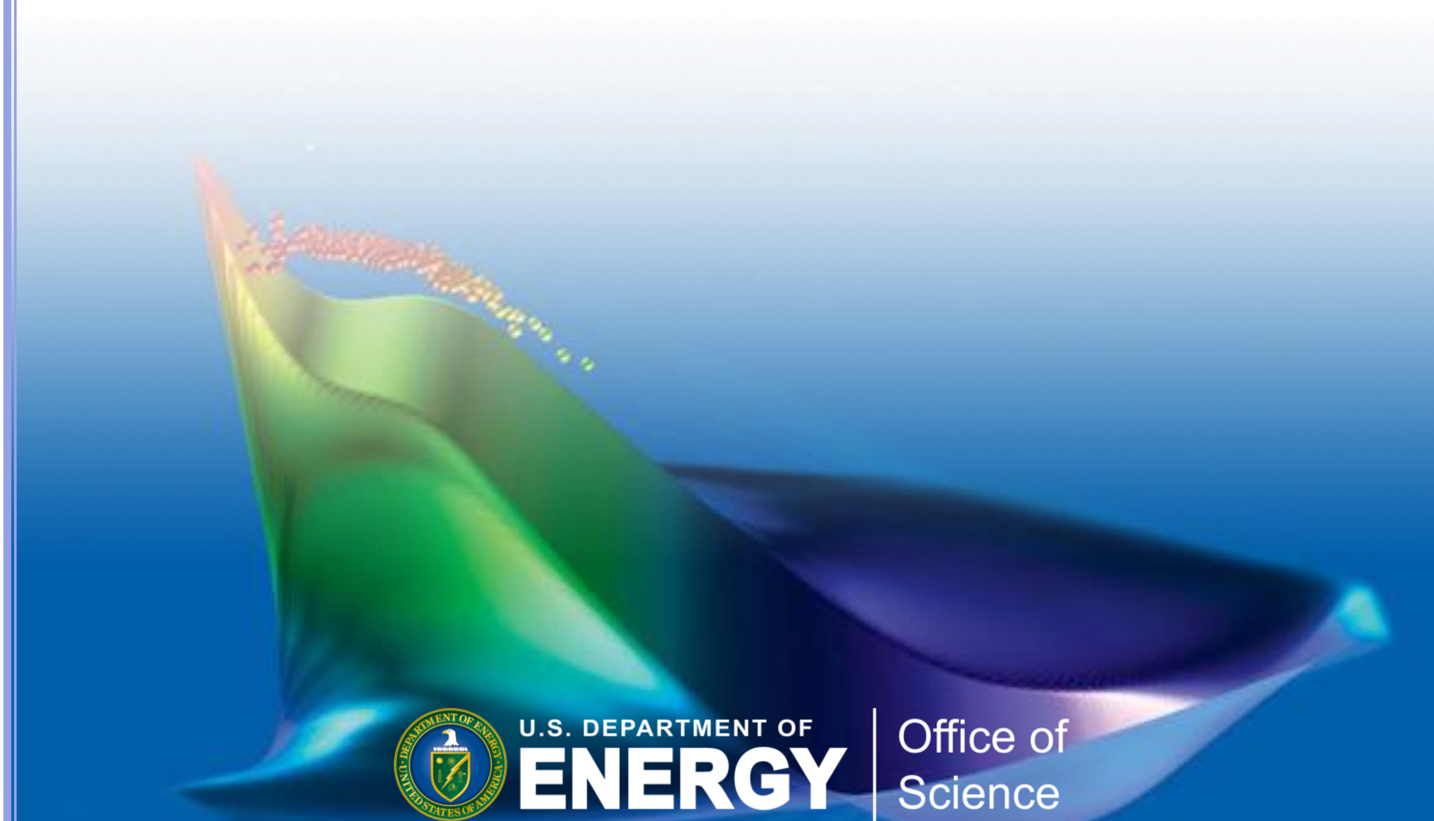
Report of the HEPAP Subcommittee for

Review of the United States Particle Accelerator School

May 2015



Cover Image: Simulation of a plasma accelerator. Credit: C. Huang, Los Alamos National Laboratory

Summary

Noting that the United States Particle Accelerator School (USPAS) "plays a key role in training the next generation of researchers and practitioners who are skilled in harnessing the research potential of particle accelerator technology to advance science and engineering across a broad spectrum of disciplines and applications," the Department of Energy (DOE) Office of Science charged the High Energy Physics Advisory Panel (HEPAP) to perform a retrospective review to examine and assess, for DOE only, the effectiveness and cumulative impact of USPAS in the context of workforce development and training, as well as to assess the overall quality and breadth of the USPAS program. For this purpose, the Chair of HEPAP assembled a subcommittee to conduct the review and assessment of USPAS. This report summarizes the conclusions of the Subcommittee.

Applications of accelerators are ubiquitous. Accelerators are used in medicine and in industry, as well as for discovery science. Members of the accelerator workforce are found in the public and private sectors. Accelerator scientists produce, accelerate, and manipulate charged particle beams, and develop advanced technologies necessary for these tasks. The realization of accelerators also requires specialized technical skills and engineering in a diverse array of disciplines and technologies. This matrix of theoretical, technical, and practical skills remains essential for operations and maintenance throughout an accelerator's lifetime. Accelerator science and technology is a multidisciplinary field, and the accelerator workforce is diverse, consisting of scientists and engineers, technologist and technicians, and operations staff. The accelerator staff at the DOE national laboratories numbers nearly three thousand, and the Subcommittee estimates that over half of this workforce requires constant training and retraining in accelerator science or technology.

USPAS very effectively delivers both training and workforce development. USPAS's effectiveness derives from an organizational model responsive to the workforce development and training needs of the DOE laboratories that simultaneously addresses key needs for workforce development and training. The central feature of the USPAS organizational model is a Consortium of eight DOE laboratories and two universities, this set of institutions, along with the Office of Science, founded USPAS. The Consortium has input to the governance and management of USPAS through representation on a Board of Governors. The Board provides an active mechanism for laboratory input to the definition and evolution of the USPAS. The Consortium member institutions are the

principal source of USPAS instructors, giving rise to further engagement in the USPAS program. The member institutions also contribute to the operating costs of USPAS program sessions, which along with providing instructors, embodies their shared commitment.

The USPAS program model involves two short program sessions per year with curricula that delivers intense training to three basic groups: practicing scientists and technical staff, who attend USPAS as a form of continuing education that will improve their skills and capabilities; scientists transitioning to accelerator science and technology from careers in other fields of science and engineering; and university students preparing for careers in accelerator science. Training for the second and third groups develops new and future members of the accelerator workforce. The structure of the sessions, curricula offering both general courses on accelerator science at various levels and courses of a more specialized technical or topical nature, along with the intense nature, small class size, and high quality instruction, effectively packs into a two-week session as much instruction as is accomplished in a university semester. Each of the two USPAS sessions per year has approximately one hundred and fifty enrollees. Since its first academic session in 1987, USPAS has had more than four thousand distinct individuals enroll. USPAS sessions move geographically around the U.S., hosted at universities and often co-located with a DOE national laboratory, which gives the field of accelerator science increased visibility.

The impact of USPAS on workforce development and training is such that the laboratory members of the Consortium uniformly commend the value of USPAS, and all attest that USPAS is vital for development and training of their laboratory workforce. The cumulative impact of USPAS is also manifest in the number of former USPAS participants who are engaged in accelerator science in the U.S. (more than 2,300), and in the number who now play leadership roles at the laboratories (more than 250) and in the private sector.

The USPAS program is of high quality and remarkable breadth. USPAS offers training in an impressively wide variety of subjects in accelerator physics and technology, which addresses the training needs of the three groups defined above. The selection of subjects stretches from general accelerator science, with these courses ranging from the undergraduate to advanced graduate student level, to special topics in accelerator science or technology, to relevant topics in project management and safety. The training that USPAS delivers is of high quality, as supported by a number of objective metrics and subjective measures. Input from the laboratories indicates that, and describes how, USPAS addresses their workforce development and training needs. Trainees attest to the program quality in evaluations provided at the time of their attendance and, in letters to the Subcommittee, many trainees attest years later to the impact that USPAS had on their careers.

The nature of the field demands that members of its workforce have a broad general overview of accelerator science and technology as well as specialized, advanced training in beam physics and accelerator technology. The rapid evolution of accelerator technology and its applications creates a near-constant need for training in new accelerator subjects, even for personnel already in the workforce. Well-trained members of the accelerator workforce are highly sought after in both the public and private sectors, to the point that it is often difficult to fill positions at the DOE laboratories. Moreover, there is a worldwide competition for well-trained accelerator scientists and engineers, who are frequently attracted from U.S. labs to non-U.S. accelerator projects.

Opportunities at universities for training to enter the discipline of accelerator science and technology are limited, and few avenues exist for existing workforce to access additional training. University programs are few, and each existing program has small numbers of students and typically only one or two faculty members. University programs produce about 15 to 20 Ph.D. academia, industry, and government bound graduates per year and are not capable of addressing the annual need for approximately forty new Ph.D.-qualified members of the DOE laboratory workforce. Consequently, university programs in accelerator science rely on USPAS to deliver courses to fill in the gaps in their own curricula. Nearly all U.S. graduate students studying accelerator science attend USPAS, typically taking two or more courses.

USPAS has developed an effective mechanism for providing workforce development and training in accelerator science and technology with a number of essential, and sometimes unique, capabilities and features. The essential capability of USPAS is serving the combined needs of the three principal audiences: the existing workforce, those seeking transition into the workforce, and students. The two major curricular features, general courses on accelerator science and a wide variety of specialized technical and topical courses, provide essential capabilities for transmitting and maintaining accelerator science and technology knowledge. The close association between USPAS and the DOE laboratories is absolutely essential to the development of the accelerator workforce and has led to very effective delivery of information. The close alignment and relationship between the laboratories and universities is another essential and unique feature; this alignment provides three essential capabilities: university instruction, a workforce pipeline, and visibility of the discipline.

The management structure of USPAS, with a Board of Governors, Curriculum Advisory Committee, and Director and staff is appropriate. The structure and management team are effective. The USPAS program is cost effective. Two features of the management structure seem to be essential. First, the Board being a governing body rather than an advisory group ensures close association between the DOE laboratories and USPAS. Second, hosting USPAS management at a stable facility committed to accelerators provides economies of scale in operations and minimizes budgetary requirements.

USPAS has a good record regarding diversity and has made efforts to increase the percentages of women engaged as instructors and as enrollees. Both percentages have grown, and the percentage of woman enrollees is now in line with national trends in the field. USPAS has also appointed a Minority Outreach Coordinator. Laboratories have noted the positive impact of USPAS on the diversity of their workforces.

In summary, USPAS effectively and efficiently serves the critical needs for accelerator workforce development and training in the U.S., particularly for the national laboratories. The need for accelerator workforce development and training in the U.S. will persist, and is expected to grow with time as application of accelerators expands. The effectiveness of USPAS is very closely connected to addressing training and workforce development; addressing the needs of its three audiences in a single program; the close association of USPAS, the DOE laboratories, and universities; and the support of the Office of Science.

Contents

1 Introduction

Accelerator scientists, engineers, and technicians design, build, and operate particle accelerators. These machines are used to produce, accelerate, and manipulate charged particle beams. Accelerators are composed of numerous subsystems, the realization of which pushes the boundaries of technology, at least at the forefront of the field. Producing an accelerator subsystem, such as high-field magnets or high-gradient radio-frequency accelerating cavities, requires understanding of science and engineering in a diverse array of disciplines. These range from classical subjects such as electromagnetism and special relativity to specialized areas such as vacuum systems, cryogenic systems, material science, and high-power microwave technology. Considering the accelerator as a whole, controlling large numbers of charged particles requires a detailed understanding of how they interact with the magnetic and electric fields that they encounter, with their surroundings, and with each other though collective effects. Many of these effects are highly non-linear and require the development of novel techniques. This matrix of theoretical, technical, and practical skills remains essential for operations and maintenance throughout the lifetime of the accelerator.

Applications of accelerators are ubiquitous. For instance, accelerators are used to diagnose and treat tumors, for communications, and for ion implantation in the semiconductor industry. In all, roughly thirty thousand accelerators are now in use worldwide [1]. Accelerator technology is a rapidly expanding area for industry, with a market increasing at a rate of ten percent per year [2]. The most sophisticated accelerators are research accelerators: x-ray light sources, spallation sources, and particle colliders. Arguably among the most powerful scientific tools available, these accelerators in the U.S. advance the research of eighteen thousand scientists each year. While no hard data are available regarding the employment of Ph.D. accelerator physicists in the U.S., approximately half appear to go into industry, about one-third work at the national laboratories, and the remainder join university faculties.

Building these powerful tools requires a highly-trained workforce, with expertise in a wide range of topics, many of which are advancing rapidly. The need for training falls into three categories, which correspond to three workforce populations:

- Professional development of mid-career accelerator scientists and engineers.
- Training of scientists new to accelerator science.
- Courses for undergraduates and graduate students in accelerator science.

Professional development of mid-career accelerator scientists and engineers: Even seasoned accelerator physicists and engineers benefit from mid-career training, either to update their knowledge or to become familiar with a new area. Training enables them to harness the latest techniques or move into new areas to meet evolving accelerator demands.

Training of scientists new to accelerator science: Approximately one third of accelerator scientists begin as a Ph.D. high-energy or nuclear physicist, or in some similar scientific discipline, and switch into accelerator science early in their careers. Some pitch in to help when the accelerator program serving their research requires assistance, have their professional interests captured, and never look back; others turn to accelerator science as an attractive career path. Those with a Bachelor's degree in physics or engineering, but no prior exposure to accelerator science, and who need a broad introduction to the field are another important category of trainees.

Courses for undergraduates and graduate students in accelerator science: Roughly 15 to 20 doctoral degrees are awarded each year in the U.S. for studies in accelerator science, from one of the dozen or so academic programs in the field. While new programs are being initiated at a few universities and the National Science Foundation (NSF) has recently launched an Accelerator Science program, it is too soon to see an increase in the number of students. There exist impediments to increasing the number or size of university programs. Impediments include the relatively small pool of federal research funding available, limited access to hands-on training with operating accelerators, and the prejudices of some university physics departments that accelerator science is too much an applied science or is mere technology. Even the largest academic programs offer few courses in accelerator science, and many of the specialized topics required by accelerators are not offered at all. Radiofrequency (RF) Technology is but one, albeit, an important example.

The United States Particle Accelerator School (USPAS), or an equivalent program with the same essential capabilities, is vital for developing and training the Nation's accelerator workforce by targeting the needs of these three groups.

The need for classroom training outside a university setting for students and early career accelerator scientists was recognized by the accelerator community as early as 1976, when a series of lecture-style courses were held over ten days at the first session of the International School of Particle Accelerators in Erice, Italy. The first session of USPAS was held in 1981 by the Department of Energy (DOE) laboratories in collaboration with the accelerator science community at the initiative of DOE's Dr. Melvyn Month, who had attended the Erice school. Since then, USPAS has continuously held one and usually two sessions annually serving approximately 100–150 participants per session. USPAS began with symposium-style lecture courses, similar to those now used by the CERN Accelerator School, which was started in 1983. USPAS evolved to its present format of academic-style sessions in 1987. Statistical data presented in this report are for the period since 1987.

2 Overview of USPAS

2.1 Purpose

USPAS plays a key role in training the accelerator science and technology workforce for U.S. government, university, medical, and industrial needs. The need is largely driven by demands at the DOE national laboratories, which together employ an accelerator workforce of roughly three thousand, including scientists, engineers, technicians, and operators, with an expected hiring rate of about one hundred fifty skilled employees per year.[1] The importance of the role USPAS has serving the DOE national laboratories is recognized in the review charge letter and by the Office of Science in memoranda authorizing their support of USPAS from 1992, 2001, and 2010, see **Appendix E**.

2.2 Session Description

USPAS holds two sessions per year, one in January and one in June. The sessions move geographically around the U.S., hosted by a university with a program in accelerator science, accelerator technology, or experimental particle physics, and often co-located with a DOE national laboratory. Each session lasts for two weeks, with both two-week classes and one-week classes. Typically, a choice of four or five two-week courses are offered, and a choice of four or five one-week courses are offered each week. Trainees can enroll either for one two-week course, for one one-week course, or for two consecutive one-week courses. The two-week courses constitute core curriculum offerings plus topical courses, and the one-week courses constitute additional topical curriculum offerings. The broad overview classes in the core curriculum meet degree requirements for graduate students attending USPAS and are attractive to non-degree seeking current employees of the national laboratories who want to learn more about accelerators generally (*e.g.*, accelerator operators). The courses include purely theoretical classes, courses that are a mix of theory and simple practical measurements, and hands-on training at accelerator facilities at a nearby laboratory. Holding the session near a na-

[1] A 2014 GAO report (available online at: http://www.gao.gov/assets/670/660449.pdf) sets the DOE-wide workforce attrition rate at 7%. To be conservative we set the laboratory attrition rate at 5%. This number is also consistent with the totaled estimated need reported by DOE laboratories in reply to committee inquiries.

tional laboratory facilitates participation by employees of that laboratory and access to equipment. The courses offered by USPAS are further described in **Section 4.2**.

In recent years about one hundred fifty trainees attend each session (with a maximum of about one hundred seventy with the current session model), with slightly more than half being current university students. Most of the university students are Ph.D. students in accelerator science and technology programs.

