process of mail-in reviews, the panel reviews, the number of reviewers, classification of the reviews in various funding tiers by the panel, and the final funding decisions by the PMs. The university proposals were reviewed by both university and laboratory reviewers. The laboratory comparative review panelists are only from universities (because of COI).

Comment: DOE should be commended for the quality and clarity of the review process and the documentation provided during solicitation, evaluation and award. The review process for the three frontiers is very uniform and has improved with the development of electronic tools.

Recommendation 2: Ensure that an adequate number (at least 3) of written reviews is in hand for each PI in advance of the panel review.

b) Cross cut, multi-thrust and transitional proposal criteria

Finding: The annual PI presentations included guidelines on handling crosscuts such as detector R&D or computational HEP (e.g., AI/ML initiatives). Proposals with strong connections to the big collaborations reviewed very well, but groups who are new to a collaboration tend to have weaker plans during the transition period.

Comment: Given the vitality that generally results from cross-fertilization, HEP should consider further steps to facilitate such transitions. For example, the office might consider emphasizing the track record of the PI in funding considerations or funding a transition period of 18-24 months, during which group members could develop their roles. Similar considerations apply for junior PIs, with a 3-5 year look back, which might also include some postdoctoral work. Procedures like these might also help integrate members from underrepresented groups.

c) Evaluation metrics to reviewers

Finding: Both the mail-in reviewers and panelists are provided with the merit review criteria and corresponding sub-questions. In addition, panelists are given other Program Policy

Factors for their deliberations such as program alignment with respect to the P5 strategic plan, fostering development of diverse cadre of supported researchers, and opportunity for early-stage investigators and/or junior scientific personnel.

Comment: The reviewer comments and scores vary widely. In order to increase consistency in reviews and homogenize the scores, it might be necessary to give more guidance, especially to reviewers who mail-in their evaluations without the benefit of panel discussion. The panels could develop uniform criteria for the comparative evaluations including scoring various program elements and weightings across the various activities, prior to their deliberations.

Recommendation 4: Develop guidance for mail-in and panel reviewers about proposal ratings in order to improve consistency.

d) Quality of feedback to PIs

Finding: The subcommittee reviewed a selection of proposal folders across a broad range of scientific missions. The selection included a balanced mixture of awarded and declined folders. Documentation of comparative reviews consists primarily of the mail-in reviews and the panel summary. In most cases, the reviews and panel summaries were of sufficient detail and expertise to guide the office in assigning actions, but the level of detail in the "Panel Summaries" varied by year, and by Frontier. In particular, some declined proposals lacked an informative summary that could help the proposers to improve their proposals for re-submission. In case of new junior PIs that were declined, reviewer and panel comments sometimes differed from one another.

Comment: Panel summaries should be provided for ALL proposals. Comparative review results should contain a clear summary that explains the panel's reasoning, including comments on the strengths and weaknesses, information about aspects that reviewed poorly (and how to improve for future submissions) and about how to attend PM "office hours" to ask questions. If the panel evaluation differs significantly from the mail-in reviews, this should be explained. A panel member could be designated to write this summary for each task PI reviewed, including the PI proposal's task's tier level. An additional summary should be provided by the Program Managers which gives the details of the final award decision and budget guidance.

Recommendation 10: Provide an explanation of funding decisions to PIs, particularly in the case of declined proposals or those with significant weaknesses.

Recommendation 11: Advise panelists to prioritize feedback to PIs through written reviews and/or summaries of panel discussions over detailed rankings of PIs and proposals.

Finding: In the sample of funded folders, the subcommittee did not find any particular bias in the reviews. Panelist comments on "declined proposals" are occasionally biased or inappropriate, and in these instances, the program manager redacted the comments prior to sharing with the PI.

Comments: During the reviews of a sample set of folders, some instances were noted where the comments from the reviewers could be improved if they were provided in a more collegial manner without altering their intent.

Panelist comments with implied biases, subjective personal opinions without any substantiations based on scientific merit could be rectified by avoiding judgements based on reputational factors external to the proposal. A guideline may need to be developed for avoiding problematic reviewers/panelists for further reviews.

A reasonably fair evaluation of "impact and role of PI in a high profile analysis" and leadership roles should be sought from experiment leadership and/or those members who have "non-competitive" oversight of analyses in the large physics groups. This practice is similar to consulting with project managers for operations in understanding roles/impacts. Reviewers from different experiments or working in different areas may not be aware of the scale and impact of contributions of all participants. Collating this information as input to the panel review should be carried out systematically and consistently, giving ample time to gather the information.

Recommendation 6: Set clear expectations for mail-in and panel reviewers that proposal evaluation should be based on proposal content and documented information, rather than informal or anecdotal information about prior performance by the PI(s).

e) Awards decisions

Finding: The final award decisions are identified by their award status. Explanations for the award decisions or evaluations of individual thrusts were rarely available. The revised budgets include the full proposal, across multiple frontier and funding thrusts, and hence the subcommittee was hampered in assessing proposal management. The limited information also prevented comparison of the success rate of proposals from individual PIs versus umbrella proposals. The subcommittee noted that the level of funding for similarly rated PIs varied among Frontiers.

Comment: Program Manager comments on award decisions and guidance for each task should be included as documentation in PAMS.

Finding: High level leadership roles in experiments may not be in synchrony with the proposal cycle. Supplements for PIs in leadership positions are available with the support of the US management of the experiments. These are different types of support (operations, project, or research), and vary by the Frontier and experiment.

Comment: The procedure for requesting supplemental funding for leadership roles in experiments should be advertised during the PI meetings.

f) Operations programs

Finding: Operations programs were reviewed independently. For the EF, the LHC operations included detector operations, computing facility operations and core-software development as part of the program. HL-LHC software and computing R&D is also included as at about 5-10% of the operations budget part of the review period.

g) Research Scientists:

Finding: HEP continues to require the appendices about Research Scientist activities and now provides guidance to PIs and panels on policies for Research Scientists. For funding outside operations and project budgets, HEP encourages physics-research related activities, including 1) algorithm development, performance studies, data collection and analysis, mentorship of students and PDs, and 2) activities in support of detector hardware design and development. Efforts should not be related to long-term operations and/or project activities, and roles and responsibilities should not be capable of being fulfilled by a term position. Some university Research Scientists are supported.

Comment: Research Scientists play an important role in some university groups by supporting activities such as computing and detector R&D and guiding students and postdocs. They can be capable of contributing significantly to an experiment in a variety of ways over the life cycle of an experiment, in a manner that does not fit neatly into other funding streams, such as operations programs or projects. They also can provide continuity to an experimental effort in a way that postdocs cannot. The COV welcomes the clear guidance on funding practices regarding Research Scientists and encourages HEP to broaden guidance to enable support of Research Scientists who may not be substantively engaged in physics-research related activities but who have well-recognized expertise in detector instrumentation or computing and software and who are significant value to their group and its experiment(s). The COV also encourages HEP program managers to convey the guidance not only to review panels but also to mail-in reviewers.

h) Documentation/PAMS

Finding: The structure of PAMS and difficulties in navigating through it to find various documents was a limiting factor in understanding the outcome of the comparative review process.

Comment: Review of the folders were limited due to difficulty in extracting useful award information from PAMS. Folder reviews could be improved by access to metrics and trends which promote understanding of the full overview of the awards. More complete information and better organization would be helpful to the next COV and may even help the PMs! Some questions that the COV could not answer are:

- Balance between large and small programs
- Parity of support across different programs.
- Correlation between the award level and panel rankings, and the occurrence of cases in which the decision differed significantly from the ranking.
- Workforce development trends (graduate students and postdocs)
- Efficiency of award processing and timeliness of the disbursement of funds

In addition, we suggest increasing the transparency of the process and the award distributions by sharing the metrics and the trends with the community via presentations at the HEPAP meetings and/or the annual PI meeting. We suggest monitoring the yearly trends for the frontiers using at least three metrics as follows:

a. *Demographics at the laboratories and the universities* to understand the workforce development trends and the diversity of the workforce. For example, plot personnel supported annually for students, postdocs, research scientists, technical staff and faculty at universities, and for scientists, postdocs and technical staff at the laboratories.

b. *Level of effort of a typical university group.* For example, plot median funding per PI vs year.

c. *Balance between small and large size grants and proposal success rates by group size* to understand any inherent bias in funding for large vs small collaborations. For example, histogram the number of PIs per group and the same broken down into successful and unsuccessful proposals.

Recommendation 12: Implement measures to improve the collection of demographic data for participants in HEP processes (PIs, personnel supported by grants, reviewers, etc.).

2. Effect of the Award Process on Portfolios

This section includes the assessment on how the award process has affected the quality of the overall portfolio, taking into account the DOE, and HEP missions, the available funding, and information presented about the portfolio of funded science.

All the proposals that were reviewed, funded and declined, were very relevant to the mission of the DOE HEP program.

a) Portfolio Quality

Findings: *The CF Program* covers three areas: cosmic acceleration, dark matter, and more recently CMB science. In the area of cosmic acceleration, the Stage III dark energy experiments DES, BOSS, and eBOSS have already delivered very important results. Others, like DESI, promise to deliver even tighter constraints very soon. The centerpiece Rubin/LSST project will start data taking in the near future. It will be a treasure trove for cosmological research for the next decade and has the clear potential to further our understanding of the cause of the accelerated expansion of the Universe. Both DESI and Rubin/LSST are part of the Stage IV dark energy program. The dark matter program is very broad which is appropriate given the many different dark matter candidates under consideration. The G2 experiments will turn on in the near future, to continue exploring the standard WIMP and QCD-axion paradigms, through SuperCDMS, LUX-ZEPLIN and ADMX. While these experiments enter their exciting operations and science-results phase, investments are being made through the DMNI program to explore an expanded parameter space of lower-mass particle dark matter and wave-like dark matter. Several small-scale experiments received initial funding in FY20 following a BRN workshop that resulted in a FOA. With regard to CMB, DOE HEP is planning to support CMB-S4, a large ground-based project with telescopes at the South Pole and in Chile. Currently, DOE HEP supports two small CMB experiments, PolarBear and SPT.

The EF Program consists mostly of US ATLAS and US CMS who are engaged in furthering our knowledge in three of the five Science Drivers of the P5 program. The US-LHC program is ~30% of the overall LHC program and thus is critical to the international program. US members have many leadership roles at all levels of the experiments, showcased by the appointments during the COV review period of Joel Butler (CMS Spokesperson 2016 – 2018), Patricia McBride (CMS Deputy Spokesperson 2018 – 2020]) James Olsen (CMS Deputy Spokesperson 2020 – 2022), Beate Heinemann (ATLAS Deputy Spokesperson 2013 – 2017), Kevin Einsweiler (ATLAS Upgrade Coordinator 2017 – 2019) and Francesco Lamni (ATLAS Upgrade Coordinator 2019 – 2021). The success and impact of the US LHC program, even in the face of constrained budgets, can be summarized by two important metrics:

i. The US LHC program graduated 355 PhDs from 2016 to 2019, and 850 in total;

ii. The LHC experiments publish about 150 papers/year, US members directly contribute to >75% of them. The US CMS collaboration submitted its 1000th paper in 2020.

There is also modest support for studies on future collider initiatives, via dedicated ILC/Japan grants and also re-direction of grants for the LHC activities. The HL-LHC program will serve as a baseline for future collider detector designs and physics performance. It has already been demonstrated that investment in innovative R&D can be incorporated in the detector upgrades with a reasonable timescale for construction.

In the IF program, the U.S. has made strategic investments in several areas of precision and intensity-based physics. In particular, the US is a leader in accelerator-based neutrino physics with both short and long baseline efforts, covering a wide range of topics. The U.S. commitment to LBNF/DUNE assures that it along with Hyper-K will be a world leader in this field going forward for decades. The ongoing NOva experiment together with T2K will yield the best available information on neutrino oscillations prior to LBNF/DUNE. Highly visible at the IF are the world-class muon experiments at Fermilab: Muon g-2, and Mu2e. The former is operating now, and the latter is well into its construction stage. Both aim at sensitive tests of physics beyond the standard model. The U.S. participates on off-shore intensity frontier projects with Belle-II and in various fixed-target CERN experiments. These are priority projects of P5. During this period, the support of 0vbb has moved to NP. The IF currently supports the research of about 420 FTEs.

Comment: *The CF program* is clearly world leading. In the Dark Energy sector, the DESI experiment commissioning is complete and ready to operate. The community is very excited about the opportunity that Rubin/LSST presents, and DOE HEP support for LSST DESC is very important to prepare for the data arrival. The G2 dark matter searches will soon advance the sensitivity to a broad range of dark matter candidates through ADMX, SuperCDMS and LUX-ZEPLIN. CMB-S4 will be unmatched world-wide as a ground-based experiment. It is very important that the support for CMB-S4 ramps up rather soon to fully take advantage of this opportunity.

For the EF, in addition to growth in LHC and HL-LHC research, there are various opportunities for growth in US participation in future colliders efforts with a focus on both physics and detector studies as being discussed in the Snowmass Community study, the ILC pre-laboratory discussions, DOE-CERN partnership evolving to include FCC projects activities, the Instrumentation BRN, and muon collider study efforts. Studies for future collider physics projections and detector design by US PIs is severely limited and only done in spare time. This has an impact on the engagement of the community in the Snowmass process. While developing scenarios for increased EF budget, in the context of leveling the overall research program to 40%, consideration should be given to funding:

- Increased support for university and laboratory participation in LHC and HL-LHC activities,
- Personnel for physics performance and simulation development studies,
- R&D for future collider detector design
- Development of FOAs which result from the BRN study for Instrumentation.

These innovative studies are also of high interest to many junior PIs and are important to their future research programs.