University credits are available for eligible trainees who take the final examination, with three semester credit hours awarded for a two-week course and half of that for a one-week course. The credits are awarded by the hosting university and by Indiana University but may be transferred, up to a limit, to the university in which the student is enrolled. Direct host-university credit for USPAS courses is attractive to students of the accelerator program at that host university.

An M.S. degree program through Indiana University is supported by USPAS. Typical students involved with the M.S. degree program would be B.S.-level accelerator operators from national laboratories and B.S.-level employees from private companies. Members of both groups substantially benefit from the degree as an incentive and as professional recognition of having achieved a higher-level degree.

Figure 1 shows the number of times each USPAS course has been offered since 1987, and **Figure 2** plots the cumulative attendance in these courses. The cumulative attendance largely follows the frequency that courses are being offered, indicating that the demand for course content is being met.

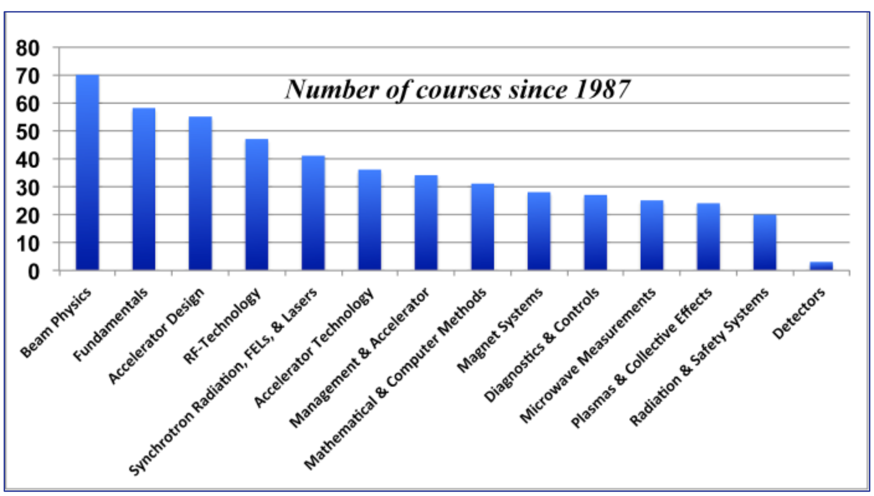


Figure 1: Cumulative USPAS course offerings since 1987. [3]

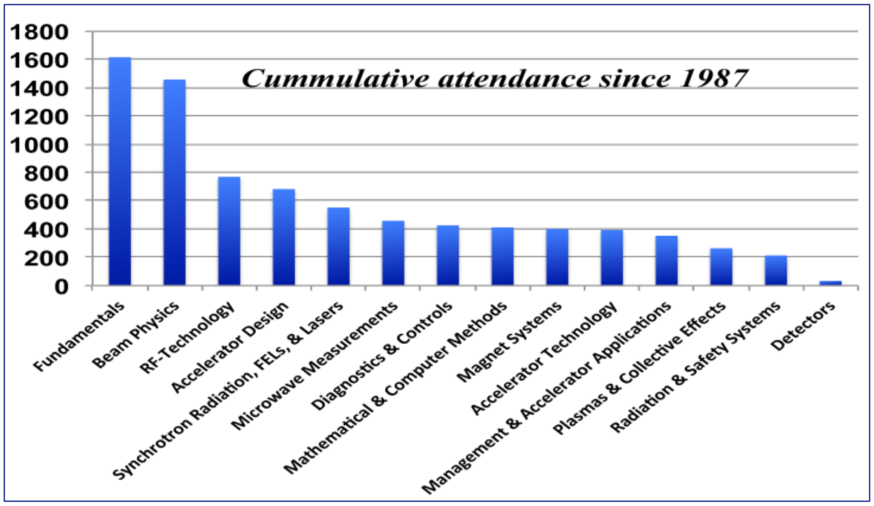


Figure 2: Cumulative USPAS attendance by course since 1987. [3]

2.3 Organization

The USPAS staff, which is funded by the Office of High Energy Physics (HEP) in the Office of Science (SC), consists of a Director, an administrator, and an administrative support person (3 FTEs total). The office staff is hosted by Fermi National Accelerator Laboratory (Fermilab). The Consortium that contributes to USPAS session operating costs comprises: seven SC laboratories, including Fermilab, Argonne National Laboratory (ANL), Brookhaven National Laboratory (BNL), Thomas Jefferson National Accelerator Facility (TJNAF), Lawrence Berkeley National Laboratory (LBNL), Oak Ridge National Laboratory (ORNL), and SLAC National Laboratory; one National Nuclear Safety Administration (NNSA) laboratory, Los Alamos National Laboratory (LANL); and two NSF-funded universities with accelerator laboratories, Cornell University and Michigan State University (MSU).

One senior manager from each of the ten Consortium member organizations, appointed by the director of that organization, serves on the ten-member USPAS Board of Governors (BOG). BOG members are typically responsible for, or involved with, their organization's workforce planning and are knowledgeable about accelerator workforce needs. The BOG reviews course offerings and planning of future sessions. The Director, with discussions with the BOG, determines the locations of future sessions. The locations are picked to balance the ability of Consortium members' employees to participate and to help develop accelerator programs at universities. The BOG is responsible for hiring and firing of the USPAS Director. The BOG also annually reviews the performance of USPAS Director, who supplies an annual report to the BOG.

A Curriculum Advisory Committee (CAC), with members mostly mapped from the Consortium members, helps outline the USPAS curriculum and session syllabi, and suggests course instructors. CAC members are selected by the Director, with the advice of the BOG. The CAC nominally meets once a year.

The authorization and guidelines for Office of Science funding for USPAS arises from memoranda in 1992, 2001, and 2010 from the directors of the Offices of High Energy Physics, Nuclear Physics, Basic Energy Science, and in 2010 from Fusion Energy Sciences (see **Appendix E**).

2.4 Financial Overview

HEP funds the USPAS office (the three FTEs) through a contract with Fermilab as the host laboratory at a level of ~$615,000 per year in direct costs. The ten Consortium members each supply $30,000 per year ($300,000 total) to support session costs. USPAS is directly funded with SC, NNSA, and NSF funds through the Consortium, and indirectly through tuition by SC, NNSA, NSF, other government, and industrial funds.

About half of the trainees per session receive scholarships (including all students from the host university), and about half pay the full registration fee (currently ~$1,400), including all trainees employed by national laboratories. With two sessions per year, in rough numbers, each session is supported by $150,000 from the Consortium and about $100,000 from registration fees, for about $250,000 total per session. The cost per trainee per session is between $1,500 and $2,000.

In addition to the direct contributions, Consortium members support USPAS with in-kind contributions by sending members of their staff to teach at USPAS sessions. Instructors also come from organizations that are non-Consortium members, with the same effective in-kind contributions. To date, approximately three hundred national laboratory employees have been primary instructors at the fifty USPAS sessions since 1987, with about fifty of those instructors coming from NNSA laboratories. Over time, a larger number of courses have been offered at USPAS sessions, with a higher fraction of national laboratory instructors (*e.g.*, two of the four classes in the first session, in 1987, were taught by national laboratory employees, whereas nine of the twelve classes in the most recent 2015W session were.) Laboratory staff teach two-thirds of the courses, university faculty teach approximately one-quarter of the courses, and the instructors of the remainder of the courses are drawn from elsewhere.

2.5 Trainee Demographics

Approximately six percent of USPAS trainees are from industry. Of the rest, somewhat more than half are university students and somewhat less than half are employees of DOE national laboratories. USPAS moves session by session around the country to facilitate attendance by trainees and instructors from the co-host laboratory and by students of the host university.

Figure 3 plots the distribution of trainees from industry, laboratories, and universities by year. The blue curve is the attendance of national laboratory employees; the red line additionally includes students from universities; the green line additionally includes U.S. industrial participation; and the violet line is the total attendance. Note that the large increase in attendance in 1992 corresponds to the first offering of two sessions per year and the drop in 1996 occurred because there was only one session that year. The recent drop in fractional attendance from DOE laboratories is attributed to the designation of USPAS attendance as conference travel and thus being subject to conference travel restrictions.

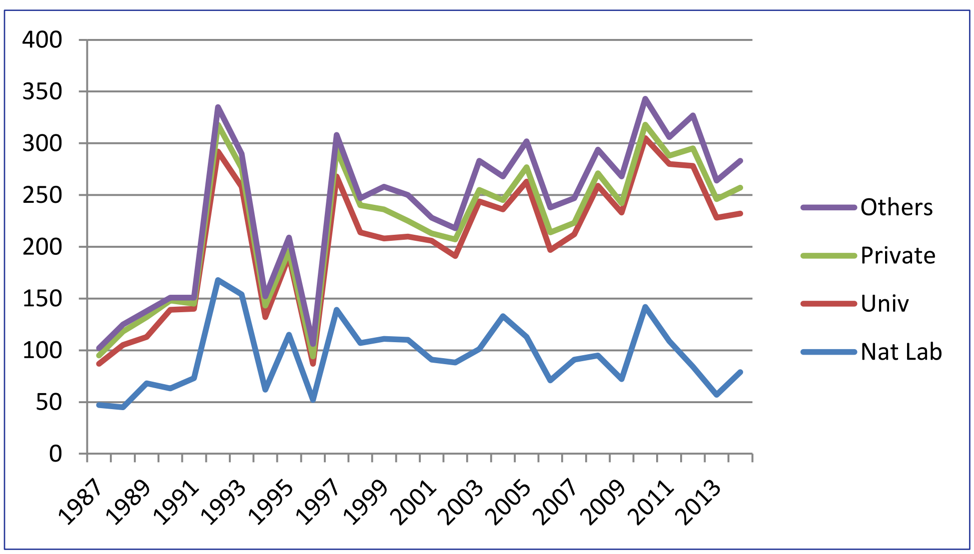


Figure 3: USPAS trainees per year. The curves are cumulative, *e.g.* the "University" curve represents the sum of university and national laboratory trainees, and so on. Data provided by USPAS.

Over the past fifteen years, the percentage of enrollees who travel from overseas to attend a USPAS session has been around twenty percent, which is very similar to the percentage of enrollees in the CERN Accelerator School (CAS) from outside Europe. Approximately 10% of USPAS instructors are from outside the U.S. USPAS and CAS together organize occasional sessions (every three years or so) under the banner of Joint

International Accelerator Schools. At these sessions, instructors and trainees are drawn roughly equally from the two regions.

3 Workforce Development and Training

3.1 The U.S. Accelerator Workforce

The accelerator workforce at the DOE national laboratories numbers nearly three thousand, as documented by input received from the national laboratories.[2] It is highly diverse, with widely ranging areas of expertise and backgrounds. Specialties range from microwave technology to beam dynamics to klystrons and high voltage supplies. Disciplines represented by this workforce include physics, many forms of engineering, and material science, among many others. Because accelerator science and technology is a transition field spanning both physics and engineering, it is often hard to describe even a high-level accelerator worker as either a physicist or engineer; indeed, accelerator science and technology Ph.D.'s are awarded by both university physics and electrical engineering departments (*e.g.*, UCLA, Colorado State, and Maryland). Additionally, many members of this workforce who entered as a Ph.D.-level nuclear or particle physicist do what would be largely recognized as engineering and many who entered as Ph.D.-level engineers do what would be largely recognized as physics. In rough numbers, the DOE national laboratory accelerator workforce can be considered to consist of about half scientists and engineers (with significantly more than half of this group recognized as doing engineering), with the balance mostly technologists and technicians. Accelerator operators constitute about 10% of the workforce.

There is a constant need for training in new accelerator subject areas even for personnel already in the workforce because of the rapid evolution of accelerator technology and its applications, and the significant movement of personnel within the workforce. Additionally, the Subcommittee estimates that approximately one hundred and fifty new individuals regularly enter the accelerator workforce at the DOE laboratories each year with approximately half of these being accelerator scientists and engineers. New accelerator construction projects create additional growth spurts in the population. The European TIARA study (documents can be found at http://www.eu-tiara.eu) deter-

[2] The Subcommittee is not aware of census data that definitively establishes the overall size and demographics of the U.S. accelerator workforce. Populations by role (*e.g.* scientist, research engineer, engineer, technician, operator), by training (*e.g.* accelerator science, other science, engineering, other field), by degree-level, and by gender and ethnicity would have been useful to this review; however, we believe that improved quantitative understanding would not have changed the conclusions of this report.

mined that the private sector adds an additional twenty-five percent to the overall accelerator workforce, and estimated twenty percent growth in the workforce over the next five years. The Subcommittee estimates that these percentages would also characterize the U.S. accelerator workforce, which is similar in size to Europe (3,000 at the national laboratories in the U.S. *vs.* 3,600 at the research institutes in Europe), yielding a total U.S. accelerator workforce of approximately three thousand eight hundred, including national laboratories, universities, and industry, with approximately four percent-per-year growth. Overall, the Subcommittee estimates that over half of the workforce requires training in accelerator science or technology in order to perform their jobs, and for most of these personnel, USPAS is the primary formal source of this training.

3.2 Pathways into the Accelerator Scientist Workforce

Accelerator scientists and engineers can either enter the U.S. accelerator workforce as graduates of a university program in accelerator science or enter the workforce with degrees in particle physics, nuclear physics, plasma physics, mathematics, or other technical fields. A third important source of accelerator scientists for the DOE laboratories has been accelerator scientists trained abroad. Typically, accelerator scientists enter the workforce with Ph.D. degrees and engineers enter with B.S., M.S., or Ph.D. degrees. Accelerator operators are often hired with B.S. degrees in physics and technicians are often without degree.

Many of the avenues available to bring engineers, operators, and technicians to the accelerator workforce do not extend to accelerator scientists. While being an important source of new accelerator scientists, U.S. university programs in accelerator science alone are insufficient to satisfy the nation's need for new accelerator scientists.[3] They do not produce enough graduates to satisfy the demand; moreover, generally speaking, their programs are not suitable to be used by individuals to retrain in order to shift careers to accelerator science. With graduation rates of about fifteen to twenty Ph.D. degrees per year, university programs fill roughly one quarter of the annual need for ac-

[3] Here we include Ph.D. engineers who are engaged in accelerator science R&D in the accelerator scientist category. We focus attention on workforce development and training of accelerator scientists, because recruitment to fill engineering positions and positions as technicians and operators is not as difficult as for accelerator scientists.

celerator scientists. The TIARA study reported a similar shortfall in Europe of graduates with respect to need. Note that the majority of university graduate programs in accelerator science rely upon the existence of a program such as USPAS to supplement their own university offerings. Without such a program, not only would there not be a formal mechanism to retrain scientists and engineers entering the accelerator field, the shortfall coming from universities would likely be even greater.

The challenge of worldwide competition renders recruitment from other nations an unreliable source of personnel for the U.S. Trained accelerator scientists are in demand in many of the world's nations, and other nations suffer the same shortage of accelerator scientists that the U.S. suffers. Worldwide competition can even be a drain, rather than a source. Highly-trained accelerator scientists tend to be mobile with respect to job location, and can be attracted away from their positions in U.S. laboratories to interesting projects outside the U.S. For instance, recently U.S. scientists have been attracted to the European Spallation Source. As medical and industrial applications of accelerators broaden, the U.S. private sector is an increasingly important source of competition for the U.S. laboratories with respect to recruitment of trained accelerator staff.

Migration into accelerator science from positions from other technical fields is a critical source for the accelerator workforce. As stated earlier, approximately one-third of accelerator scientists have switched into the field. As discussed later, training through a program such as USPAS facilitates migration, and is in many cases critical to enabling migration.

Based on the reported difficulty of recruiting to fill accelerator science positions at the DOE laboratories, even combined, the above three sources of accelerator scientists are insufficient to meet the annual needs of the laboratories. With roughly one-quarter of accelerator scientists coming as graduates of Ph.D. programs and roughly one-third transitioning to accelerator science from another field, there is a deficit to overcome of roughly forty percent of the approximately forty new Ph.D. accelerator scientists needed per year. Without relying fully on recruitment from outside the U.S., training opportunities in accelerator science must be fostered in order to further develop the pathways into the workforce of accelerator scientists from graduate programs and from other fields.

3.3 Effectiveness and Cumulative Impact of USPAS

The program offered by the USPAS addresses the training and development needs of the U.S. accelerator workforce in five primary ways:

1. Complements and supplements university programs in accelerator science, thus increasing the number of, and improving the quality of, new accelerator scientists entering the field from universities.
2. Facilitates transition to the fields of accelerator science or accelerator technology from other fields, such as particle, nuclear, astro-, quantum, and plasma physics.
3. Provides re-training and continued training opportunities for existing scientific and technical staff in advanced and specialized topic areas.
4. Provides basic training in accelerator science and technology for operators of accelerator facilities.
5. Offers an opportunity for accelerator staff to further refine their knowledge and skills through being an instructor.

The following subsections outline how USPAS impacts the workforce development and training needs of each of a number of types of institutions.

3.3.1 DOE Office of Science Laboratories

Over the 27-year history of USPAS academic-style courses, staff members of the national laboratories have enrolled in USPAS courses two thousand six hundred times. **Figure 4** shows the cumulative attendance from each national laboratory.