The IF Program covers a rather broad assortment of experimental efforts including experiments with neutrinos, muons, kaons, and e+e- collisions. Any panel comparing efforts must be broad enough to recognize the requirements of each project to succeed, the role played by those submitting, and the relative balance and importance of the science mission in the broader P5 priority landscape. As the P5 priority leads toward LBNF/DUNE, the community will need to migrate toward that effort. This will occur over a long term compared to typical grant cycles, and consequently there will always be "new" groups attempting to join.

b) Balance between large and small projects

Finding: In the CF portfolio, a large number of small to medium scale projects are currently supported in all areas plus Rubin/LSST and CMB-S4 as large projects. The DM community recently responded to a FOA for small-scale, potentially higher-risk, experiments. The EF is driven by research at the LHC experiments (ATLAS and CMS), with very minimal funding for ILC management tasks. No funding is directed to future collider physics performance/projections and detector design studies, and this activity is not considered as part of the "balanced" proposal or programmatic priority. The IF projects span all scales, from larger neutrino and muon collaborations to the small-scale experiments (ANNIE, COHERENT, PROSPECT).

Comment: In the CF, the community has different opportunities to provide input, for example at Snowmass, Cosmic Visions, and Basic Research Needs, however, it is often unclear how this input is used and acted upon by DOE HEP.

c) Balance between Laboratory vs University Research Program

Finding: In FY 2016 and 2017, Fermilab deprioritized EF research, resulting in reduced staffing of its CMS program.

Comment: The reduction at Fermilab has had significant consequences for the US CMS research program, the laboratory-university partnerships, and the LHC Physics Center (LPC). Given that Fermilab acts as the host laboratory for US CMS, its continued support for US CMS is essential.

d) Potential synergies among programs

Finding: The recent DOE-HEP efforts to augment the research funding by capitalizing the synergy with AI/ML initiative is commendable. Some of the HEP computing programs (SciDAC, CCE) are important across the frontiers and are making an impact on the experimental frontiers. There is some small support from the detector R&D programs as noted by the awards. There are a handful of such awards in the EF with limited opportunities. There are synergies between Liquid Noble detectors between CF direct dark matter experiments, IF neutrino experiments, and Nuclear neutrinoless double beta decay experiments. Likewise, IF electron-based dark sector probes (e.g., LDMX) may have synergies with neutrino experiments and nuclear physics.

Comment: For the CF, there is important synergy with the detector R&D program, in particular for new dark matter experiments but also in the area of cosmic acceleration and CMB. There is also technical synergy between liquid noble experiments across IF and CF, as well as with the office of Nuclear Physics, for example, DUNE, LZ, and nEXO. CF programs also stand to benefit from the investment from QIS in the development of new sensors, detectors, and fabrication capabilities.

Recommendation 15: Strengthen existing and explore new collaborative, multi-disciplinary efforts that could advance the P5 science goals and increase the science productivity of the field.

3. The 2014 Particle Physics Project Prioritization Panel (P5)

Findings: In the CF program, DOE HEP has been following the P5 recommendations closely with regard to new experiments. CMB-S4 has successfully undergone CD-0. In the dark matter area, small-scale project opportunities have been provided via the recent FOA. The overall CF research budget is $46-48M with the university research budget increasing from $12.7 to $13.7M between 2016-2019. The number of funded PIs has increased from 80 to 90 during this time.

The two LHC experiments, ATLAS and CMS, continue to be the flagship components of the EF program and a DOE HEP priority as recommended by P5. Participation in all aspects of the program, i.e., physics research, detector operations, and HL-LHC upgrades is supported by DOE HEP. Run 3 operations and HL-LHC upgrades remain on budget and on schedule. The projected personnel [See LHC portfolio review] increase needed to mount a successful program has not materialized due to the declining research budget. The EF university research budget has decreased by ~10% from $39.4M to $35.8M between 2016 and 2019. The number of PIs has decreased slightly from 180 to 175.

The IF research budget bumped up during the review period, largely owing to new university and laboratory awards. Small projects also contributed to the overall increase in the IF total funding. With costs and timelines increasing for the larger projects (e.g., Mu2e, DUNE) there are likely hidden costs in maintaining the research support for personnel/groups awaiting data taking. The IF university research budget has slightly decreased from $22.7M to $22.2M. The number of PIs has decreased from 108 to 90.

Comments: There appear to be significant stresses on the research budgets that could impact science delivery for the P5 projects. Operations costs, which draw from the same pool, are higher than expected. The degree of over-extension is felt in base research grants needed to effectively deliver the science in these areas. Further erosion of support directly impacts the scientific workforce needed to meet the project deliverables and threatens timely delivery of results. A plan should be developed to mitigate the impact of the constrained budgets on overall Experimental Research Program by providing adequate support for the core HEP experimental program and committing to a sustained level of support throughout the lifecycle of individual experiments in order to reap maximal scientific output from investments made.

In the Cosmic Frontier, CMB-S4 developments have been slower than expected. The first large CF experiment, Rubin/LSST, is expecting first data in the near future. It will be very important to provide sufficient research support in the near future to continue these projects on a successful path forward, and to support the analysis and research component of the projects sufficiently to enable the best possible science outcome. To achieve these goals, the office has and will likely need to rely on strategic partnerships both internally (QIS, Detector R&D, computing) and externally (NSF, international partnerships) to deliver on P5 science while also needing to invest in the next round of projects (e.g., CMB-S4, DMNI).

The Energy Frontier program has seen the largest decrease (~10% of the budget). The decline in research program funding and its impact on the EF since the last COV period and the last decade has strained participation in the overall LHC program. The overall reduction in personnel contributing to LHC since 2016 is about 6-16% for US ATLAS. CMS estimates for FY19-22 a drop in the fraction of supported FTEs available for research from 36% to 25% as scientific labor is rolled into the operations and upgrade programs. Compared to 2010 the scope of the program has increased to include scientist participation in Operations, Physics, and HL-LHC Upgrades. The 2018 HEP Portfolio Review Report of the LHC Subpanel projected that US ATLAS and US CMS will each need ~2000 FTE-yr over 4 years in order to meet US responsibilities. A reduction in scientific personnel also leads to fewer US scientists being available for leadership positions. Actions should be taken to rectify this decline of research support in one of the high priority projects recommended by P5.

In the Intensity Frontier, the university research funding is flat at a time when the field is continuously exploiting ongoing experiments (e.g., NOvA, g-2, HPS, ANNIE, PROSPECT, etc.), bringing new experiments into operation (e.g., SBN), while also constructing new projects (e.g., Mu2e, DUNE). Personnel supported on research funding are expected to contribute to experiments at all stages, and with stagnant research support over 2016-2019, there is insufficient personnel to carry out all these activities. In particular, the ramp up of the DUNE project as the flagship program for US HEP has not been met with a required commensurate increase in research support, even as the ongoing neutrino program continues unabated and new groups seek roles in the experiment.

Recommendation: Increase effort in the Experimental, Theoretical and Technology programs in order to realize the promise of the portfolio of experiments and to prepare for future endeavors. In the next year HEP should present a strategy to HEPAP for increasing the allocation to these programs by at least 4% per year until it comprises 40% of HEP expenditures. As recommended by P5, the Accelerator and Detector R&D programs should return to pre-P5 levels.

4. Response to the 2016 Committee of Visitors Report

Particularly relevant for this sub-committee were the following three recommendations.