As discussed earlier, the trends in attendance over time are given in **Figure 3**. Attendance from the national laboratories continues at a high level, with roughly one hundred national laboratory employees attending USPAS per year. Training provided by USPAS benefits the DOE Office of Science laboratories in all five ways outlined above.

USPAS technical and topical courses are essential for re-training and continued training of laboratory scientific and technical staff, and are available nowhere else. As TJNAF writes, "[the technical and topical courses] are highly useful in assuring that our staff has access to state-of-the art ideas and accelerator science," and as BNL says, "Such

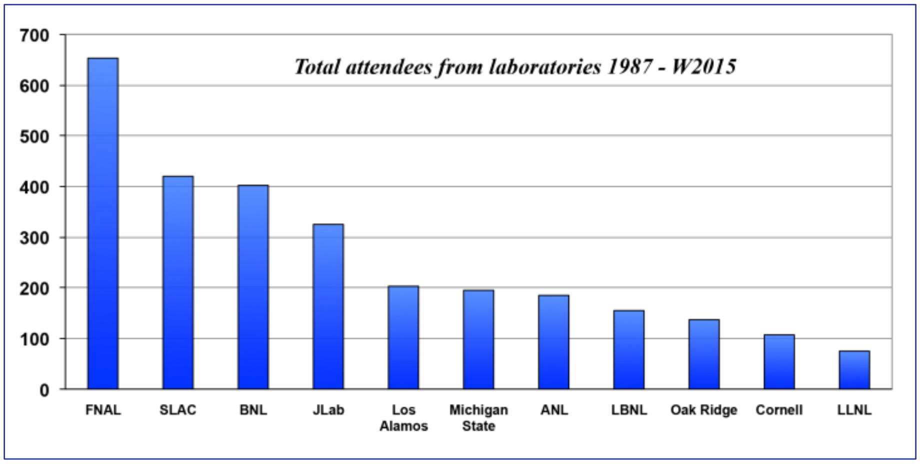


Figure 4: USPAS laboratory attendance. Data provided by USPAS.

topics are not taught anywhere else but are absolutely needed for the development and operation of particle accelerators."[4] USPAS technical and topical courses also enable laboratory staff to respond to changing demands. The construction of LCLS-II, for example, is triggering a wave of need at the laboratories for expertise in superconducting RF acceleration and in cryogenic engineering. LBNL writes that USPAS courses offer "the latest knowledge in the field." TJNAF reports that "more senior scientists and engineers will attend these courses in order to rapidly obtain information on forefront topics." Managers, project administrators, and safety teams also enroll in USPAS courses directed at their needs.

Many USPAS participants from the national laboratories are new to accelerator science. ANL writes about the impact of USPAS on this group, "Without USPAS, Argonne employees would have no access to world class training in accelerator physics, radiofrequency power system engineering, beam diagnostic system engineering, vacuum systems, insertion devices, and x-ray beamline design and engineering." An important large staff group new to accelerator science is recently hired operators, who typically

[4] The Subcommittee solicited input from the national laboratories that participate in the USPAS Consortium, from the largest university programs, from the private sector companies sourcing the largest numbers of attendees, from the American Physical Society Division of Physics of Beams (DPB), from the USPAS Board of Governors (BOG), and from a number of past attendees chosen at random. Letters from national laboratories can be found in **Appendix G**, letters from universities in **Appendix H**, a letter from the DPB in **Appendix I**, and a letter from the BOG in **Appendix J**. Quotations are from the letters received in response to the Subcommittee's requests.

have a B.S. degree in physics but no prior knowledge of accelerators. The laboratories rely on the USPAS Fundamentals intensive courses to give this group basic training in accelerator science and technology. For instance, the Operations Group at Fermilab currently has a staff of twenty five, and fourteen have attended a USPAS course. These figures are typical; the number is limited by how many can be spared to attend. As one lab writes, USPAS is a "rite of passage."

Another group of USPAS participants from the national laboratories that is new to accelerator science consists of physicists transitioning from other fields. LANL explains, "USPAS provides fundamental accelerator physics training for early-career LANL staff that are transitioning into accelerator science from another field, helping to fill a nationwide hiring gap due to the limited number of U.S. university programs offering courses in accelerator science and technology." Emphasizing how important USPAS training is to workforce development, ORNL makes a similar remark, "USPAS is an essential part of workforce development and training for ORNL staff that support accelerator science and technology, of which only a very small fraction have degrees in accelerator science and technology." Staff transitioning from other fields rely on USPAS technical and topical courses to become effective, and frequently enroll in the core graduate-level accelerator physics course. As stated by BNL, "New members of the staff in both operations and engineering are generally not trained in accelerator science and technology but this knowledge is critically needed. USPAS is our main venue to provide this knowledge, in addition to on-the-job training." The short one- to two-week format of USPAS sessions enables this training to occur without major interruption to work schedules.

USPAS offers an M.S. degree program through Indiana University. This degree is sometimes valuable to trainees from the laboratories who do not have advanced degrees. According to Fermilab, this degree program also serves as an incentive, "In the present formulation, the Indiana University/USPAS Master's Degree in Beam Physics and Technology is an attractive element of USPAS for a good number of Fermilab's participants. . . . The degree outcome was a key motivator for the full participation."

The laboratories benefit from graduate students who enroll in USPAS. Graduate student contributions to research at the laboratories is enhanced by the training that they receive from USPAS courses in which they enroll as part of their doctoral program. Moreover, many of these students will go on to work at one of the national laboratories after graduation. The laboratories have commented on the role of USPAS in the university student pipeline into their accelerator workforce; for instance, ANL reported, "Argonne also depends on USPAS to assure a robust talent pipeline of future scientific staff." An estimated 30% of accelerator science and technology Ph.D. graduates are employed by national laboratories, with about 50% in industry and 20% in academia.

USPAS also benefits the laboratories indirectly, by making undergraduates aware of accelerator science as a potential career path. Through advertising, undergraduates at the host universities near sites of USPAS sessions learn about the opportunity to take USPAS courses and earn course credit, and some of these students go on to pursue accelerator science as a career, a path that is otherwise nearly invisible. This contact with undergraduates increases the pipeline of students into the field, and helps meet the needs of the national laboratories. The Lee Teng Internship Program for undergraduates run by Fermilab and ANL in conjunction with USPAS plays a similar role. In this program, undergraduates do research internships at one of the laboratories and take USPAS courses as part of their program. Additional internship or research experiences for undergraduate programs would be beneficial to the supply of future accelerator scientists.

The majority of USPAS instructors are from the national laboratories. As mentioned above, being an instructor at USPAS proves to be a valuable experience for laboratory staff members. They benefit from consolidating and refining their knowledge of subject areas, which leads TJNAF to remark, "Therefore, we regard teaching a USPAS course as a valuable staff development activity for the instructors too." LANL goes on to say, "USPAS also allows participation by junior staff as assistants to the more senior expert instructors. This enables the development of these early- and mid-career staff as instructors and increases their level of expertise." Instructors also benefit from contact with USPAS trainees, who they frequently later recruit.

The need for accelerator training for laboratory staff development will continue in the future. Each year, the labs hire about one hundred and fifty new accelerator staff members to fill openings due to retirements and departures, and the demands of future accelerators may require hiring at even greater rates. Just as they do today, the newly hired staff will need accelerator training. Mid-career training in specialty topics will also continue to be essential. Accelerator science is a dynamic field, with a forefront that is constantly moving, and access to state-of-the-art training at USPAS will keep laboratory capabilities at the frontier.

3.3.2 Other Public Sector

The major non-SC public sector stakeholder and beneficiary of USPAS is the National Nuclear Safety Administration. Of the NNSA laboratories, LANL sends the most employees both as trainees (approximately two hundred total since 1987) and instructors (about thirty total). Additionally, LLNL has sent employees as trainees (approximately eighty total) and instructors (about twenty total). LANL is a member of the USPAS Consortium.

Correspondence from senior LANL management, identified the benefit to LANL of all five of the workforce development roles outlined in **Section 3.3**. Through USPAS, LANL trains three to five accelerator operators per year and two to three scientists and engineers. USPAS addresses both real and anticipated attrition due to retirement and upcoming additional workforce needs (up to fifty near term for the MaRIE Injector Test Stand and up to fifty to one hundred more for the MaRIE XFEL).

3.3.3 Private Sector

Figure 5 shows the historical percentage of trainees from the private sector (*i.e.*, U.S. industries). The running average is about 6%.

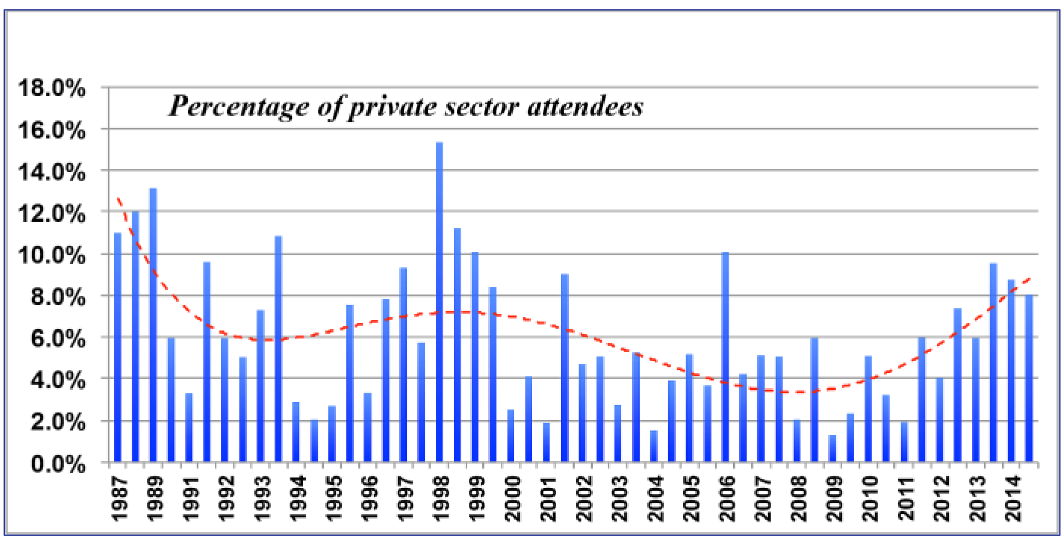


Figure 5: Percentage of USPAS trainees from industry. [3]

Figure 6 shows the level of historical participation from the companies with the largest overall attendance.

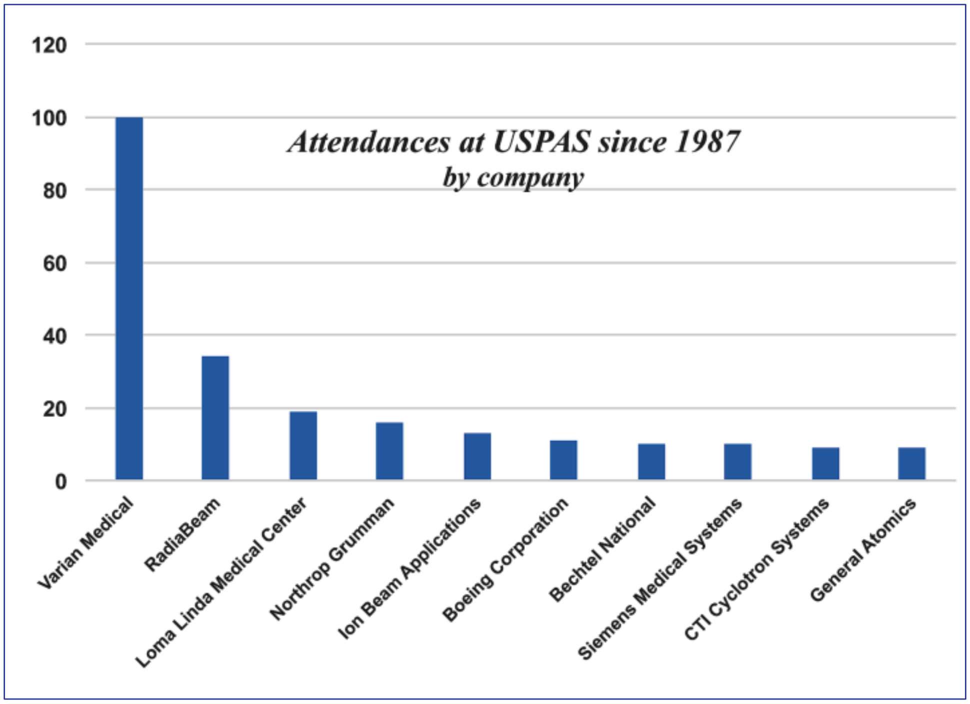


Figure 6: Number of USPAS trainees by company. [3]

The main categories of industrial involvement in USPAS are (with rough percentages of the total industrial involvement):

1. *Medical accelerators:* Varian Medical and previously Siemans build medical linacs, and CTI Cyclotron Systems and Ion Beam Applications build medical cyclotrons. This category corresponds to ~60% of total industrial trainees.
2. *Accelerator components:* RadiaBeam builds accelerator components. (~10% of total industrial trainees)
3. *Training for operating accelerators:* Loma Linda University Medical Center installed a synchrotron for proton therapy in 1990. (~10% of total industrial trainees averaged over time)
4. *Urgent programmatic need for expertise:* Northrup Grumman, Boeing, and General Atomics attendance was likely in short spurts driven by programmatic needs (~20% of total industrial trainees averaged over time)

Much of the industrial attendance is focused on training in traditional RF engineering, which is important to a number of commercial products and which is an area in which USPAS offers arguably the Nation's only remaining full curriculum.

The Subcommittee received a strongly supportive letter from the Chief Technology Officer of RadiaBeam, which states, "USPAS presents a unique and critical opportunity for our scientists and engineers to be exposed to new concepts and to master important techniques. These unique skills are immediately taken back to the company and applied to their work." Correspondence from the manager at Varian responsible for microwave and accelerator physics and engineering speaks to the training value to his employees, particularly noting the USPAS M.S. program, "I think USPAS offers a unique and rare opportunity for continuing education in the accelerator field and has contributed directly to the strengthening of my group's technical understanding in our technology."

At least three former USPAS trainees have started their own accelerator technology companies (*i.e.*, Niowave, Cyclotronics, and D-Pace), and all partially attribute their ability to do so to USPAS. These companies range from a couple of part-time employees to having tens of millions of dollars in annual income. Both Niowave and RadiaBeam support USPAS by providing scholarships. Surprisingly, and in contrast to RadiaBeam, Niowave does not regularly send employees to USPAS for workforce training. The review committee did not receive enough quantitative information from these companies to comment on the impact of the USPAS on their recruitment and staffing needs.

3.3.4 Universities

The university community considers USPAS an essential and high quality component of student education in accelerator science and technology. Cornell University states that "USPAS . . . fills an essential need in preparing our students for research, and it provides opportunities for networking that have proven beneficial for many research projects and for many young careers." Old Dominion University attests, "USPAS has had a clear impact on our ability to offer a high-quality graduate program in accelerator science." With respect to quality, the letter from Colorado State University characterized both the instructors and coursework as "world class."

University students have enrolled in USPAS courses over three thousand times since its inception. Participation in USPAS by students enrolled in the largest university graduate programs in accelerator science is shown in **Figure 7**. At any given time, only about a half dozen programs have more than two faculty in accelerator science, and even these graduate programs tend to be small, usually with enrollments of fewer than a dozen students. Even at the universities with the largest programs, accelerator courses

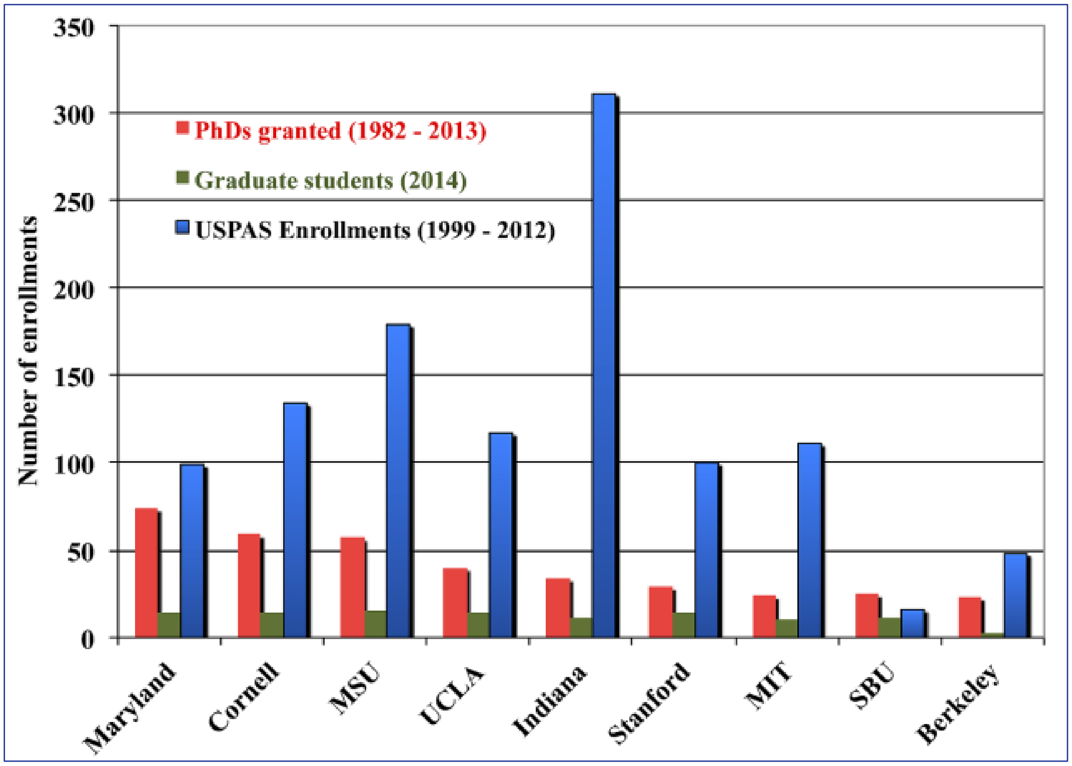


Figure 7: Ph.D. degrees granted from 1982–2013, number of graduate students enrolled in 2014, and USPAS participation from 1992–2012, for eight universities with graduate programs in accelerator science. [4]

can be offered only intermittently, and as a consequence, students rely on USPAS to fill the gaps. In letters to the Subcommittee, almost all the universities point out the role USPAS serves to ameliorate the curricular limitations imposed by small faculty numbers. Most universities report that graduate students typically take two or more basic and special courses. The Northern Illinois University letter highlights the need for technical and topical courses, stating, "some of our students who already started their research are often sent to USPAS to enroll [in] special topics. The latter type of class is an important element of the USPAS as it enables the students to get educated in a very specific topic — this turns out to be very valuable at the early stage of the research work."