> *COV 2016 Recommendation #15:* Change the organization of future CoVs to amalgamate the review of the three experimental frontiers into one subpanel that is smaller than the sum of the three current subpanels

Finding: Done. Recommendation 15 was followed to amalgamate the review of the three experimental frontiers into one subpanel. During this COV review, given the broadened format and scope, the subcommittee would have benefited from more time for discussions, allowing for more focus on cross frontier discussions on common issues. If this structure is kept in the future, it has to be ensured that this subcommittee has enough time to carry out the review.

> *COV 2016 Recommendation #22:* Consider for support, through research and operations funding, research scientists making clear and critical contributions to cosmic frontier experiments and construction projects

Finding: Done.

> *COV 2016 Recommendation #23:* Fill the Program Manager position for the Intensity Frontier as soon as possible.

Finding: Done. The hiring of Dr. Brian Beckford as the IF PM is an important development since the last COV and very welcome news.

Appendix VI: Theory Program Summary Report

Theoretical physics forms one of the pillars of the high energy physics program of the DOE. The P5 report, which is the primary guidance document from HEPAP for high-energy physics, indicated that the field requires a thriving theory program.

1. Portfolio Quality

Finding: The funding profile of researchers has remained relatively flat among the tiers, in some cases falling and some cases increasing marginally, since the last COV's findings.

Comment: The current program does fund excellent research, thanks to the fair and expert guidance of the program manager. However, the level of funding has shrunk in purchasing power to the point where strong research proposals are being under-supported, especially in the middle tiers, threatening the P5-mandated goal of maintaining a thriving theory program.

Recommendation 1: Increase effort in the Experimental, Theoretical, Accelerator R&D and Detector R&D research programs in order to realize the promise of the portfolio of current and new experiments and to prepare for future endeavors. In the next year HEP should present a strategy to HEPAP for increasing the allocation to these programs by at least 4-5% per year until effort returns to the pre-P5 level, and should strive to return to 40% of HEP expenditures.

2. Efficacy and Quality of the Program's Processes

Comment: The current reporting of specific budget items to the field (e.g., in the HEPAP and PI meetings) is somewhat confusing and difficult to track. Helping the community have greater clarity of funding trends within theory would be beneficial for more technical discussions with the community on allocation of effort and resources.

More precise reporting, broken down specifically into different programs would allow for more meaningful feedback. In particular, it would be valuable to report spending on the individual Theory, Computing, AI/ML and QIS programs. It would also be valuable to report numbers of personnel at different levels and in both university and lab settings.

Comment: Key to a thriving theory program is the administrative management of the program itself given the funds allocated. This requires assessing the methodologies and implementation of policies of the program manager in carrying out the program as indicated in the following comments.

Finding: The review method for universities requires both mail-in reviews and panel reviews of each PI in the proposals, which can be a time-consuming process. In rare cases, lack of response by mail-in reviewers has created extra challenge to the in-person panelists to deliver an optimal review.

Comment: Although time consuming, the comprehensive approach to reviewing university groups is a highly effective method to rank individual PI performances and decide which PIs will be funded. Keeping the mail-in and panel review processes, fully functioning, continues to be beneficial to the program.

The COV is less certain that the funding levels should be matched so algorithmically with individual PI performances considered in isolation. The COV suggests some additional flexibility in assigning funding to groups based on group synergies.

Recommendation 2: Ensure that an adequate number (at least 3) of written reviews is in hand for each PI in advance of the panel review.

Finding: Laboratory reviews are conducted very differently from the reviews of university groups; in particular the members of the laboratory review panel are not anonymous and there are no prior mail-in reviews.

Comment: We note these large differences between how university theory groups and laboratory theory groups are assessed. We are also concerned that the members of the laboratory review panel are not anonymous, which could influence the frankness of their reviews. There are likely to be good elements of each method (university reviews vs. lab reviews) that the other could use to lower the burden on the program manager and perhaps even raise the quality of the overall review process.

The COV suggests that the reports submitted by the laboratories as part of the review be shortened to a more manageable length for reviewers.

Recommendation 3: Solicit mail reviews as part of the laboratory comparative reviews. The mail reviewers should include university scientists.

Comment: The COV notes that in some cases in comparative reviews that the panels' summaries do not clearly explain the reasons why certain proposals or PIs are assigned to a particular rank. This is particularly difficult for junior researchers who might not have a clear picture of what is being judged by the panel to be insufficient or wrong in their proposals.

The COV suggests that each PI have a panel member assigned, who is instructed to write the ranking of each theory PI in the panel summary, and to give a concise but instructive overview for the reasons behind those rankings.

Recommendation 11: Advise panelists to prioritize providing feedback to PIs through written reviews and panel summaries over determining the detailed rankings of PIs and proposals.

Comment: The long-standing synergy between particle theory and QIS is now quite mature. This raises the question as to whether the requirement for partnerships as part of QIS proposals is counterproductive in some cases.

In addition to the overall COV recommendation to facilitate better integration of the QIS and HEP communities, we suggest that "traditional theory" researchers who are well advanced in QIS have access to the program more directly through HEP/QIS cooperation, and we advocate the removal of artificial barriers that could prevent highly qualified theory PIs from being funded through QIS, such as requirements in FOA's for multi-disciplinary proposals.

Finding: Overall the program manager is highly conscientious and has done an excellent job with the funding made available to the program and in following review recommendations. This work requires highly intensive effort by the program manager.

Comment: We reiterate the earlier recommendation in this report that HEP renew its effort to hire an IPA to aid the program manager. Ideally this would be someone with experience in the university program.

Recommendation 14: Fill the open positions for a program manager for the AI/ML and HEP computing program and for a Theory IPA as soon as possible

3. Response to the 2016 Committee of Visitors Report

> *2016 COV Recommendation 25:* The proportion of panelists should better reflect the balance of thrusts among the PIs being reviewed in order to provide more informed discussion and rankings.

Finding: The theory program appears to have achieved better balance in the subfields of the panelists taking part in the comparative review during the period of this review compared to the period reviewed by the 2016 COV.

Comment: The COV commends HEP for this improvement.

> *2016 COV Recommendation 26:* We reiterate this recommendation. Such a hire will assist with the heavy peak workload and should help provide a balanced perspective to program

Finding: The position is not yet filled.

Comment: The COV reiterates this recommendation.

Appendix VII: Accelerator R&D and Accelerator Stewardship Summary Report

(Draft 11/14/20)

1. Efficacy and Quality of the Program's Processes

a) Solicit, review, recommend, and document proposal actions

Findings: GARD supports accelerator science and technology R&D aimed at enabling HEP discovery science. It does so by developing new accelerator concepts, materials, designs and by pushing the performance limits, while acquiring and broadening the knowledge base of accelerator science. GARD funds medium- and long-term accelerator R&D primarily aimed at supporting the High Energy Physics mission. However, the long-term generic R&D may also benefit other applications—it is "accelerator stewardship" in lower case.

GARD program includes 5 thrusts, as well as an annual US/Japan program FOA. The Accelerator Stewardship program is entirely based on annual FOAs.

Comments: GARD and Accelerator Stewardship programs conduct their proposal reviews in an efficient and high-quality manner. Much attention is paid to panel selection. We commend the program managers for their diligence in organizing solicitations, reviews, and communications. For the review process, the panel process has some notable issues: the lack of panel summaries for a large percentage of the proposals; and the non-uniformity of the grading given by the external reviewers. It is highly desirable that all proposals receive panel summaries, which describe the panel discussions and give a ranking according to a well-defined rubric. Likewise, the language given in the guidance for mail-in reviews should be sharpened, to improve the understanding of the role of numerical grades and permit more reliable use of these grades in panel decisions.

Recommendation 10: Provide an explanation of funding decisions to PIs, particularly in the case of declined proposals or those with significant weaknesses.

Recommendation 11: Advise panelists to prioritize providing feedback to PIs through written reviews and panel summaries over determining the detailed rankings of PIs and proposals.

The Committee believes that the reduction in GARD funding increased the rate of declined proposals (65% new proposals declined, on average) and discouraged proposal submission. The large fraction of declined proposals stresses the comparative review process and therefore requires greater care in those reviews. 'Blue-sky', or high-risk innovative proposals, receive poor marks (on average) from generally conservative reviewers. This leads to **Recommendation 1** of this COV.

b) Monitor active project and programs

Findings: The following programs are part of the GARD portfolio:

1. US-Japan Program

2. Accelerator Traineeship Program

The US-Japan program supports U.S. investigators in bilateral cooperative research activities as part of the U.S.-Japan Science and Technology Cooperation Program in High Energy Physics. This annual National Lab Announcement solicits proposals with scopes of work in HEP that involve substantial collaboration with Japanese investigators. Proposals are reviewed separately in US and Japan. Reviews are shared and recommendations discussed in a Joint Review Panel meeting to coordinate and align award selections. A total of about $1.8M is awarded in this program on an annual basis with about 20 proposals funded, typically.

The DOE Traineeship in Accelerator Science & Engineering supports the training of the next generation of STEM professionals at Universities through the following goals:

1. Advance the DOE mission by advancing specific STEM workforce competencies required for the DOE's unique mission to ensure America's security and prosperity by addressing its science and technology challenge.
2. Address priority DOE technical workforce needs and identified gaps by advancing those critical STEM disciplines and competencies specifically relevant to the DOE's mission where other development programs do not exist or where DOE-relevant applications are not being leveraged to support specific DOE mission responsibilities.

The DOE Traineeship in Accelerator Science & Engineering currently funds three institutions: MSU, SUNY Stony Brook, and IIT.

Comments: These programs appear to be very competitive and well managed.

2. Effect of the Award Process on Portfolios

a) Breadth and depth of portfolio elements

Findings: Following the P5 report and the GARD subpanel report (2015), the Office commissioned roadmaps for each GARD thrust. Three out of 5 roadmaps now exist and are posted on the DOE HEP website.

Comments: The roadmaps are quite valuable and required substantial community and OHEP effort to create. They form the basis of the award process by indicating and communicating direction and are intended to be used by the PI in developing a proposal. The existing roadmaps, and the Accelerator R&D Panel report have been somewhat prescriptive. Also, the GARD program is now fractured into five distinct thrusts with little cross-thrust integration between roadmaps. The Accelerator and Beam Physics thrust can play such an integration role. Snowmass discussions will also provide more venues for cross-thrust integration.

b) National and international standing of the portfolio elements

Findings: The GARD program has successfully led revolutionary developments in the past (i.e., the GARD program managers know what they are doing). For example, the GARD/ILC-funded research in SRF led, in 2012, to a revolutionary improvement in cavity cryogenic performance that was completely unforeseen. These cavities have been used to build a world-leading free-electron-laser in the US and will be a key part of PIP-2. This was a big boost for the US technical leadership across the world and has contributed to the inception of the QIS program.

Comments: The present GARD-based program has been weakened to the point where such a revolutionary change is unlikely to occur soon. Much critical work is now supported through Early Career Awards. Subcritical efforts are supported in GARD in emerging areas, e.g., cryogenic high field RF cavities. The advanced accelerator program emphasizing very high gradient plasma techniques remains tenuously near the frontier, with emerging strong competition in Europe and Asia challenging the traditional leading role played by the US in this arena.

3. The 2014 Particle Physics Project Prioritization Panel (P5)

Findings: The 2014 P5 recommended that GARD focus on Advanced Technology R&D strategy to increase performance and dramatically improve cost effectiveness. HEPAP Accelerator R&D Subpanel (ARDS) provided prioritization advice on medium- and long-term accelerator R&D.

Shortly after the P5 report was released, there were significant reductions in the accelerator R&D funding through the GARD program, from $64M (FY13 actual) to $47.4(FY19 actual, including a reduction in university-based accelerator R&D of about 25%. (2016 COV report Finding).

Comments: The Committee believes that the reduction in GARD funding increased the rate of declined proposals (65% new proposals declined, on average) and discouraged proposal submission. The GARD program is considered to be "bare-bones". Project-based accelerator studies, often based at labs, suffer less than university-based work.

Within the constraints of the funding, the HEP has performed an admirable job in maintaining both forward motion in research and in adherence to the detailed recommendations of the HEPAP P5 GARD subpanel report. In regard to long term planning, HEP has encouraged community-based development of roadmaps to more clearly identify current and future research priorities. In the light of these developments, progress in all areas of accelerator R&D are noted, albeit with strict limitations on the rate of this progress due to funding constraints, which are severe. Some areas (e.g., those related to the intensity frontier) may be seen as subcritical, while others (advanced accelerators) are advancing in a way, which risks their competitive impact in the worldwide context.

While an overall increase in funding levels could mitigate the issues associated with the implementation of the P5 GARD subpanel report, even in the absence of this increase, an important opportunity to expand the horizons of accelerator research both inside and outside of HEP remains in the formation of the new ARDAP office. This leads to **Recommendation 16** of this COV:

Recommendation 16: Seek a principal role for HEPAP in the future advisory processes for ARDAP.

An update to the P5 GARD 2014 planning exercise is essential, with wide community input. Given the nature of accelerator R&D in the US, this planning effort is most naturally centered in the HEP context.

4. Response to the 2016 Committee of Visitors Report

Findings: The 2016 Committee of Visitors made the following recommendations in its subpanel report for this program:

> 2016 COV Recommendation 29: Work to address the accelerator R&D subpanel recommendations to ensure a healthy and vigorous basic accelerator R&D portfolio.

HEP agreed with the Recommendation and in response HEP commissioned roadmaps to outline paths that might be followed to make progress in accelerator development. These are quite valuable and required substantial effort to create. They form the basis of the award process by indicating and communicating direction and are intended to be used by the PI in developing a proposal.

Comments: Two constraints dominate and ultimately block the support and development of a healthy and vigorous basic accelerator R&D portfolio: 1) project-driven work and 2) line-item initiatives.

The COV advises HEP to commission a sub-panel to revise the Accelerator R&D Subpanel report, taking into account these practical constraints.