Undergraduates also enroll in USPAS, often when their university hosts a session. For many of these undergraduates, USPAS provides the only exposure to accelerator science as a career path. An estimated thirty percent of university-trained graduate students in accelerator physics go on to careers at the national laboratories.

USPAS has arranged for students at universities around the country to obtain rigorous academic credit. To students of some universities, this credit helps them to meet degree requirements in accelerator science and technology. The USPAS M.S. degree program offered through Indiana University is also of value to some, particularly those pursuing technical careers either at a national laboratory or in the private sector.

USPAS courses have led to several widely used textbooks by laboratory scientists, as well as course notes that are frequently used as reference material.

3.4 Need for Program Like USPAS

As discussed above, building and operating the nation's accelerators requires a highly-trained workforce, with need for training in three broad categories: professional development of mid-career scientists and engineers; training of scientists new to accelerator science; and courses for undergraduates and graduate students in accelerator science. USPAS addresses the need for training and workforce development in five primary ways, which benefits the DOE Office of Science laboratories, other public sector institutions particularly NNSA laboratories, the private sector, and universities. In short, laboratory staff, in both public and private sectors, need an extramural program, such as USPAS, that will provide and/or update their specialized skills. The laboratories need such a training program in order that their scientists can continue to develop professionally and can keep up with the recent scientific and technological advances. Furthermore, individuals transitioning from other fields into the accelerator workforce need a program, such as USPAS, that will provide them with both the general background and the specialized training that they need in order to successfully transition. In turn, the laboratories need such a program in order that these scientists can successfully transition to laboratory careers. Finally, universities with graduate programs in accelerator science need an extramural program, such as USPAS, that offers courses to complement and supplement their own course offerings. In turn, the accelerator science community, and the DOE laboratories in particular, need such a program in order that the workforce can be strengthened by the availability of well-trained graduates of university programs.

The input received from the laboratories and universities that are members of the USPAS Consortium attest to the need for a program like USPAS. For example, ANL states, "we have relied on the USPAS to help us train and maintain a cutting-edge workforce" and "USPAS is fundamental to the world-leading research performed at these facilities." LBNL said, "USPAS plays a unique and vital role in the education of early career scientists, in developing the accelerator science workforce, and ensuring that the most modern developments in accelerator technology are widely disseminated." Several laboratory letters also comment on the ongoing and/or future need for such a program. For instance, TJNAF explained, "we regard this program an essential element in our future plans." BNL summed up by stating, "It is not an exaggeration to say that if USPAS didn't exist it would have to be created." This statement is not surprising, given that USPAS was created in order to address the needs of the laboratories for workforce development and training.

3.5 Unique and Essential Capabilities and Features of USPAS

The essential capability of USPAS is the **development and maintenance of the accelerator workforce** required for the Nation's scientific and technological enterprise. The workforce serves the laboratories, academia, and industry. With the large, approximately 3,000-member workforce discussed earlier, the DOE laboratories are particularly dependent on USPAS to ensure the availability of a workforce qualified to accomplish the DOE mission. The training provided by USPAS to develop and maintain the accelerator workforce has three principal audiences:

1. the existing accelerator workforce,
2. those seeking professional transition into the accelerator workforce, and
3. undergraduate and graduate students.

The latter group is particularly important as a pipeline of individuals essential for the long-term viability of the accelerator workforce. Over time, USPAS has developed and refined a number of essential relationships and features, some unique, for delivery of content to the three target populations:

The USPAS has **two major curricular features**, basic courses and technical and topical courses, which provide essential capabilities for transmitting and maintaining accelerator science and technology knowledge.

1. The basic courses on accelerator science in areas such as beam physics or fundamentals of accelerator science are essential for delivering content to those attendees entering or transitioning into the accelerator workforce.
2. The wide variety of technical and topical courses such as those on RF technology and magnet systems or *The Physics of Free Electron Lasers* (FEL) serve all three audiences. The topical courses are especially important as the DOE accelerator complex changes over time with changing mission needs. The rise of FELs uti-

lized by the Office of Basic Energy Sciences provides a good example of the changing environment. These technical and topical courses are not available anywhere else in the U.S. and are a unique resource for the accelerator workforce.

The **close association between UPSAS and the DOE laboratories** is absolutely essential to the development of the accelerator workforce and has led to very effective delivery of information by USPAS. Hosting of USPAS management at a single laboratory provides the stability and resiliency needed for the success of the USPAS. There are four major capabilities provided by the close association:

1. Through its Board of Governors, USPAS is highly responsive to the training needs of the laboratories — the principal stakeholders are essentially driving the supply chain. For example, laboratory curricular needs are transmitted by the Board to the USPAS Director. (As mentioned in **Section 5**, the Board's role in governance is an essential feature of the USPAS management structure as an avenue to ensure the support of the laboratories.)
2. As the single largest cohort of accelerator scientists in the country, the DOE contingent provides a majority (two thirds) of USPAS instructors. The deep expertise provided by laboratory staff, particularly DOE staff, is another essential aspect of USPAS, particularly with respect to presentation of technical and topical courses.
3. USPAS offers a mechanism for the DOE laboratories to share and leverage their knowledge with one another, and with the larger accelerator community. By sharing curriculum development and instructors, content is available to all laboratories that no one laboratory could provide.
4. To ensure a complete and well-structured curriculum, USPAS must also have access to laboratory facilities and equipment.

The involvement of the DOE laboratories in curriculum oversight and provision of instructors and facilities is essential for ensuring that USPAS meets the needs of the Nation's and DOE's accelerator workforce and for DOE's mission.

The **close alignment and relationship between the laboratories and universities** is another essential and unique feature of USPAS; the alignment provides three essential capabilities: university instruction, a workforce pipeline, and visibility for the accelerator science discipline:

1. Of course, the universities provide instructors for USPAS and no similar relationship exists anywhere between institutions delivering courses on accelerator science and universities.
2. Perhaps more importantly, this relationship provides a key pipeline of students into the national accelerator workforce. The pipeline begins with the undergraduates attracted to accelerator science by USPAS. The USPAS also provides credit hours for graduate degrees that the majority of universities cannot provide themselves, due to limited faculty and low student enrollment. As seen in their letters, students introduced to the discipline through USPAS are captured by the depth of topic and the enthusiasm of the community.
3. Further, by aligning each session with a host university, the USPAS promotes development of accelerator science as an academic discipline, through increased visibility at the academic level and through recruitment of "local" students.

An additional number of important characteristics or capabilities of USPAS, some of them unique, add great value to the enterprise:

1. The periodic and compact, fast delivery of subject matter is very important. For instance, laboratory employees are best served by this format as their time away from work is minimized. Similarly, university students are well served by the summer sessions, for which they can easily interrupt their research with a two-week hiatus. As attested by many of the trainee letters, the one-on-one interactions fostered by intense day-long sessions improves transmission of information.
2. The involvement of laboratory staff also imbues the curriculum with a focus on real-world and practical applications. This attribute of the USPAS makes the transmission of information much more effective for the laboratories.
3. The multidisciplinary nature of the curriculum and of the instructors is unique; nowhere else can trainees find such varied instruction.
4. On the part of the instructors, teaching is an important aspect of professional development. In fact, a number of textbooks, widely used in the field, can trace their origins to course delivery at USPAS.
5. As a broader benefit of the USPAS, the twice yearly convocation of accelerator experts maintains and builds the community and collaborations. As mentioned by BNL, "[USPAS] fosters the development of an accelerator science and technology community."

4 Overall Quality and Breadth

4.1 Overall quality

A number of objective metrics and subjective measures attest to the high quality of USPAS. The curriculum is broad with both basic and technical or topical courses and serves the full accelerator community. Instructors are recruited from the deep and broad pool of talent available in the United States; instructors from abroad further strengthen the faculty. The enrollment has been steady or increasing over the past fifteen years (see **Figure 3**) and is now near capacity. Trainee assessments show good, very good, or excellent ratings by 95% or more of the trainees. Furthermore, a more subjective measure in the form of letters from universities, trainees, and DOE laboratories shows very high regard for USPAS. The following sections offer further detail on these measures of quality.

4.2 Breadth of curriculum and session format

Over the years, USPAS has offered an impressively wide variety of courses in accelerator physics, technology, controls, management, and safety. The full list of courses offered in the years 2000 to 2014 is given in **Appendix F**. Here the courses are grouped into fourteen categories, and for each course and category the average and total number of enrollments is shown, together with the number of times that the course has been offered.

From the data, an important feature of the USPAS program can be seen. Some courses, such as Accelerator Fundamentals and Accelerator Physics, have appeared thirty times in fifteen years; in other words, they are considered essential and are taught at every USPAS session. Others, such as Microwave Measurements, appear regularly and are taught yearly. The courses mentioned, and others like them, are of two-week duration and form the core part of the curriculum, accounting for about half of the courses offered at any session.

For the rest of the topic areas, courses are provided according to need. In assessing need, the Director consults with members of the BOG and with members of the CAC. These bodies also provide advice and suggestions on suitable instructors for the courses.

Given the breadth and comprehensiveness of the syllabus, a clear definition of the courses (with course numbers, descriptions, durations, and whether a core course or otherwise) and what use the courses might be towards the various academic accreditation schemes would be useful. Similarly, the process for selecting session programs could be made more definite. The core part looks after itself, except perhaps for the choice of instructor; on the other hand, how the content of the variable part is decided appears to be informal. The CAC could be more engaged by meeting on a regular basis and documenting discussions and decisions.

The structure of the sessions provides a solid base for teaching the essentials while allowing flexibility to adapt a session to currents needs. The parallel structure serves to keep the number of trainees following any particular course rather low, from a few to a maximum around thirty. The low number allows for quasi one-on-one teaching, given by an expert in the field, which is very much appreciated by the trainees.

4.3 Instructors

Even at the introductory level, courses on accelerator science and technology are multidisciplinary in nature. At a higher level, some topics are so specialized that they are currently not taught anywhere else in the U.S. For these reasons, accelerator science and technology has become a specialized field in its own right. The instructors are drawn almost entirely from the Consortium of laboratories and universities involved in USPAS, and this pool allows access to a highly skilled group of experts, many of whom have shown themselves to be excellent teachers. Pooling of resources in this way provides a formidable breadth and depth of expertise that would not be available to any single institution. As noted in the Fermilab letter, "A primary benefit is the exposure to a world-class community of experts represented by USPAS instructors."

4.4 Enrollment

Yearly USPAS attendance has increased steadily in the last fifteen years, with the average over the past five years around three hundred (one hundred fifty trainees per session). While up to half of enrollments formerly came from USPAS sponsoring institutions, in recent years this fraction has fallen to approximately thirty percent, with almost sixty percent of attendees now being undergraduate and graduate students from U.S. universities. This fraction highlights the function of USPAS as a pipeline for the national accelerator workforce.

Roughly two-thirds of all trainees enroll for university credit, and a little under half of all trainees (forty-five percent) receive financial aid. The general trend over the last five years is for more requests for financial aid. The stated aim is to reach out to as many as possible through scholarships. This practice tends to increase the number attending USPAS. Very few applicants are refused.

The present enrollment of one hundred fifty trainees per session is judged by USPAS to be close to the limit of what can be accommodated in the present session format. Expansion of an individual session much beyond this number would stretch the capacity of venues and logistics. The straightforward response to increased demand would be to increase the number of annual sessions. In this sense, USPAS is robust and scalable; of course staffing needs would need to be evaluated as the number of sessions increased.

4.5 Evaluations

Evaluation data for the 2013 sessions are typical of evaluations routinely collected from the trainees. The 2013 data, shown in **Table 1**, reflect a high level of satisfaction in both the courses and in the instruction.

Two 2013 sessions	Overall course rating (%)	Instructor performance (%)
Excellent	42	54
Very good	31	28
Good	20	15
Fair	6	3
Poor	1	0

Table 1: Trainee evaluation summary for USPAS 2013 sessions. Data provided by USPAS.

The letters sent from the laboratories and universities generally have nothing but praise for USPAS; it is hard to find anything remotely critical. Following are some characteristic remarks:

- "Such topics are not taught anywhere else but are absolutely needed . . ."
- "The broad curriculum and session format make it an ideal mechanism . . ."
- "We have a continuing need to access specialized courses . . ."
- "USPAS provides depth and breadth beyond the reach of a single university"

The letter from the USPAS Board of Governors has many and only positive comments on the breadth and evolution of the syllabus.

The data available on the career evolution of USPAS alumni shows a very positive impact of USPAS on the community. Of the more than four thousand distinct USPAS attendees, more than half work or have worked in the field, with most of these at DOE national laboratories. Some two hundred fifty alumni have taken intellectual or leadership positions in the U.S. accelerator community.

5 Management

5.1 Management Structure

The overall management structure is appropriate and has some features that are essential to the success of the USPAS.

The governance of USPAS has some parallels to university governance. The Board of Governors (BOG) plays a role similar to that of the Board of Trustees of a university. They hire and fire the Director, as a Board of Trustees would a university president. The Director oversees the Curriculum Advisory Committee (CAC), which plays somewhat the role of the faculty in university governance; namely, responsibility for the detailed curricular content and quality, as well as the selection of their fellow faculty members. In this case, the CAC is more advisory to the Director, who seems to take fuller responsibility for final instructor selection (which is probably appropriate because the instructors are not permanent, but rapidly cycling compared to tenured university faculty). This model with a BOG appears to provide adequate accountability and oversight of the Director. The appointment of the BOG by the Laboratory Directors assures that the goals and budget decisions of USPAS are well aligned with the stakeholders, particularly the Laboratory Directors and DOE. The BOG conducts annual reviews of USPAS and sets priorities for which programs are offered and when. A periodic, more retrospective and external review, perhaps every five to seven years, would be valuable to consider.

Some BOG members are also instructors of the USPAS; consequently, there is some similarity here to the organizational structure of a law firm managed by partners who are also practitioners. The Subcommittee had no real concern with this overlap of roles. Because the teaching roles are unpaid, there is not the conflict of interest there would be in other circumstances.

The management of USPAS is accomplished by three FTEs, which is appropriate to the workload and size of the program, and is comparable to that of the CERN Accelerator School (CAS). The role of Director appears to require a full FTE, and that is the case here and at CAS. The directorship conceivably could be shared among more than one person, though the Subcommittee believes that it is essential that the Director have USPAS as their primary focus, that they have gravitas in the community, and exceptional ability to cultivate collaboration and teamwork.

The Subcommittee found some features of the management structure that appear to be critical to the success of USPAS. First is that the Board be a governing, rather than advisory, board. The empowerment of the Board by the Laboratory Directors and the trust that they have placed in the Board is critical to ensure continuing support by all the laboratories, as well as the smooth and responsive operation of the program. A second essential feature is the hosting of USPAS management at a facility that is both stable and committed to accelerators. The economy of scale of being in a larger organization, including shared services (IT, accounting, *etc*.) and other infrastructure, plays a large role in the success of USPAS and in minimizing budgetary requirements.

There are a number of ways in which the current management structure, though not the only possible structure, is a best practice:

1. Economy of scale of conducting a shared program rather than individual training programs at each laboratory.
2. Cross-pollination of knowledge and expertise across the laboratories, carried physically by the participation of trainees and co-instructors.
3. University involvement is a differentiating advantage for USPAS over CAS, and enhances the role of USPAS. The primary role for both programs is the preservation and transmission of accumulated knowledge in accelerators. The inclusion of universities also enables USPAS to develop the next generation of scientists and engineers who will expand that knowledge.
4. The USPAS is a model for breaking silos between DOE offices, enabling collaboration and dissemination that benefits DOE and the nation.

5.2 Effectiveness of Management

The management structure and team have been effective. Over its nearly thirty-year history, the session cost of delivering the program per trainee and course has risen at a rate slower than inflation, and over the past fifteen years has been around $1,500 per trainee per session. The networking value of USPAS has prompted industry-based instructors to volunteer a significant amount of time, and likewise the university-based faculty time is largely release time, and in that sense, a contribution from the universities, both private and public. Both bring added value and enhance the cost-effectiveness of the program. Laboratory-based faculty members are paid through release time from their other responsibilities, but one should not assume that the taxpayer benefit of this exchange is zero sum. Nobel Laureate Richard Feynman described anecdotally the value of teaching to the creative process of research in his book, *Surely*

You're Joking, Mr. Feynman! Years later, the positive correlation between teaching and research effectiveness has been confirmed by social science research, as presented in [5] and [6].

The BOG appears to look closely at budgets and priorities and to ensure cost-effective investment. It appears to have well-aligned incentives to do so. As stated in the presentation to the Subcommittee by Fermilab COO Tim Meyer, "Every dollar saved [in the running of USPAS] is available for research of the member labs."

The CAC performs a number of important roles, and its increased engagement would be of benefit to the program. The benefits of engagement include establishing a pool of knowledgeable (of USPAS) talent to ensure succession and respond to emergencies, and include identifying an even deeper and better pool of instructors for the program.

6 Participation of Women and Under-represented Minorities

USPAS has a good record regarding diversity. USPAS has made efforts to increase percentages of women, both as instructors and as enrollees. Both percentages have grown, and the percentage of woman enrollees is now in line with national trends in the field. Gender diversity, for both instructors and enrollees, is comparable for USPAS and the CERN Accelerator School. USPAS has also appointed a Minority Outreach Coordinator.

6.1 Women Participants

The number of women attending USPAS sessions has steadily increased through the lifetime of USPAS, as shown in **Figure 8**. In recent years, a deliberate effort has been made (see below) to have more women instructors at USPAS sessions, in the belief that they act as excellent role models and thereby attract more women to enroll. The evolution of female attendance at USPAS closely follows the steady increase of women in science in the U.S., which can be seen in a recent publication by the American Institute of Physics Statistical Research Center [7].

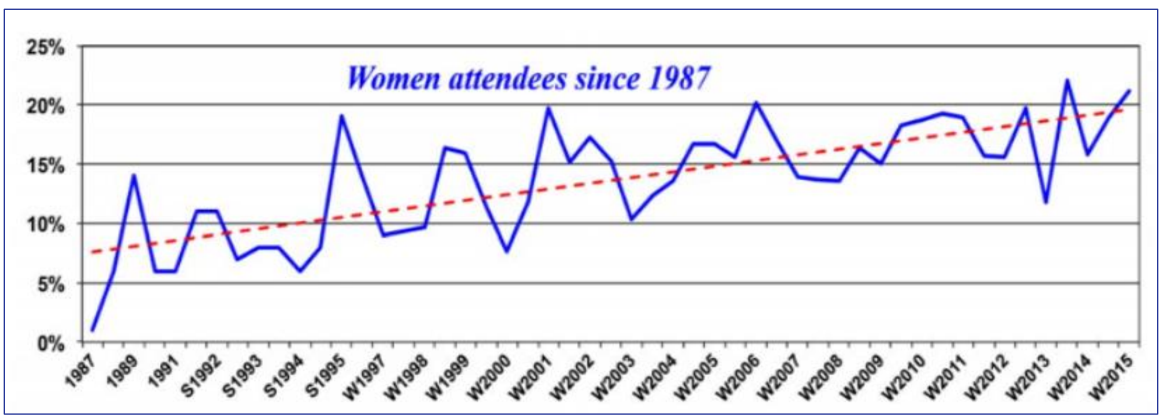


Figure 8: Women attending USPAS sessions as a percentage of all attendees. [3]

The current level of women attending USPAS is around twenty percent. This percentage compares well with the level of women achieving M.S. and Ph.D. qualifications in physics in the U.S. at the end of the last decade, and exactly matches the level of women attending the CERN Accelerator School (CAS) in Europe in recent years.

The percentage of women instructors at USPAS sessions is shown in **Figure 9**. The recent efforts to increase the number are clearly seen. The average over the whole period is 6.5%; while in the last five years, it is over 10%. For comparison, the average level of women teaching at the CAS in recent years is 7%. Recruitment of more women as instructors and for the CAC may further increase participant gender diversity.

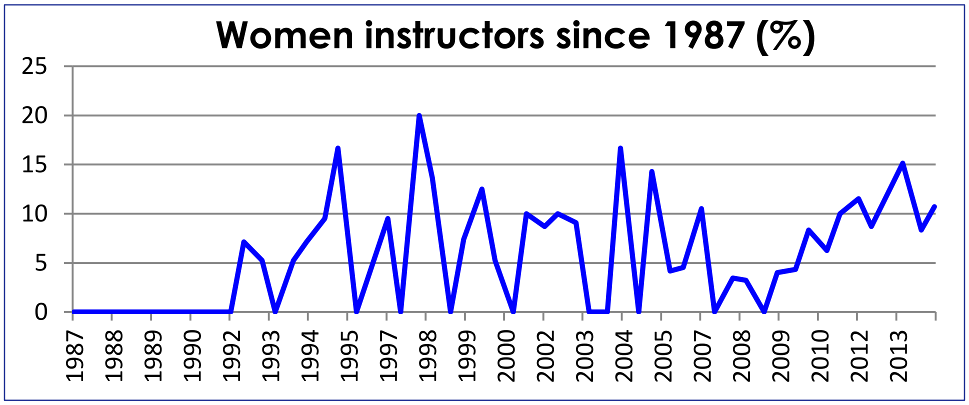


Figure 9: Percentage of women instructors at USPAS sessions. Data provided by USPAS.

6.2 Under-represented Minorities

No data is available on the participation of under-represented minorities according to discussions with USPAS management. However, the Subcommittee notes that in 2011 the USPAS Board of Governors voted to name Professor Paul Gueye, of Hampton University and Jefferson Laboratory, as Minority Outreach Coordinator. He assists the USPAS Director in attracting more minorities into accelerator physics and engineering. In the future, diversity data on under-represented minorities should be collected on a regular basis.

6.3 Input from DOE Laboratories

In their letters, several of the laboratories note that USPAS has been a vehicle for increasing the diversity of their accelerator staff. For example, BNL points out that their operations group, which draws on students with Bachelor's degrees from across physics, has more than 50% greater proportion of women than the rest of the accelerator division. USPAS enables them to draw from this larger pool. They observe, "With the training provided, the pool of applicants can be significantly enlarged." Other laboratories make similar comments, *e.g.*, "USPAS has provided the opportunity for ORNL to considerably strengthen its demographics within accelerator science and technology.

Key female employees who are ‘graduates’ of USPAS include the group leader of our Controls Systems Group, two accelerator operations shift supervisors, and one of our best mid-career accelerator physicists.”

7 References

[1] U.S. Department of Energy, "Accelerators for America's Future," 2010.

[2] R. Hamm and M. Hamm, "Industrial Accelerators & Their Applications," World Scientific Publishing, 2012.

[3] W. Barletta, "Self-Assessment of the USPAS Program," document prepared for HEPAP review of USPAS, 2015.

[4] W. Barletta, "Annual Report of the United States Particle Accelerator School," 2014.

[5] M. Qamar uz Zaman, "Review of the Academic Evidence on the Relationship Between Teaching and Research in Higher Education," *UK Department for Education and Skills Research Report RR506*, 2004.

[6] H. Wei, Z. Cheng and K. Zhao, "On the relationship between research productivity and teaching effectiveness at research universities," *Frontiers of Education in China*, vol. 2, no. 2, pp. 298-306, 2007.

[7] American Institute of Physics, "Physics Graduate Degrees (p. 6, Figure 3)," July 2011. Available online at: http://www.aip.org/sites/default/files/statistics/graduate/graddegrees-p-08.pdf

Appendix A. Charge

U.S. Department of Energy
and the
National Science Foundation

FEB 12 2015

Professor Andrew Lankford
Chair HEPAP
University of California at Irvine
Physics & Astronomy Department
4129H Frederick Reines Hall
Irving, CA 92697

Dear Professor Lankford:

In addition to advice on broad initiatives and strategic opportunities for particle physics, the Department of Energy (DOE) Office of Science also requires periodic input from the High Energy Physics Advisory Panel (HEPAP) on specific investments of critical importance to the Department. One of these investments is the U.S. Particle Accelerator School (USPAS), a long-standing partnership between several DOE laboratories and the Office of Science. This program plays a key role in training the next generation of researchers and practitioners who are skilled in harnessing the potential of particle accelerator technology to advance science and engineering across a broad spectrum of disciplines and applications. This program also plays an important role in attracting very well qualified researchers to the national laboratories to advance DOE missions.

With this letter, we are charging HEPAP to assemble a sub-committee to examine, for DOE only, the effectiveness and cumulative impact of the USPAS over the past two and a half decades, in the context of both workforce development and training; as well as to assess the overall quality and breadth of the program. The sub-committee should take into account the unique qualifications and skills of accelerator scientists and their role in the public and private sectors, and how USPAS training prepares participants for careers in accelerator physics and accelerator R&D. It should evaluate the need for this kind of program, given the available academic resources and worldwide competition for a skilled technical workforce; and address which unique and essential capabilities are provided to the program via the involvement of the DOE laboratories. It should also address the efficacy of the current USPAS management model, the participation of women and under-represented minorities in this area, and the projected need for trained accelerator scientists to support both DOE science missions and continued U.S. leadership in accelerator science.

This assessment will be a critical milestone in the development of this activity and can inform the future evolution of the program. We would appreciate the committee's preliminary comments by April 2015 and a final report by May 2015. We appreciate HEPAP's willingness to undertake this important effort.

If you have any questions regarding this matter, please contact either Jim Siegrist, the Associate Director of the Office of Science for HEP or Glen Crawford, the Designated Federal Official for HEPAP.

Sincerely,

Patricia M. Dehmer
Acting Director, Office of Science
U.S. Department of Energy

Dr. F. Fleming Crim
Assistant Director
Directorate for Mathematical and Physical Sciences
National Science Foundation

Appendix B. Subcommittee Membership and Activities

The High Energy Physics Advisory Panel (HEPAP) received a charge (see **Appendix A**) from the Department of Energy and the National Science Foundation on February 12, 2015, to review the United States Particle Accelerator School (USPAS). The charge requested a preliminary report by April 2015 and a final report by May 2015. In response, a HEPAP subcommittee was formed and began meeting immediately. The membership included Roger Bailey (CERN), Gerald C. Blazey (Northern Illinois University), Bruce Carlsten (LANL), Tom Katsouleas (Duke), Andy Lankford (chair; UC Irvine), and Ritchie Patterson (Cornell). Brief biographies of the committee members are included in **Appendix B.1**.

The Subcommittee met four times via teleconference in preparation for a face-to-face meeting March 13–14, 2015, in Chicago, Illinois. In preparation for the face-to-face meeting, the USPAS Director provided extensive and detailed information on the USPAS (see **Appendix D**), including a self-assessment based upon guidelines established at the University of Pittsburgh for conducting the evaluation of academic programs (available online at: http://www.pitt.edu/~provost/guidelines.pdf). Prior to the Chicago meeting, letters were sent to the accelerator community requesting information about the USPAS and the nation's accelerator workforce; letters were solicited from:

1. the DOE laboratories with accelerator programs,
2. universities with the largest graduate programs in accelerator science,
3. the private sector organizations that have sent the most employees to USPAS sessions, and
4. a random selection of former USPAS trainees.

The Subcommittee received letters from ANL, BNL, Fermilab, LANL, LBNL, NSCL/FRIB, ORNL, SLAC, and TJNAF (see **Appendix G**). Universities responding were Colorado State, Cornell, Indiana, MIT, Michigan State (see NSCL/FRIB), Northern Illinois, Old Dominion, Stony Brook, and UCLA (see **Appendix H**). Sixteen letters were received from former trainees and two from industry. Letters were also requested and received from the American Physical Society Division of Physics of Beams (see **Appendix I**) and the USPAS Board of Governors. (see **Appendix J**).

On the first day of the Chicago meeting the Subcommittee discussed relevant information from the 2014 HEPAP report on HEP Workforce Development Needs; heard a detailed overview of USPAS from William Barletta, USPAS Director, and an overview of European accelerator workforce training; and received information from the USPAS Board of Governors and remarks from Fermilab as host laboratory for the USPAS. There was ample time for discussion of the presentations with the presenters and in executive session to discuss the information received from the community. The Subcommittee spent the second day drafting the major findings for the report. The meeting agenda is included in **Appendix C**.

Following the meeting, the Subcommittee continued to meet via teleconference and draft the report.

Appendix B.1. Subcommittee Biographies

Roger Bailey
CERN Laboratory
Geneva, Switzerland

Roger Bailey obtained a Ph.D. in experimental particle physics from the University of Sheffield, United Kingdom, in 1979. This was followed by a postdoctoral appointment with Rutherford Laboratory, Oxford, United Kingdom until 1983. During both of these activities, he worked on high energy physics experiments at the CERN Super Proton Synchrotron (SPS), being based at CERN from 1977. In 1983, he joined the operations group at the CERN SPS, with responsibility for accelerator operation during the fixed target and proton-antiproton programs at this facility until 1989. He then joined the CERN Large Electron-Positron Collider (LEP) commissioning effort, and subsequent operation, becoming Operations Group Leader in the late 1990s. After closure of LEP, he became progressively more involved in the Large Hadron Collider (LHC), developing the planning and building the team for LHC commissioning with beam. He was actively involved in LHC commissioning and early operation in the years 2008 to 2010. Since 2011, he has been the director of the CERN Accelerator School (CAS) in Europe, which organizes two-week residential courses on accelerator science and technology in the CERN member states three times per year.

Gerald (Jerry) C. Blazey
Department of Physics
Acting Associate Vice President for Research and Innovative Partnerships
Northern Illinois University

Gerald Blazey received his Ph.D. in Physics from the University of Minnesota in 1986. Over the past thirty years he has been involved in research at colliding beam experiments and in detector development. He is a Fellow of the American Physical Society. Since joining Northern Illinois University in 1996, he has been appointed a Distinguished Research Professor and has been principal investigator for federally funded grants from the National Science Foundation, the Department of Energy (DOE), the Department of Education, and the Department of Defense. While participating in the Fermi National Accelerator Laboratory collider program he served as co-Spokesperson of the DZero collaboration. He was a program manager for the International Linear Collider in the DOE Office of High Energy Physics and was Assistant Director for Physical Sciences in the Office of Science and Technology Policy in the Executive Office of the President of the United States. Currently he is Acting Associate Vice President for Research and Innovative Partnerships at Northern Illinois University.

Bruce Carlsten
Senior R&D Engineer
Los Alamos National Laboratory

Bruce Carlsten received his Ph.D. in Electrical Engineering from Stanford University in 1985. He has been at Los Alamos National Laboratory since 1982, researching the generation and transport of high-brightness electron beams and novel RF source technologies. He built two linacs for accelerator research at Los Alamos in the 1990s, and from 2005 to 2012 was Group Leader of the group High-Power Electrodynamics, overseeing the Laboratory's projects on advanced acceleration schemes, free-electron lasers, and various RF and THz sources. He is a Fellow of both the American Physical Society and Los Alamos National Laboratory, and a 1999 recipient of the USPAS Prize for Achievement in Accelerator Physics and Technology. He holds six U.S. Patents, is a member of several U.S. Government advisory panels, and is a member of the Advanced and Novel Accelerators Panel of the International Committee for Future Accelerators. He is an editor of *Physical Review Special Topics – Accelerator and Beams* and is the chair of the Program Advisory Committee of Brookhaven National Laboratory's Accelerator Test Facility.

Tom Katsouleas
Vinik Dean of Engineering, Pratt School of Engineering
Duke University

Tom Katsouleas received his Ph.D. in Physics from UCLA in 1984. He is a specialist in the use of plasmas as novel particle accelerators and light sources. His work has been featured on the covers of *Physical Review Letters*, the *CERN Courier*, and *Nature*. He has authored or co-authored over two hundred publications and given more than fifty major invited talks. He has been at Duke since 2008, where he is the Vinik Dean of Engineering and Professor of Electrical and Computer Engineering and Professor of Physics. Before that Katsouleas was a professor, associate dean, and vice provost at the University of Southern California. He is a fellow of the APS and IEEE and the recipient of the IEEE Plasma Science Achievement Award.

Andrew J. Lankford
Department of Physics & Astronomy
University of California, Irvine
Chair, High Energy Physics Advisory Panel

Andy Lankford received his Ph.D. in Physics from Yale University in 1978. He subsequently held staff positions at Lawrence Berkeley Laboratory from 1978 to 1982, and at the Stanford Linear Accelerator Center from 1982 to 1990. He became Professor of Physics at the University of California, Irvine in 1990. He served as Department Chair from 2002 to 2007. His research area is accelerator-based experimental particle physics, working on experiments using colliding beams at CERN's ISR, at SLAC's SPEAR, PEP, SLC, and PEP-II, at Fermilab's Tevatron, at BEPC at IHEP Beijing, for the SSC, and now at CERN's Large Hadron Collider. He has collaborated on the ATLAS Experiment at the LHC since 1994, and served there as Deputy Spokesperson from 2009 to 2013. He has participated in and chaired numerous DOE and laboratory review committees and participated in two National Academies studies, chairing the Committee to Assess the Science Proposed for a Deep Underground Science and Engineering Laboratory. He is a Fellow of the American Physical Society and a National Associate of the National Research Council. He has served as Chair of the High Energy Physics Advisory Panel for DOE and NSF since 2012.