Appendix VIII: Quantum Information Science Summary Report

1. Efficacy and Quality of the Program's Processes

a) Solicit, review, recommend, and document proposal actions

Findings: The pilot project QIS program (QuantISED) reviewed more than 100 proposals in a two-year period. The success rate was about 45% overall, albeit higher (about 60%) for proposals led by DOE laboratories. Proposals were reviewed by a panel, augmented with mail-in reviews.

Proposal aspects of the QuantISED program were well-run by the program manager, including solicitation, reviews, recommendations, and associated documentation.

Comments: In future QIS/HEP solicitations and reviews, it will be important to communicate clearly to prospective PIs and to reviewers the broad definition of QIS relevant to HEP, so that the best science can be supported.

b) Monitor active project and programs

Findings: In February 2016, HEP joined with ASCR to organize a roundtable on "Quantum Sensors at the Intersections of Fundamental Science, Quantum Information Science, and Computing". This followed a 2014 study group report on Grand Challenges at the Interface of Quantum Information Science and Particle Physics, and Computing and Quantum Sensors at the Intersections of Fundamental Science and Quantum Information Science and Computing. Funding Opportunities were subsequently announced in FY 2018 and FY 2019.

In addition to these foundational workshops, HEP has communicated QuantISED goals and funding guidelines at its annual PI meetings.

Comments: The program manager has an excellent relation with the investigators and monitors progress regularly and effectively.

The DOE QIS kick-off meeting, held Jan. 31 to Feb. 1, 2019, was effective in furthering cross-disciplinary communication at the QIS/HEP interface and across the SC QIS spectrum.

Future such DOE QIS PI meetings should be encouraged. The detailed format of such meetings should be left to DOE discretion; but it would be ideal to invite the full range of HEP PMs and SC QIS PMs to attend, as well as PIs from other HEP activities (theory, accelerator, etc.), to encourage communication across all boundaries at the QIS/HEP interface and across the SC QIS spectrum.

Recommendation 15: Strengthen existing and explore new collaborative, multi-disciplinary efforts that could advance the P5 science goals and increase the science productivity of the field.

2. Effect of the Award Process on Portfolios

a) Breadth and depth of portfolio elements

Findings: The quality and balance of the QuantISED pilot efforts are excellent. Award scope, size, and duration are reasonable for first-stage pilots.

Comments: Key challenges remain in (i) integrating the QIS effort effectively with other parts of HEP and (ii) defining how the QIS program will achieve continuity and evolve to include new PIs and science thrusts.

b) National and international standing of the portfolio elements

Comment: The national and international standing of the QIS portfolio elements is strong, in terms of the potential of a set of small, short-term pilot efforts and stature of PIs. Further development of the most successful pilots could result in national and international leadership.

Recommendation 18: Strengthen the HEP QIS program through 1) greater integration of traditional HEP research efforts with the QIS program; 2) clear articulation of QIS goals that capitalize on and advance HEP expertise; and 3) advancing QuantISED pilots that promise to address the P5 science drivers.

Appendix IX: Detector R&D Summary Report

1. Efficacy and Quality of the Program's Processes

a) Solicit, review, recommend, and document proposal actions

Findings: The program reviews on average 22 proposals per year. The success rate has decreased to about 40% in the last year. The majority of proposals are multi-year, new proposals. Proposals are reviewed by a panel, augmented with mail-in reviews.

Proposals are solicited for generic detector R&D with emphasis on long-term, high-risk, high-impact and broad applicability. Proposals for blue-sky scientific research on innovative technologies are strongly encouraged.

The solicitation for proposals is clear and seeks a balance between incremental and transformative R&D with a focus on promising new technologies with U.S. leadership. The response for blue-sky R&D proposals has been moderately successful.

The number of reviewers for each proposal is high and the reviewers all have the right technical background and are very knowledgeable in the topics being reviewed.

There are few, more or less standing, larger umbrella grants that mostly support technical capabilities and expertise for use as a community resource.

In 2018 a new Graduate Instrumentation Research Award (GIRA) fellowship was created, managed by the Detector R&D program, that supports at least one graduate student for one to three years.

Comments: The review process overall is managed very efficiently and proficiently with adequate and timely feedback provided to the proponents.

The program manager does an excellent job at getting an adequate number of reviewers (5+) for the proposals with broad knowledge about the topics at hand, balanced between mail-in and panel reviews.

Although the level of funding is based on peer review, programmatic factors and availability of appropriated funds come into play that are not (always) reflected in the feedback to the proponents. The high-level feedback of the program manager to the individual PIs is limited and would add value to the review process, especially for the proposals that have been declined.

The call for "blue-sky" detector R&D proposals has had limited success to date. Providing a prospect for longer-term funding at the outset in the FOA, with mid-term evaluations, might increase the interest in blue-sky detector R&D proposal.

The program manager is very proactive to leverage support from synergistic Research Frontier efforts. There is a clear desire to maximize support for junior personnel, which the CoV strongly endorses.

Although the written evaluations are quite consistent among the reviewers, the numerical values assigned by each reviewer can differ significantly. Clearer guidance on the evaluation metric and numerical ranking would be beneficial to the overall review process.

The Program Manager is to be congratulated on supporting the new GIRA fellowship, which has been quite successful in attracting competitive first-rate instrumentation proposals. Working with CPAD, increasing its visibility and size is encouraged.

b) Monitor active project and programs

Findings: The program manager has an excellent relation with the investigators and monitors progress on a continuous basis.

The PI meeting and the annual CPAD meeting provides a great venue for the program manager to interact with the researchers.

Comments: The program manager makes very good use of the PI and CPAD meeting to interact with the community and follow the progress of the supported research.

2. Effect of the Award Process on Portfolios

a) Breadth and depth of portfolio elements

Findings: The program is heavily weighted towards supporting the detector R&D programs at several national laboratories. Nearly 80% of the funding goes towards the national laboratories, of which about ⅔ goes towards research and ⅓ towards operations of facilities. A relatively small fraction of the funding goes towards the universities.

The distinction between facility support and research for the detector R&D program at the national laboratories is not crisp.

The budget has remained relatively flat over the period reviewed; this budget, however, is significantly less than the pre-P5 budgets for this program.

Following the P5 recommendation, the program has successfully supported directed R&D for the high-priority P5 projects.

During the period of review one "traveling" laboratory comparative review was held, which was deemed very effective.

Comments: This research program is of high scientific merit as it develops the technologies for future experiments. Although the funding has remained constant during the period that is being reviewed, it has seen a significant reduction compared to the pre-P5 budget. Furthermore, the program operates in a very constrained budgetary environment, with a large fraction going to the national laboratories that support facility operations, leaving little room for long-term high-risk high-reward investments.

The CoV has three main concerns. The Detector R&D program has followed the P5 recommendation supporting the high priority P5 projects with directed R&D and has been very successful in launching these projects, despite decreasing budgets. The CoV strongly encourages the program to sharply pivot to support non-directed, more blue-sky R&D and support more vigorously innovative, transformational developments. Our second concern is the balance between support for the national laboratories and universities. The current program is heavily tilted towards supporting the national laboratories, leaving little free energy for support for university-based instrumentation development. Lastly, the overall level of funding for this program is becoming sub-critical to establish a foundation to build a healthy and vibrant future HEP portfolio. The Office invests only about 1.5% of its total budget in the development of new instrumentation, which are the crucial tools to probe nature; and this amount is most likely an overestimate.