Ritchie Patterson
Department of Physics
Director of the Cornell Laboratory for Accelerator-based Sciences and Education
Cornell University

Ritchie Patterson received her Ph.D. in 1990 from the University of Chicago, and then moved to Cornell, where after a few years as a post-doc, she joined the faculty of the Department of Physics. Patterson's research is in particle physics, where she has contributed to experiments addressing strange mesons at Fermilab, charm and bottom mesons at CESR, and currently, the energy frontier at the Large Hadron Collider. She was an NSF National Young Investigator from 1994 to 1999, an Alfred P. Sloan Fellow from 1994 to 1996, received Cornell's Provost Award for Distinguished Scholarship in 2005, and is a Fellow of the American Physical Society. She has served on numerous professional committees and panels, including the National Research Council decadal study for elementary particle physics, *EPP2010*, and the Physics Policy Committee of the APS. At Cornell, she has chaired the Department of Physics, and since 2012 has led Cornell's accelerator programs as the director of the Cornell Laboratory for Accelerator-based Sciences and Education.

Appendix C. USPAS Review Meeting Agenda

USPAS Review
March 13–14, 2015
Chicago, Illinois

Online agenda with links to material available at: https://indico.cern.ch/event/379681/

Friday, March 13, 2015

Time	Event	Presenter
07:30 – 09:30	Executive Session	
09:30 – 10:00	Summary of HEPAP Subcommittee on Workforce Development Report	R. Patterson
10:00 – 10:30	BREAK	
10:30 – 11:15	Overview of USPAS	W. Barletta
11:15 – 12:15	Overview of European Situation and CAS, TIARA, JUAS	R. Bailey
12:15 – 13:00	WORKING LUNCH	
13:00 – 13:30	Perspective from USPAS Board of Governors	R. Gehrig
13:30 – 15:00	Remarks from USPAS on specific charge points	Barletta, *et al.*
15:00 – 15:15	BREAK	
15:15 – 16:15	Fermilab perspectives	T. Meyer
16:15 – 17:45	Executive Session – Summary of input	
17:45 – 18:00	BREAK	
18:00 – 19:30	Executive Session	

Saturday, March 14, 2015

Time	Event	Presenter
07:30 – 09:00	Working Breakfast – Executive Session	
09:00 – 09:30	BREAK	
09:30 – 12:00	Executive Session	
12:00 – 13:00	Working Lunch – Executive Session	
13:00 – 14:30	Executive Session	

Appendix D. Materials Provided by USPAS Director

1. Annual Report of the United States Particle Accelerator School, December 2014.
2. USPAS Self-Assessment, March 2015.
3. Description of core USPAS courses.
4. Authorizing Letters from Department of Energy Office of Science Associate Directors to Chair of the USPAS Board of Governors (see **Appendix E**).
5. Testimonial letters from USPAS students and instructors.
6. W.A. Barletta, S. Chattopadhyay and A. Seryi, "Educating and Training Accelerator Scientists and Technologists for Tomorrow, "*Reviews of Accelerator Science and Technology*, vol. 5, pp. 313–331, 2012.
7. Task Force on Accelerator R&D, "Office of High Energy Physics Accelerator R&D Task Force Report," May 2012. Report and Appendices available online at: http://science.energy.gov/hep/research/accelerator-rd-stewardship/workshop-reports/
8. Kircher, F., *et al.*, "TIARA Education and Training Survey Report," *TIARA-REP-WP5-2012-006*, 2012. Available online at: http://cds.cern.ch/search?p=TIARA-REP-WP5-2012-006
9. Burrows, P., *et al.*, "TIARA Needs for Accelerator Scientists Report," *TIARA-REP-WP5-2013-005*, 2013. Available online at: http://cds.cern.ch/search?p=TIARA-REP-WP5-2013-005
10. Nuclear Science Advisory Committee Subcommittee on Workforce Development, "Assessment of Workforce Development Needs in the Office of Nuclear Physics Research Disciplines," July 2014. Available online at: http://science.energy.gov/np/nsac/reports/

Appendix E. USPAS Authorizing Memoranda

Department of Energy
Washington, DC 20585

SEP 3 1992

Dr. Richard Briggs
Deputy Director
SSC Laboratory, MS 1072
2550 Beckleymeade Avenue
Dallas, Texas 75237

Dear Dr. Briggs:

We are writing to you in your capacity as Chairman of the Steering Committee for the U.S. Particle Accelerator School. As we are all aware, there has been extensive discussion in recent months within the Department of Energy (DOE) and within your committee about future directions of the School, future funding scenarios, and oversight requirements. We believe, after considerable reflection, that it is timely for the DOE to formally state its position with regard to the future support of the School and to move to a new, less complicated management arrangement.

The DOE Division of High Energy Physics (DHEP) has been the principal financial supporter for the U.S. Particle Accelerator School since the first School was held at Fermilab in 1981. We know of no better way to have expressed the DOE's continuing, enthusiastic endorsement of the School's product than this continuing financial support. The formal training of personnel in accelerator science, engineering, and technology in early schools at national laboratories and recently at universities has been beneficial to all of our programs. The series of seminars on forefront topics held at various U.S. national laboratories have provided a badly needed forum, far more concentrated in content than possible at particle accelerator conferences, to keep all of the U.S. accelerator community abreast of current research. The Joint U.S./CERN School has also contributed strongly to the international exchange and dialogue in the most advanced accelerator science topics, a dialogue essential in a forefront research field. Most significantly, the U.S. Schools have produced a series of books of archival quality,.covering in detail and comprehensively every aspect of accelerator science, engineering, and technology. A whole literature has been created where none existed before.

We are concerned, however, about recent difficulties encountered in the business side of this enterprise, specifically in the budgeting, financial management, and oversight areas, which the DOE is bound to manage according to well-established and formal requirements. After examining the process for supporting recent Schools and the School Office, and Dr. Burton Richter's memorandum of May 27, 1992, in which similar deliberations at the School's steering committee meeting of April 22, 1992, are recounted, we have concluded that some changes are needed if the School is to continue to flourish and be of benefit to the wider communities of science and technology that it now wants to support.

Consequently, we propose the following policy to resolve the issues which we see before us. First, the DHEP will continue to provide funding support for the School Office at Fermilab, as it has in the past, as long as this activity continues to have the endorsement of the Fermilab Director. The activities of the Office appear well organized, the staff highly qualified, and the function important to the Schools and to the publication of the School Proceedings. Second, the DHEP will, in response to specific requests, provide funding for the Joint U.S./CERN School whenever it is held in the U.S. Third, we strongly endorse the principal embodied in Dr. Richter's May 27, 1992, memorandum that a single national laboratory be responsible for budgetary and business management oversight, and we believe that it is essential that these activities be performed with care and attention to detail. We note that Dr. Richter's memorandum indicates that Fermilab is to assume this role.

Before continuing to the fourth point, some important facts must be considered. Most significant, the present mode of funding for the university-based Schools routes the funding through two channels: DOE funds for School Office participation on site at a particular university-based School are provided directly to Fermilab, and DOE funds for each specific School are provided directly to the university hosting the School, which as manager for the grant controls the largest portion of that School's funds. This dual arrangement has proved awkward at best and is the source of part of the agency's concern about the business management and financial oversight aspects. Further, Fermilab does not inherently have the necessary legal authority to carry out oversight activities over a grant that DOE has placed with a university. We note also that the primary management responsibility for the activities of the School is through the Steering Committee that you chair, whose present membership includes representatives from Brookhaven National Laboratory, CEBAF, Cornell University, Fermi National Accelerator Laboratory, Stanford Linear Accelerator Center, and the Superconducting Super Collider Laboratory. Moreover, this group of laboratories has provided at least half of the financial support for the June 1992 U.S. Particle Accelerator School at Stanford University.

We believe that good management practice requires the funds for an activity such as this to flow through the same channel as the management control. This consolidates the power of management and finance in a single entity. Therefore, as our fourth point we propose that funding for all future U.S. Particle Accelerator Schools at universities be provided in total, except as noted in points one and two above, directly by the laboratories represented on the steering committee--following the precedent set by the funding for the June 1992 Stanford School. This approach has the additional advantage that the most affected and interested field representatives of the various scientific disciplines supported by accelerator science and technology can decide at the field level what topics the School will address, how often the Schools are to be held, and the amount of financial resources to be applied.

As senior DOE managers for each of the scientific areas identified by the Particle Accelerator School as potential sources of future financial support, we have reviewed the School's history, its successes, and the promised benefits of its continuation. We have determined that if the members of the Accelerator School Steering Committee, representing the relevant scientific disciplines and national laboratory organizations, decide that a given School is needed for training personnel, we will support that decision, and we will, as a consequence, accept the steering committee's collective judgement as adequate justification for funding the U.S. Particle Accelerator School with the Federal funds that our programs provide to the respective laboratories.

In summary, the major change that we propose is for the funding of future university-based Particle Accelerator Schools to be provided by the interested and benefitting national laboratory program organizations with a single national laboratory (perhaps Fermilab) being responsible for budgetary and business management oversight. We think this approach is fair, equitable, and consistent with the proven success of "field run" science management, and it will become effective as of the start of Fiscal Year 1993. If you wish to discuss further the reasoning behind this plan please feel free to contact any of us. Specific questions can also be directed to Dr. David F. Sutter of the Division of High Energy Physics at (301) 903-5228.

Sincerely,

Robert E. Diebold
Director
Program Coordination Division
Office of Superconducting Super Collider

David L. Hendrie
Director
Division of Nuclear Physics
Office of Energy Research

Louis C. Ianniello
Acting Associate Director
for Basic Energy Sciences
Office of Energy Research

John R. O'Fallon
Director
Division of High Energy Physics
Office of Energy Research

cc:
Martin Blume, BNL
Hermann Grunder, CEBAF
Boyce McDaniel, Cornell
Melvin Month, BNL
Ewan Paterson, SLAC
John Peoples, Fermilab
Burton Richter, SLAC
Richard Stephens, ST-50

Department of Energy
Germantown, MD 20874-1290

DIRECTOR'S OFFICE
FEB 20 2001

FEB 15 2001

Dr. Michael S. Witherell
Fermilab, MS 105
P.O. Box 500
Batavia, IL 60510-0500

Dear Dr. Witherell:

This letter is to confirm agreements reached concerning future management and financial support of the U.S. particle Accelerator School (USPAS) during a conference call on November 13, 2000. The parties to the conference call were Stephen D. Holmes, Fermilab Associate Director for Accelerators; William A. Barletta, Chairman of the USPAS Board of Governors; David F. Sutter, Senior Program Officer for Technology R&D, DOE Division of High Energy Physics; and myself. The purpose of the phone call was to review a proposal originating with Mel Month, the founding Director of the USPAS to the University Research Association (URA) that the management responsibility for USPAS be moved from Fermilab to URA where it would become a separate management entity similar to Fermilab. The question of a fulltime USPAS Director was also discussed.

This office has been a strong supporter of the USPAS since its inception in 1981, and we recognize that the benefit to high energy physics has been substantial and ongoing. The expansion of the school's programs to support sciences other than high energy physics has been impressive and greater than anticipated. We would note that this expansion and broadening was in fact one of the anticipated and intended effects of the policy established by the Department of Energy (DOE) in the letter to Richard Briggs, the Chairman of the USPAS steering Committee, the predecessor to the present USPAS Board of Governors, on September 13, 1993, and signed by four Senior DOE Office of Science Program Managers. The letter endorsed funding the USPAS courses through interested, supporting laboratory "customers." The subsequent financial support and management oversight by eleven prestigious DOE and National Science Foundation supported laboratories has, we believe, contributed strongly to the health vigor, and productivity of the USPAS educational activities and confirms the, at that time controversial, policy decision. Continuation of the eleven laboratory support is essential, and we very strongly endorse continuation of their participation in the USPAS management.

We also believe that the necessary, detailed administrative and financial oversight by Fermilab of what is in fact a rather large operation that spends a good deal of money has also contributed in a very important way to the success of the USPAS. It has assured all who contribute financial support and policy backing to USPAS that the many rules and regulations involved in any government funded enterprise are being obeyed. Therefore, if the Division of High Energy Physics is to continue its present level of support for the School Office, and in particular, if as noted below, we are to expand that support to include funds for a full time director, then we must insist that management oversight by Fermilab is essential and must continue.

In view of the above points, we do not support the proposal for changing the USPAS school status to that of a contractual entity managed directly by URA. During the above referenced conference call, it was agreed that this would not be pursued.

Finally, we agree with the recommendation in the proposal that the Director of the USPAS needs to be essentially a full time rather than a part time position, and we will work with Fermilab in taking the actions necessary to establish such a full time position at Fermilab. At present, the salary for the USPAS Director is not included in the approximately $270,000 provided by DOE annually to Fermilab for support of the USPAS school office. The total needs to be adjusted to include the Director's salary, and Fermilab should submit to this office a Field Task proposal requesting appropriate funds for the operation of the USPAS office including the director at Fermilab beginning in FY 2002. We assume that the present support and participation by the eleven laboratories continues. It is our understanding that the goal is to have hired a new School Director by the start of Fiscal Year 2002 and that the present Director, Professor S.Y. Lee of Indiana University has indicated his willingness to continue as Director until the new one is hired.

If you have further questions or wish to discuss the USPAS management further, please do not hesitate to call me. More detailed administrative questions can be addressed to Dr. Sutter at (301) 903-5228.

Sincerely,

John R. O'Fallon
Director
Division of High Energy Physics

Department of Energy
Office of Science
Washington, DC 20585

NOV 2 4 2010

Dr. Derek Lowenstein
Collider Accelerator Department
Building 911B
Brookhaven National Laboratory
Upton, NY 11973-5000

Dear Dr. Lowenstein:

We are writing to you in your capacity as Chairman of the Board of Governors of the U.S. Particle Accelerator School (USPAS). Since 1992, management and support of the USPAS has operated under guidance articulated in a September 13, 1992, letter to Richard Briggs, Chairman, USPAS Steering Committee – the predecessor to the present USPAS Board of Governors and signed by four senior Department of Energy (DOE), Office of Science, program managers. This guidance was reconfirmed and extended in a February 15, 2001, letter from the Director Office of High Energy Physics (HEP), to the Director, Fermi National Accelerator Laboratory, which serves as the managing institution for the USPAS consortium. That letter noted that the impressive expansion of the school's programs to support sciences other than high energy physics was one of the intended effects of the policy established in 1992. Via the Joint U.S./CERN/Japan/Russia School, the USPAS has also contributed strongly to the international exchange and dialogue in the most advanced accelerators.

The DOE (HEP) has been the principal financial supporter for the USPAS since the first school was held at Fermilab in 1981. We know of no better way to have expressed the Department's continuing enthusiastic endorsement of the school's product than this continuing financial support. The formal training of personnel in accelerator science, engineering, and technology in rigorous academic courses hosted by major research universities has been beneficial to all of our programs. Hundreds of graduate students who were trained at USPAS sessions have become internationally recognized intellectual leaders in their field. Many of these graduate students now teach for the USPAS. The United States schools have also led to a series of textbooks covering in detail and comprehensively every aspect of accelerator science, engineering, and technology. A whole literature has been created where none existed before.

Since that time, the structure and management of the DOE Office of Science has changed as has the Management and Operating contractor for many of the consortium laboratories. We believe that it is timely for DOE to formally restate its position with regard to the future support of the school and its management arrangement. The 1992 agreement was intended to maintain the stability of the business side of this enterprise, specifically in the budgeting, financial management, and oversight areas, which the DOE is bound to manage according to well-established and formal requirements.

We propose the following policy to maintain the strong and well-tested practices that have served the accelerator-based science and technology communities well:

1) Good management practice requires the funds for an activity to flow through the same channel as the management control, thereby consolidating the power of management and finance in a single entity. Therefore, funding for all future USPAS at universities should be provided in total, except as noted in points two and three below, directly by the institutions represented on the Board of Governors–continuing the practice adopted since the June 1992 Stanford School. The financial support and management oversight by 11 prestigious DOE and National Science Foundation supported laboratories has, we believe, contributed strongly to the health, vigor, and productivity of the USPAS educational activities. Stable continuing support by the 11 laboratory consortium is *essential* to the financial health of the USPAS, and we very *strongly* endorse continuation of their participation in the USPAS. This approach has the additional advantage that the most affected and interested field representatives of the various scientific disciplines supported by accelerator science and technology can decide at the field level what topics the school will address, how often the schools are to be held, and the amount of financial resources to be applied.
2) We reconfirm the principle that a single national laboratory is responsible for budgetary and business management oversight and we believe that it is essential that these activities be performed with care and attention to detail. We further reconfirm that Fermilab should continue to perform this function.
3) We reconfirm that HEP will continue to provide funding support for the USPAS office at Fermilab including a full-time USPAS Director, as it has in the past. The activities of the office appear well organized, the staff highly qualified, and the function essential to the schools.
4) HEP will, in response to specific requests, provide support for the Joint U.S./CERN/Japan/Russia School whenever it is held in the United States. Partial support for joint schools held outside the United States will be considered on a case-by-case basis.