The strong imbalance between university and national laboratory support has not been conducive to better coordination between the laboratories, leading to less-than-optimal use of resources and a lack of cross-field interactions. To mitigate this imbalance, some fraction of the budget could be explicitly reserved for joint proposals from laboratory and university PIs.

The recent BRN was very timely and will provide the detector R&D program with clear guidance to develop a program for detector R&D that ensures the field will be positioned for a promising future. It could provide a nice opportunity for increasing the budget for this program.

Recommendation 17: Generate a roadmap for investments in detector R&D based on future research needs of the field, with emphasis on innovation, including a substantial role for university-based R&D.

Comment: The communication between the technology and research program could be enhanced and opportunity could be realized to build a stronger research program. The efforts on QIS have been extremely successful and the QIS and Detector R&D program managers are to be congratulated with its success. Exploring synergies between the detector R&D program and QIS can enhance US leadership. Further exploring synergies between both areas will help to develop a truly compelling research program as articulated in **Recommendation 18**.

Recommendation 18: Strengthen the HEP QIS program through 1) greater integration of traditional HEP research efforts with the QIS program; 2) clear articulation of QIS goals that capitalize on and advance HEP expertise; and 3) advancing QuantISED pilots that promise to address the P5 science drivers.

b) National and international standing of the portfolio elements

Findings: The COV was not provided with any material regarding instrumentation effort in the international community.

Comments: Given that no quantitative information was provided with regard to detector development in other countries, only a qualitative assessment can be provided based on the experience of the CoV committee members. The CoV is of the opinion that the U.S. community is lagging in the development of innovative new technologies for particle physics compared to Europe and Japan. Recent advances in detection sensitivity of particle physics detectors have mainly originated overseas, be it in the area of cryogenic, cherenkov or semiconductors.

It is strongly recommended that the funding and stature of the detector R&D program be restored at least to pre-P5 levels with appropriate balance between universities and national laboratories as noted in **Recommendation 1**.

3. The 2014 Particle Physics Project Prioritization Panel (P5)

Findings: The P5 report contained two recommendations pertaining to the detector R&D program: i) Focus resources toward directed instrumentation R&D for high-priority projects in the near term. As the technical challenges of current high-priority projects are met, restore to the extent possible a balanced mix of short-term and long-term R&D; ii) Strengthen university-national laboratory partnerships in instrumentation R&D through investment in instrumentation at universities. Encourage graduate programs with a focus on instrumentation education at HEP-supported universities and laboratories, and fully exploit the unique capabilities and facilities offered at each.

The program has been very successful in launching the high-priority P5 projects through support for directed R&D.

A graduate student fellowship for instrumentation was created.

Comments: The program has also been very successful encouraging graduate programs with a focus on instrumentation education through the creation and support of the graduate instrumentation research award.

The university-national laboratory partnership in instrumentation has remained very favorable towards the national laboratories.

To address the imbalance between laboratory and university-based detector development, as a first step the university-national laboratory partnerships should be strengthened through an expansion of the graduate fellowship program to at least three fellowships per year with a dedicated fellowship for underrepresented talent.

Appendix X: Artificial Intelligence & Machine Learning and Computational HEP Summary Report

Comment: The Artificial Intelligence, Machine Learning and Computational HEP subpanel considered in its scope four aspects of the HEP program:

- the "Computational HEP" program, which includes the Scientific Discovery via Advanced Computing (SciDAC4) competition and a Scientific Computing component.
- the cross-cutting role of computing in HEP including the operations programs of large projects,
- the cross-cutting role of machine learning / AI in light of the new budget allocations being devoted to this topic, and
- the cross-cutting cyberinfrastructure components that do not fall under the umbrella of a particular project, but which the community relies upon.

1. Efficacy and Quality of the Program's Processes

Finding: The CompHEP sub program goal is to advance HPC use at HEP, connect to ASCR resources, & foster crosscut solutions. It has a budget of approximately \$8M/year with \$2.5-3.5 devoted to the SciDAC component (not including comparable allocation from ASCR), \$5-6M devoted to the Scientific Computing component (which includes the HEP Center for Computational Excellence), and a small portion that supports projects such as INSPIRE and Geant4.

Comment: The presentation to the COV for CompHEP was merged with the QIS presentation; however, QIS dominated the material and time allocation. The material focused primarily on the SciDAC4 program. The subcommittee sought additional information, which HEP responded to promptly.

Finding: The Scientific Discovery via Advanced Computing (SciDAC4) competition reviewed 13 proposals leading to 3 awards and 2 pilot projects.

Comments: The competition was generally well-run with each proposal receiving multiple reviews.

There was some imbalance between the research themes in the SciDAC4 proposals and the expertise of the panel and reviewers. In particular, the emphasis on machine learning in the proposals was not met with corresponding expertise among the panel and reviewers.

Finding: Computing and software are a significant fraction of the cost of projects (roughly 50% of operations in some experimental areas), which is significantly larger than expenditures of the SciDAC4 program whose goal is to advance HPC use at HEP.

2. Effect of the Award Process on Portfolios

a) Quality of the resulting portfolio

Finding: The SciDAC4 awards and the recent Center for Computational Excellence have established an important baseline effort devoted to computing R&D for future experiments.

Comments: Computing models for big collaborations are very complex. It is important to support computing models that enable a range of tasks efficiently. Taking advantage of HPC resources clearly is very important, however, they are most likely not a good fit for every task and a careful analysis for the different computing needs of the collaborations is very important.

Accounting for the total cross-cutting effort in computing and software in HEP is not straightforward as it is distributed across CompHEP, the research program, and the operations program. Furthermore, understanding the breakdown of that investment in terms of personnel devoted to software development or R&D efforts, personnel devoted to operations and support, and computing facilities is also not straightforward.

HEP should Assess software and computing needs and risks across the HEP program with the goal of implementing the P5 vision. Identify areas where cross-cutting research can be carried out and explore opportunities to bring in expertise or resources from outside HEP.

Recommendation 19: Develop a cross cutting view of the allocations in computing, software, and AI/ML broken down by program and type of cost (e.g., computing facilities, FTE, operations, R&D).

b) National and international standing of the portfolio elements

Finding: The support for important shared cyberinfrastructure has been drastically reduced over the years.

Comments: The global research community relies on a few important pieces of shared cyberinfrastructure, which can result in a classic tragedy of the commons. The subcommittee noted a few prime examples including INSPIRE, the particle data group (PDG), GEANT4, data repositories for long-term data preservation, and science gateways that help the field exploit multiple experimental data sets and aid in theoretical interpretation.

To address this, HEP should establish a more formal process, perhaps resembling the comparative review, for such shared cyberinfrastructure components taking into account that some projects involve global cooperation. HEP should establish sufficient support for the maintenance and further development of shared cyberinfrastructure components and ensure that it is understood that this is a crucial component of the program and be part of the portfolio of the CompHEP Program Manager.