As senior DOE managers for each of the scientific areas identified by the USPAS, we have reviewed the school's history, its successes, and the promised benefits of its continuation. We have determined that if the members of the USPAS Board of Governors, representing the relevant scientific disciplines and national laboratory organizations, decide that a given school is needed for training personnel, we will support that decision. Furthermore, we will, as a consequence, accept the Board of Governors' collective judgment as adequate justification for funding the USPAS with the Federal funds that our programs provide to the respective laboratories. In summary, we confirm that the funding of university-based USPAS sessions is to be provided by the interested and benefiting national laboratory program organizations plus other institutions that join the USPAS consortium in accordance with its Memorandum of Understanding with a single national laboratory, Fermilab, being responsible for budgetary and business management oversight. We think this approach is fair, equitable, and consistent with the proven success of "field run" science management and it will become effective as of the start of Fiscal Year 2011.

If you wish to discuss further the reasoning behind this plan, please feel free to contact any of us. Specific questions can also be directed to Dr. Bruce Strauss of the Office of High Energy Physics at (301) 903-3705.

Sincerely,

for Dennis Kovar
Associate Director of Science
for High Energy Physics

Timothy J. Hallman
Associate Director of the Office of Science
for Nuclear Physics

for Harriet Kung
Associate Director of Science
for Basic Energy Sciences

for Edmund J. Synakowski
Associate Director of the Office of Science
for Fusion Energy Sciences

Appendix F. USPAS Courses from 2000 to 2014

	Course Category / Course Name	Average Number Enrolled	Total Number Enrolled	Number of Courses
1	Fundamentals	26	952	36
	Accelerator Fundamentals	29	873	30
	Classical Mechanics and EM	13	79	6
2	Microwave Measurements	17	278	16
	Microwave Measurements / Instrum. Lab.	17	278	16
3	Beam Physics	20	839	43
	Accelerator Physics	23	676	30
	Advanced Beam Dynamics	15	30	2
	Interm. Acc. Physics / Special Topics	12	93	8
	Beam Dynamics Experiments	11	22	2
	Special Topics / Others	18	18	1
4	Plasmas & Collective Effects	10	201	21
	Collective Instabilities, Wake fields	10	58	6
	Space Charge Effects, Beam Halos	10	67	7
	Plasma Physics and Accelerators	10	76	8
5	Mathematical & Computer Methods	12	209	17
	Computer Modeling	7	7	1
	Hamiltonian / Lie Algebra	4	8	2
	Mathematical Methods / Computer Modeling	15	146	10
	MATLAB and Acc. Phys, Data Acquisition	12	48	4
6	Accelerator Design	11	385	36
	Damping Rings / Storage Rings	8	32	4
	Induction Linear Accelerators	4	4	1
	Cyclotrons	11	44	4
	Linear Accelerators	14	198	14
	Linear Colliders	10	10	1
	Linear Collider Sub-Systems	7	13	2
	Physics and Design of Hi-Intensity Accel.	7	13	2
	Recirculating Linear Accel / ERL	9	27	3
	Spallation Neutron Source, Ring & Target	5	5	1

	Course Category / Course Name	Average Number Enrolled	Total Number Enrolled	Number of Courses
	Spallation Neutron Source, Front End & Linac	17	17	1
	Pulsed Power / High Current Beams	6	11	2
	Beam Delivery	11	11	1
7	RF Technology	14	504	35
	High Power Microwave Sources, Klystron	13	77	6
	Power Engineering	13	88	7
	RF Engineering and Signal Processing	19	58	3
	RF Superconductivity / Applications	13	50	4
	RF Superconductivity / Technology	14	97	7
	RF Structures	21	42	2
	RF Systems	15	92	6
8	Diagnostics & Controls	15	313	21
	Controls and EPICS	17	150	9
	Beam Based Diagnostics	14	124	9
	Feedback & Beam Stability	13	39	3
9	Accelerator Technology	11	283	25
	Alignment Techniques	10	19	2
	Beam Experiments / Manipulation	12	24	2
	Cryo Engineering	14	54	4
	Vacuum Systems	12	61	5
	Electron Sources and Cathodes Physics	12	62	5
	Ion Sources	9	55	6
	Beam Targets	8	8	1
10	Radiation & Safety Systems	11	156	14
	Safety Systems	12	71	6
	Radiation Physics, Rad. Damage	11	85	8
11	Magnet Systems	13	239	18
	Magnet Systems / Measurement	14	129	9
	Superconducting Magnets	11	68	6
	Superconducting Materials	12	23	2
	Applied Electromagnetism	19	19	1

	Course Category / Course Name	Average Number Enrolled	Total Number Enrolled	Number of Courses
12	Synchrotron Radiation, FELs, & Lasers	13	312	24
	EM Radiation / Synchrotron Radiation	8	24	3
	Laser Physics and Technology	17	33	2
	Lasers in AP	12	49	4
	FELs, High Gain FEL	15	161	11
	HE Accelerators, Light Sources, X-ray Laser	11	45	4
13	Management & Accelerator Applications	11	290	27
	Management of Scientific Labs / Projects	11	91	8
	Manag. II (Managing Organiz. Behavior)	8	16	2
	Medical / Other Applications	12	117	10
	Neutrons and Materials Research	5	9	2
	Physics of H-ion Hohlraum Targets	5	5	1
	Radiography	16	31	2
	SynRad and Material Sciences	11	21	2
14	Detectors	11	32	3
	Fund. of Detector Physics and Meas. Lab	10	10	1
	Semiconductors	8	8	1
	HEP Physics Principles and Instrumentation	14	14	1

Appendix G. Letters from National Laboratories

Peter B. Littlewood
Director
President, UChicago Argonne, LLC

Argonne National Laboratory
9700 South Cass Avenue, Bldg. 201
Argonne, IL 60439-4832

1-630-252-5749 phone
1-630-252-7923 fax
director@anl.gov

March 10, 2015

Andrew J. Lankford
Professor, Dept. of Physics and Astronomy, UC Irvine
Chair, High Energy Physics Advisory Panel

Dear Professor Lankford,

Thank you for this opportunity to express my very firm support for the U.S. Particle Accelerator School, which plays such a critical role in supporting our work here at Argonne National Laboratory and in furthering the overarching mission of the U.S. Department of Energy.

Particle accelerators are absolutely central to Argonne's ability to conduct world-leading research in science and engineering, and our success is dependent on the training and abilities of the scientists, engineers, technicians and operators who use and maintain our scientific facilities. For nearly three decades, we have relied on the USPAS to help us to train and maintain a cutting-edge workforce. As we look ahead to the future of our nation's particle accelerators, we are counting on USPAS to continue to provide high-level training programs that are aligned with the evolving needs of accelerator-based science in this century.

Argonne operates two accelerator-based scientific user facilities within DOE's Office of Science: the Advanced Photon Source (APS), and the Argonne Tandem-Linac Accelerator System (ATLAS). The APS is a storage ring-based X-ray light source facility that hosts the largest user base of any DOE scientific user facility, with more than 5,000 unique users in FY 2014. Those users, who come from more than 400 U.S. universities, private firms and laboratories and from 200 foreign institutions, represent an incredibly broad base of scientific disciplines – ranging from materials science, chemistry, environmental and geosciences to life sciences and biology. The productivity of this scientific facility is enormous, resulting in more than 1,600 publications last year. In 2009 and 2012, the Nobel Prize in Chemistry was awarded for work done in part at the APS. Today, Argonne is planning a transformative upgrade to the APS that will usher in a generational leap in storage ring performance and assure the facility's international scientific leadership for decades to come.

ATLAS is the nation's only DOE-funded user facility for low-energy nuclear research and rare isotope beams, serving a research community of about 500 users from academia and national laboratories. Research at ATLAS addresses forefront issues in nuclear structure, nuclear astrophysics, and fundamental interactions. An important component of the ATLAS research portfolio focuses on applications of nuclear science in medicine, geology, archeology, and nuclear energy.

The USPAS is fundamental to the world-leading research performed at these facilities. Since the School's inception in 1987, ANL has supported USPAS training for 185 employees, ranging from early-career accelerator scientists and engineers, to established x-ray and beamline scientists, to accelerator operators and safety and health professionals. We also have been proud to join our fellow consortium members in funding USPAS since 1993. In return, the entire laboratory has benefited from the top-tier workforce development, training and continuing education that USPAS provides, which assures that our staff have the relevant skills and expertise both to operate today's facilities and to design, build and commission the next-generation facilities of the future.

USPAS courses, taught by the world's leading experts, consistently offer training at a level that is available nowhere else. Without USPAS, Argonne employees would have no access to world-class training in accelerator physics, radiofrequency power system engineering, beam diagnostic system engineering, vacuum systems, insertion devices, and x-ray beamline design and engineering. USPAS classes are targeted to meet the evolving needs of the community; for example, USPAS instructors have developed and presented courses in x-ray beamline design and engineering – a specialty that is critically important to the APS and its Upgrade, and one that simply is not available through university coursework. Additionally, the USPAS curriculum design, which offers intensive courses in one- or two-week sessions, reflects the needs of working professionals and their employers; by comparison, a traditional university-style class schedule would take longer, would cost more, and would be tremendously disruptive to staff productivity.

For the APS and ATLAS to maintain their standing as world-class research facilities serving large and growing user communities, it is essential that we attract, develop and retain the highest quality accelerator staff. Given that we anticipate turning over one-third of our 300-person accelerator staff within the next decade, USPAS training is critical to our workforce development plans. In addition, the APS Upgrade will drive a need for additional highly trained staff to design and build this state-of-the-art facility; over the next 10 years, we expect approximately 80 Argonne accelerator staff members to take advantage of USPAS training. USPAS also plays a central role in training Argonne's accelerator operators. We routinely send new accelerator operators to the USPAS for training in the fundamentals of particle accelerators; there is no alternative source for this type of instruction.

Argonne also depends on USPAS to assure a robust talent pipeline of future scientific staff. I would especially like to highlight the Lee Teng Undergraduate Internship in Accelerator Science and Engineering, a collaborative effort by Argonne, Fermilab and USPAS. The Lee Teng program, a 10-week summer internship for 10 highly qualified students, combines the USPAS' excellent educational experience with hands-on laboratory training. Through the Lee Teng internship, which was established in 2007 and named for an eminent Argonne accelerator scientist, USPAS is further expanding its mission of attracting and training outstanding young accelerator scientists and engineers.

We have come to rely on USPAS to help us train research staff who may be new to accelerator science, to ensure that they can be productive in operating the present accelerator facilities and that they can contribute effectively to the design, building and commissioning of future facilities, such as the APS Upgrade. USPAS also provides a swift and thorough orientation for new staff who join Argonne teams pursuing fundamental research into beam physics and advanced approaches to particle beam acceleration. Argonne employees who have attended USPAS courses have gone on to laboratory leadership positions, including group leaders, division directors, and project managers and directors.

Over the years, approximately 35 USPAS courses have been taught by nearly 40 Argonne staff members. By investing staff time in USPAS instruction, Argonne helps to ensure that the program's costs remain reasonable. We are very proud that our researchers' forefront knowledge and methods have been recognized by USPAS, and we are honored to join in this important

3

effort to assure that U.S. accelerator scientists and engineers have access to the best possible training in the diverse, multi-disciplinary field of beam physics and accelerator technology.

The U.S. DOE Office of Science operates the most advanced suite of accelerator-based scientific facilities and instruments in the world. These user facilities are the crown jewels of our nation's scientific infrastructure – but they would be of far less value without the skills and knowledge of the 2,500 men and women who staff them. As we look to the future, we see a pressing need to develop and expand the talent pool and to make ongoing world-class training available to all accelerator staff throughout their careers. USPAS provides the primary training opportunities for this workforce, and there is simply no alternative that can come close to matching the depth and breadth of its curriculum and the expertise of its instructors.

USPAS plays a crucial rule in Argonne's workforce development, ensuring our ability to design, build, and operate these increasingly complex scientific tools for the benefit of this nation. The U.S. Particle Accelerator School has earned Argonne National Laboratory's wholehearted support, and we look forward to benefiting from its unique, high-quality and irreplaceable training programs in the years to come.

Sincerely,

Peter B. Littlewood
Director
President, UChicago Argonne, LLC

BROOKHAVEN
NATIONAL LABORATORY

P.O. Box 5000
Upton, NY 11973-5000
Phone 516 344-8000
managed by Brookhaven Science Associates
for the U.S. Department of Energy

3 March 2015

Andrew J Lankford
Professor, Dept. of Physics & Astronomy, UC Irvine
Chair, High Energy Physics Advisory Panel

Need for USPAS at Brookhaven National Laboratory

Dear Prof. Lankford:

In response to your request for input, this letter summarizes the effectiveness and usefulness of the US Particle Accelerator School (USPAS) for the workforce development, training within the accelerator community at Brookhaven National Laboratory as well as its important documented impact on diversity within the Collider-Accelerator Department.

Workforce development – Over the last 29 years 402 students and 62 instructors from BNL took part in USPAS courses. These numbers clearly demonstrate our need for and active participation in USPAS. We expect that a similar and likely growing level of participation is needed in the future. As we look among our colleagues the average age is trending toward retirement, and with NSLS II coming into operation, the ATF II upgrade moving forward and a possible start of construction of Electron Ion Collider at BNL, the need for a rigorous accelerator physics and engineering training program is ever more pressing.

We use USPAS for 3 purposes:

1. Coursework for students in accelerator science and technology:
   Accelerator Science and Technology is a recognized field of specialization. For students in this field within our organizations USPAS provides for coursework in parallel to the research work performed at our machines. The coursework credits earned at USPAS can be applied to the university requirements of the student's home institution.

2. Training of new employees in accelerator science and technology basics:
   New members of the staff in both operations and engineering are generally not trained in accelerator science and technology but this knowledge is critically needed. USPAS is our main venue to provide this knowledge, in addition to on-the-job training.

3. Advanced training in specialized accelerator topics:
   USPAS provides for advanced training in specialized topics (e.g. microwave measurements of accelerator components). Such topics are not taught anywhere else but are absolutely needed for the development and operation of particle accelerators.

The workforce training provided by USPAS to the staff has been essential to the highly successful development and operation of accelerators at BNL. The inclusion of laboratory staff as teachers makes USPAS particularly useful in helping to disseminate their highly specialized but critical expertise across the DOE laboratory system. USPAS is likely the only rigorous accelerator physics and engineering training program that is within the reach of full time employees of the laboratory. The course notes have proven useful to staff beyond those who are able to participate directly, and USPAS has in fact been the wellspring from which a number of highly influential and classic textbooks in the field have arisen.

For graduate students in Accelerator Science USPAS dependently provides introductory and advanced courses in Accelerator Physics that most university programs do not provide. Without USPAS it would be very difficult to attract students to the field of accelerator science, which, in turn, would make it impossible to maintain a viable Accelerator R&D program at BNL.

The intensive nature of the USPAS experience and the broad participation from National Laboratories such as BNL also fosters the development of an accelerator science and technology community. Students and faculty from multiple institutions become acquainted with each other, and the work of their respective laboratories. Fruitful collaborations and technology developments supporting the entire field have been borne of this community which might otherwise never have occurred. That alone is an achievement of USPAS that would be difficult to replicate in any other way.

It is not an exaggeration to say that if USPAS didn't exist it would have to be created. Note that accelerator schools exist in Europe and Asia, and without USPAS we would have a clear competitive disadvantage compared to those regions.

Diversity – USPAS also allows for increasing our workforce diversity. With the training provided the pool of applicants can be significantly enlarged, resulting in a much more diverse workforce. The Operations Group in the Collider-Accelerator Department (C-AD), for which we send almost all new members to USPAS, best illustrates this. The Operations Group has a higher fraction of females and minorities than the department as a whole. About 1/3 to 1/2 of the members of the Operations Group will transition to other professional positions in the department.

	Operations group in C-AD	C-AD BNL	US population 2009 Census
Female	18.2%	11.4%	51.1%
Minority	27.3%	19.9%	22.3%

In summary, for BNL USPAS has been essential to train new employees in the Accelerator Physics, Operations, and Technical Groups. It also provided invaluable training in advanced courses to physicists and engineers on topics that are not taught at any other institution. In addition, USPAS has enhanced our workforce diversity since a larger pool of applicants is accessible. Please don't hesitate if you need any further information.

Sincerely,

Wolfram Fischer

Dr. Wolfram Fischer

Associate Chair for Accelerators and Accelerator Division Head
Collider-Accelerator Department
Brookhaven National Laboratory

Erik D. Johnson

Dr. Erik D. Johnson

Deputy Director for Construction
National Synchrotron Light Source II
Brookhaven National Laboratory

Fermilab

Sergei Nagaitsev
Chief Accelerator Officer
Fermi National Accelerator Laboratory
630.840.4397 office
630.840.4552 fax
630.862.4270 mobile
nsergei@fnal.gov

March 10, 2015

Andy Lankford
Chair, HEPAP Sub-panel to Review USPAS

Dear Andy,

Please find below our comments regarding the U.S. Particle Accelerator School (USPAS). In this letter, Fermilab affirms the value of USPAS to the laboratory mission and identifies the unique role that USPAS plays in attracting, developing, and retaining the future accelerator science and technology workforce. In this letter, we also comment on five elements of the USPAS program-delivery model that have been essential to its success.

In brief, we believe that USPAS serves an important role in driving U.S. scientific and technological competitiveness, primarily through the training and development of technical professionals in accelerator science, technology, and operations.