The increased use of contemporary data science tools as well as AI/ML techniques in the field presents both opportunities and risks. This development is well aligned with the national priorities in workforce development as well as national strategic initiatives in AI and computing. However, maintaining a sustainable workforce with this expertise may become more challenging in the future as these skills are highly valued in industry. The increased engagement with industry also presents the opportunity to leverage the SBIR program in HEP.

To address this, HEP should explore and encourage opportunities to support computing, software, AI and machine learning through the SBIR program.

c) Diversity

Comments: The lack of diversity in computer science and in the information technology sector of the economy, especially among women and underrepresented minorities, is a well-recognized challenge. This challenge is compounded with the challenges faced by physics, which should be kept in mind

The COV noted the importance of INSPIRE in assessing the qualifications of the PI as it provides a comprehensive and uniform written record for the community.

3. The 2014 Particle Physics Project Prioritization Panel (P5)

Finding: The P5 report, the 2016 COV recommendations, and the 2018 HEPAP LHC Subpanel's report all emphasize that computing and software are a significant fraction of the cost of projects (roughly 50% of operations in some experimental areas, most of which is tied to computing pledges for large, international collaborations) and that it is imperative that the large experiments develop new computing models that can better exploit high-performance computing (HPC) resources. Furthermore, they have all recommended strengthening cooperation and to seek synergies across experiments in an effort to reduce costs and to develop workforce expertise in the field.

Since 2016 HEP has taken various actions to address these recommendations including data calls to the laboratories and large experiments in 2017, which revealed that 'business as usual 'would be unaffordable. A second data call to the laboratories and large experiments culminated in an Inventory of Computing Needs Roundtable in 2018. In addition, ATLAS and CMS received Performance Evaluation and Measurement Plan (PEMP) Notables, and submitted plans for High-Luminosity LHC software & computing R&D activities planned for the next 2-3 years with specific milestones for deliverables under the U.S. Subsequently, various pilot projects were identified to explore more efficient use of HPC resources. In addition, the Center for Computational Excellence received renewed funding and the SciDAC4 funded projects partially addressing these issues.

Comment: While these are all laudable steps, the challenges of computing and software continue to be of critical importance and should be addressed with dedication and urgency.

To address this, Office should develop a cross-cutting view of the allocations in computing, software, and machine learning / AI broken down by program and type of cost (e.g., computing facility, FTE in operations, support, R&D). This will facilitate not only the next COV, but also the Program Managers in navigating the complex computing landscape of the program.

Finding: A significant appropriation (~$10-35M) is anticipated for AI and Machine Learning in the next few years.

Comment: This cross-cutting AI/ML investment will be relevant for the research program as well as for addressing the computing challenges referred to above.

We emphasize recommendations from this report:

Recommendation 14: HEP should fill the open positions for a program manager for the AI/ML and HEP computing program as soon as possible.

Finding: Funding and support of software and computing for current operations is quite separate from funding for R&D devoted to meeting the computing demands of future experiments. While there is much in common between these efforts in terms of expertise and personnel, there is no clear mechanism to rebalance the relative budgets between these needs and there are bureaucratic barriers to doing so even if it is in the best interest of the HEP program.

To address this, the program manager should develop strategies and mechanisms to assess and potentially rebalance the HEP allocations in computing, software, and AI/ML that support the current operations program and allocations that are devoted to meeting the needs for forthcoming experiments.

This effort within HEP could be augmented with a standing committee to help navigate the complex computing landscape of the program. Activities might include soliciting written input from the community, performing a basic needs assessment, hosting workshops, and, perhaps, modifications to the FOAs that have a major computational component.

4. Response to the 2016 Committee of Visitors Report

The 2016 COV recommendations related to computing are addressed in Section E.5 of this report.

Appendix XI: List of recommendations

Recommendation 1: Increase effort in the Experimental, Theoretical, Accelerator R&D and Detector R&D research programs in order to realize the promise of the portfolio of current and new experiments and to prepare for future endeavors. In the next year HEP should present a strategy to HEPAP for increasing the allocation to these programs by at least 4-5% per year until effort returns to the pre-P5 level, and should strive to return to 40% of HEP expenditures.

Recommendation 2: Ensure that an adequate number (at least 3) of written reviews is in hand for each PI in advance of the panel review.

Recommendation 3: Solicit mail reviews as part of the laboratory comparative reviews. The mail reviewers should include university scientists.

Recommendation 4: Develop guidance for mail-in and panel reviewers about proposal ratings in order to improve consistency.

Recommendation 5: Inform review panels and mail-in reviewers about the impact of biases regarding gender, race, age, and institution.

Recommendation 6: Set clear expectations for mail-in and panel reviewers that proposal evaluation should be based on proposal content and documented information, rather than informal or anecdotal information about prior performance by the PI(s).

Recommendation 7: Promote the importance of effective mentorship as a consideration in the proposal review process.

Recommendation 8: Work with SC for more timely release of FOAs in order to allow adequate time for proposal preparation and review and PI notification before the start of the award period. In the case of the Early Career awards, the timeline should accommodate both mini-panel and super-panel reviews.

Recommendation 9: Notify PIs of award decisions promptly, whether positive or negative.

Recommendation 10: Provide an explanation of funding decisions to PIs, particularly in the case of declined proposals or those with significant weaknesses.

Recommendation 11: Advise panelists to prioritize providing feedback to PIs through written reviews and panel summaries over determining the detailed rankings of PIs and proposals.

Recommendation 12: Implement measures to improve the collection of demographic data for participants in HEP processes (PIs, personnel supported by grants, reviewers, etc.).

Recommendation 13: In consultation with SC, develop and implement strategies and policies to foster diversity, equity and inclusion in supported university groups as well

as at the laboratories. The policies should be widely publicized to the community, for example through presentations to HEPAP and at PI meetings.

Recommendation 14: Fill the open positions for a program manager for the AI/ML and HEP computing program and for a Theory IPA as soon as possible.

Recommendation 15: Strengthen existing and explore new collaborative, multi-disciplinary efforts that could advance the P5 science goals and increase the science productivity of the field.

Recommendation 16: Seek a principal role for HEPAP in the future advisory processes for ARDAP.

Recommendation 17: Generate a roadmap for investments in detector R&D based on future research needs of the field, with emphasis on innovation, including a substantial role for university-based R&D.

Recommendation 18: Strengthen the HEP QIS program through 1) greater integration of traditional HEP research efforts with the QIS program; 2) clear articulation of QIS goals that capitalize on and advance HEP expertise; and 3) advancing QuantISED pilots that promise to address the P5 science drivers.

Recommendation 19: Develop a cross cutting view of the allocations in computing, software, and AI/ML broken down by program and type of cost (e.g., computing facilities, FTE, operations, R&D).

Recommendation 20: Establish a mechanism in consultation with HEPAP to advise HEP when a programmatic choice must be made that significantly deviates from the P5 plan or when the context for that choice has evolved significantly from P5 expectations.