Since its inception in 1987, the USPAS has served the Fermilab mission extremely well. Overall, a total of nearly 700 participants have been from Fermilab. The actual number of unique attendees is lower because of employees taking multiple classes at different sessions. The training provided by USPAS has been of tremendous value to the laboratory. Several examples of where the USPAS made a difference in the training and development of Fermilab's workforce are given below.

a. Operation of Fermilab's proton accelerator complex user facility relies on a cadre of highly skilled and experienced accelerator operators who support the facility 24 hours a day, seven days a week. These individuals are typically recruited (three or four per year) with a Bachelor's degree in physics and yet require additional expert training to be fully effective. The USPAS provides a natural and well-aligned opportunity for these incoming operators to enhance their knowledge, skills, and abilities in general and basic-level accelerator physics. They typically take multiple classes and some even enroll in the Master's degree program. In this regard, USPAS serves as an informal on-boarding training program for bringing new talent into the field.

b. Early and mid-career engineers in RF, magnet design, controls, vacuum, and so on, benefit from USPAS physics and technology classes. They increase their expertise, build peer networks, and increase their value to the Fermilab program through USPAS training.

c. Post-doctoral researchers coming from fields outside of accelerator physics usually require additional training before being able to substantively contribute to accelerator science and technology research. USPAS provides a natural path for them with its intermediate and advanced accelerator physics classes.

In all of these cases, a primary benefit is the exposure to a world-class community of experts represented by the USPAS instructors.

A crucial element driving the value of USPAS is the involvement of the DOE National Labs. The national labs provide instructors to the USPAS to teach classes, provide IT support and infrastructure, and in many cases provide equipment (for example, oscilloscopes and network analyzers) for hands-on training. Upon occasion, a USPAS session has been held adjacent to an operating accelerator facility (e.g., Cornell's CESR machine) and the training opportunity for the participants was magnified. This type of direct, experience-based training is the hardest to come by and the most valuable. Going forward, more opportunities like this one should be pursued such as hands-on experience in accelerator control rooms.

The involvement of universities in USPAS is equally important in the same way that an executive MBA has value in offering a validated, easily-recognized credential. USPAS training and development is highly specialized and engaging the academic community is enormously helpful. Universities can even help foster communities of practice and their participation helps support accelerator science and technology as a profession of value and accomplishment. In the present formulation, the Indiana University/USPAS Master's Degree in Beam Physics and Technology is an attractive element of USPAS for a good number of Fermilab's participants. Of ten Master's degrees granted thus far, four were granted to Fermilab employees. The degree outcome was a key motivator for the full participation. The Master's program element provides other value as well. One requirement of the degree is completion of a research thesis. This element offers substantial value to Fermilab because it creates opportunities for focused research and development in accelerator science and technology. The participants are required to apply his/her knowledge in a practical setting. Consider the example of a Fermilab employee, Mr. Michael B. He came to Fermilab in 2004 as an Operator I with a B.S. degree in Physics. In 2006 he enrolled into the IU/USPAS Master's degree program. In

2013 he was granted the Master's degree and is now employed at Fermilab in one of the Accelerator Machine departments as an Engineering Physicist. USPAS was essential in providing a professional-development path for him. This career path is very attractive to Fermilab, because it brings young people into accelerator operations first, provides training and then these employees move on from operations to machine and support departments, and serve as invaluable members of the team. At present, two additional Fermilab employees are enrolled into the IU/USPAS Master's degree program.

There are three other elements of the USPAS management model that drive its value and success.

a. A dedicated logistics and administrative staff to support efficient operations;
b. The *pro bono* Curriculum Advisory Committee with a broad university and national lab representation to enable high-caliber classes and instructors to be selected; and
c. The ability to work with multiple stakeholders and funders in organizing and delivering programs allows needed flexibility in budget and operations.

Going forward, we believe the stature and the leadership of the USPAS director will be important for attracting world-class instructors as well as students and for communicating with stakeholders.

We trust that these comments are helpful to you and your committee. It has been a privilege for Fermilab to serve the entire U.S. accelerator community as USPAS host and we would be happy to do so in the future.

Sincerely,

S. Nagaitsev

Sergei Nagaitsev
Chief Accelerator Officer

cc: file

Los Alamos
NATIONAL LABORATORY
EST 1943

Office of the Associate Director for
Engineering Sciences (ADE)
PO Box 1663, MS F696
Los Alamos, New Mexico 87545
505-606-0000 /Email: sgirrens@lanl.gov

Date: March 2, 2015
Symbol: ADE:15-007

Professor Andrew J. Lankford
Chair, High Energy Physics Advisory Panel
University of California, Irvine
Physics & Astronomy Department
4129H Frederick Reines Hall
Irvine, CA 92697-4575

Dear Dr. Lankford:

I'm writing today to strongly endorse the US Particle Accelerator School (USPAS).

Accelerator physics and accelerator research and development are recognized as important capabilities within Los Alamos National Laboratory (LANL), providing many of the underlying fundamental research and technological developments crucial to successfully advance Defense Programs weapons research, the nuclear and non-nuclear components of Global Security, applied energy and environmental research, medical imaging and therapy, industrial applications, and the pursuit of high-priority fundamental research, as identified in current strategic plans of Office of Science programs in Basic Energy Sciences, Nuclear Physics, High-Energy Physics, and Fusion Energy Sciences. The latter developments are evident by the magnificent new and upgraded light and neutron sources, and particle physics linacs and colliders completed or presently under construction. These $B-class world-leading facilities have and continue to redefine the missions of the DOE National Laboratories.

Nuclear weapons capabilities needed to support the Stockpile Steward program are centered on key accelerator-based facilities at LANL, such as the Dual-Axis Hydro Test (DARHT) facility and the Los Alamos Neutron Scattering Center (LANSCE). These facilities provide important radiography capabilities, are used to measure needed nuclear cross-sections, and are used to understand materials properties and performance. Accelerator-based facilities at LANL (LANSCE) meet much of the Nation's need for medical radioisotopes, supported by DOE Office of Science. Accelerator-based technology is being used to generate electromagnetic radiation applied to both interrogation and defeat of present and developing threats.

The present LANL accelerator workforce that supports our current missions is numbered in the hundreds. Many of these staff benefit now from having attended USPAS courses after beginning employment at

ADE:15-007 - 2 - March 2, 2015

LANL or as part of their accelerator education prior to being recruited here. The USPAS provides fundamental accelerator physics training for early-career LANL staff that are transitioning into accelerator science from another field, helping to fill a nation-wide hiring gap due to the limited number of US university programs offering courses in accelerator science and technology. Since its inception, LANL has taken advantage of the USPAS to help fill this need. Since 1987, several hundred LANL staff have attended USPAS courses. Many of our present early-career accelerator staff attended recent USPAS courses, some even as part of their prior degree programs.

The USPAS also provides basic training for DARHT and LANSCE operators and operations staff, enhancing their understanding of the machines they are tasked to successfully operate. Each year several operators from each facility attend a USPAS session. The broad curriculum and session format of the USPAS makes it an ideal mechanism for continuing education and career enhancement for these staff which would otherwise be difficult to match. In addition to basic courses, the USPAS also offers advanced courses on special topics relevant to current trends in accelerator science or accelerator technology, or that meet the needs of those wanting to become specialists. Such courses have benefited even senior LANL accelerator staff and have directly impacted several programs that required new training or knowledge to advance.

The benefit that LANL receives from the USPAS is reciprocated by our staff participating as instructors of many of the courses. Almost every year several of our staff teaches both fundamentals courses and advanced topic courses at the USPAS. Recently, up to five instructors have been provided during a single USPAS course session. At least one widely-accepted textbook, authored by one of our Laboratory Fellows (T. Wangler), has resulted from notes developed to teach a USPAS course. The USPAS is a cost effective means for developing both students and expert instructors in the accelerator field. Because the USPAS solicits help from the national laboratories, recognizing our expertise in many areas, there is the opportunity and flexibility for our staff to teach a course(s) without the long-term or more formal constraints of teaching at a conventional university. This is a great benefit to us. The USPAS also allows participation by junior staff as assistants to the more senior expert instructors. This enables the development of these early- and mid-career staff as instructors and increases their level of expertise. One of the best ways to learn more about something is to be tasked to teach it to someone else.

The future need for well-trained accelerator staff at LANL is not expected to diminish. Every year on average LANL sends 3-5 accelerator operators and 2-4 scientists/engineers to a USPAS session for career enhancement and to meet the steady-state training needed to support LANSCE and DARHT. As attrition continues due to an aging accelerator workforce we expect the value of the USPAS for us to further increase over the next 5-10 years.

We are presently in the process of pursuing formal project definition of mission need (CD-0) with NNSA to begin the design and construction of a 42-keV, x-ray free-election laser that will transform the LANSCE facility into the next-generation multi-probe experimental facility needed to study matter-radiation interactions in extremes (MaRIE). The MaRIE facility will combine the present LANSCE proton radiography capability with electron radiography and x-ray probes to understand and design the materials of the future. Several hundred additional staff will be needed to realize MaRIE, including many new staff trained in accelerator science and accelerator technology to solve challenging technical issues and to operate this new facility. The near-term plans include building and operating an electron-accelerator test stand for MaRIE technology maturation. Approximately 50 additional accelerator staff will be needed in the near-term to support the test stand. The level of staffing is expected to continue

ADE:15-007 - 3 - March 2, 2015

ramping up by another 50-100 over the next decade to fully support the MaRIE project and its operations. This new workforce will require additional accelerator training, much of which can be provided by the USPAS. We expect the USPAS to continue to play an integral part in the development of the essential capabilities we will need to make MaRIE a success and to maintain a viable accelerator workforce.

The USPAS continues to provide a valuable service to us in support of DOE science and national security missions. We strongly endorse the USPAS.

Sincerely,

Steven P. Girrens
Associate Director

SG:ll

Cy:
Mary P. Hockaday, ADEPS, MS A106
Kurt F. Schoenburg, ADEPS, MS H845
John L. Erickson, AOT-DO, MS H809
Robert W. Garnett, AOT-DO, MS H809
Donald J. Rej, SPO-SC, MS A121
ADE Correspondence File, MS F696

BERKELEY LAB

Paul Alivisatos
Director

March 10, 2015

Dr. Andrew J. Lankford
Professor, Physics and Astronomy
Chair, High Energy Physics Advisory Panel
University of California, Irvine
3180 Frederick Reines Hall
Irvine, CA 92697-4575

transmitted via electronic mail to andrew.lankford@uci.edu

Dear Professor Lankford:

I am writing in response to your request for input from the Lawrence Berkeley National Laboratory (LBNL) to the retrospective review by HEPAP of the U.S. Particle Accelerator School (USPAS). As I will discuss below, the USPAS plays a unique and vital role in the education of early career accelerator scientists, in developing the accelerator science workforce, and in ensuring that the most modern developments in accelerator technology are widely disseminated through the national laboratory system and beyond. While the USPAS is important to the discipline of accelerator science, however, its most significant impact for the nation is to ensure that the accelerator facilities operated by the U.S. Department of Energy and the National Science Foundation will provide state of the art research opportunities for the tens of thousands of academic and industrial scientists who use them.

Accelerator science is a discipline with important practical applications, yet the opportunities for undergraduate and graduate students to enter the field are limited. Those universities that provide graduate courses typically do not have the depth and breadth on their faculty to teach all critical aspects of the field. The USPAS Schools, which take place twice per year, provide high quality courses covering the full range of topics which a practicing accelerator scientist will encounter—from operating an accelerator at a national laboratory to designing and building accelerator components at a private-sector company. All the courses carry full academic credit. The schools are lively and well organized and are always hosted by a University that has an accelerator science program. The USPAS has always placed emphasis on developing diversity in the accelerator science workforce.

It should be noted that attendance at the school is not restricted to college students. Most of the attendees from LBNL are early career scientists who need to develop expertise in areas which were not part of their graduate student experience. They value the opportunity to be taught by experts in the field, and the long-term connections which are made by attending a school. Over the years, many employees from LBNL have benefitted from attending classes to broaden or deepen their knowledge of accelerator science and technology.

Accelerators have long been central to high energy and nuclear physics, and thousands of patients a year are treated at accelerators in hospitals. In recent decades, however, with the construction of synchrotron radiation and neutron spallation sources, the materials science and biology communities have also become heavily reliant on accelerator technology. From the perspective of the Department of Energy, it is essential that any one laboratory building a new facility, or operating an existing one, have access to the latest knowledge in the field. Much of this knowledge is unavailable in the literature and I believe that the USPAS plays an essential role in maintaining the highest standards across the laboratory system.

Lawrence Berkeley National Laboratory has enthusiastically supported the USPAS since its inception. On average, five graduate level courses are taught by our scientists each year, and about the same number of our early career scientists will attend a school. We value the teaching and the learning equally highly. We also value the new relationships, which are created at the school. As we move forward with plans to upgrade the Advanced Light Source, and develop new facilities based on advanced technologies, we will rely heavily on the continued excellence of the USPAS. It has my strongest support.

Sincerely,

A. Paul Alivisatos

Cc: Wim Leemans, Division Director
James Symons, Associate Laboratory Director
Chris Yetter, Chief of Staff

USPAS and Michigan State University

Michigan State University is home to the top-ranked nuclear physics graduate program in the U.S., in no small part due to its accelerator facility. The National Superconducting Cyclotron Laboratory at MSU is home to the first superconducting cyclotron accelerator to become operational world-wide – and now houses two superconducting cyclotrons within the present Coupled Cyclotron Facility. The Facility for Rare Isotope Beams presently under construction, with its 400 kW superconducting linac, will allow MSU to maintain world leadership in nuclear physics for years to come. The FRIB project has led to a recent increase in the Laboratory's staff from roughly 300 to over 600 employees (both NSCL and FRIB) during the past five years including a rise in the number of accelerator science faculty and graduate students performing accelerator research on campus. The NSCL/FRIB staff includes approximately 50 accelerator physicists, 50 accelerator engineers, and 100 accelerator engineering physicists/technicians. The U.S. Particle Accelerator School has been highly beneficial to MSU and its accelerator program over the past several decades both for the training of NSCL staff and for our accelerator physics graduate program.

NSCL/FRIB and the USPAS

NSCL and FRIB regularly send scientists and engineers to take courses at the USPAS to obtain an introduction or overview to the field of accelerator and beam physics or to improve their skills or learn about new techniques. In recent years NSCL and FRIB have been sending roughly 3-5 staff to the USPAS per year in addition to the accelerator physics graduate students discussed below.

The nearly $1B, DOE-funded Facility for Rare Isotope Beams will be the world's leading rare isotope beam facility. With FRIB will come the continuous need for a well-trained staff of technicians, engineers and scientists to deliver the ultimate high-power rare isotope beams to the user community. FRIB is expected to increase its staff to roughly 500 employees by the time it becomes operational, with a greater percentage of these employees being accelerator professionals as compared to the present NSCL. As NSCL transforms into FRIB, the use of the USPAS to help train these technical employees will continue to be highly beneficial.

MSU Accelerator Research/Academics and the USPAS

Traditionally, over the past 50 years, roughly 2-3 faculty members at MSU have had research interests in accelerator science at any one time; today, with FRIB comes an increased academic presence. There are now 8 such faculty members at MSU between the Department of Physics and Astronomy, the NSCL/FRIB, and the College of Engineering. The current number of PhD students working on accelerator science projects for their degree is roughly a dozen. In every case each of these students routinely attends sessions of the USPAS, often several times, during the course of their studies. Of the various U.S. universities that send students and staff to USPAS, MSU ranks second (behind Indiana University), typically sending 2-3 students per session (two sessions per year).

The U.S. Particle Accelerator School has always been important to MSU but in recent times it has become an integral part of the MSU experience for graduate students pursuing a career in accelerator science and technology. Through the Department of Physics and Astronomy three on-line courses exist at MSU for accelerator physics, and there is the usual "special topics" course that is occasionally used for accelerator subjects. In addition, the School of Engineering occasionally offers its course in plasma physics as related to accelerator systems. However, much of the training at MSU has relied upon USPAS over the past two decades. While the courses mentioned above are in the university curriculum, it is unusual to have more than 2-3 new students ready for a course at any given point in time, resulting in many courses being cancelled or only offered infrequently. On the other hand, through the USPAS, students have access to the intense accelerator courses twice each year and hence our flow of students through the program can remain steady.

Graduate students from MSU typically qualify for USPAS financial assistance to cover the cost of USPAS fees and room and board, thus making the two-week trips to the school locations affordable. Through a special arrangement with the USPAS, MSU students receive MSU credit for USPAS courses, no matter at which university the USPAS course is being held. Thesis committees for accelerator PhD candidates often request certain USPAS classes be taken to enhance students' backgrounds for their degree program. And often times the more senior PhD students at MSU are sought after as graders, assistants, and even future instructors at the USPAS, which adds value to students' training and to their resume.

Several members of the staff and faculty at NSCL/FRIB and in the Department of Physics and Astronomy have been instructors at the USPAS, including Profs. Berz, Lund, Marti, Syphers, Wangler and Wei. These instructors have interacted with well over 600 students in the accelerator field through the USPAS courses they have taught over the years and many students have come to MSU due to the interactions they have had with these instructors during the USPAS sessions. The USPAS summer session has been hosted by MSU in 2007 and 2012 and a future session to be hosted by MSU is being discussed.

Of the past MSU students that have participated in the USPAS program, many have gone on to become university professors and researchers, staff scientists at DOE national labs, and researchers in industrial and medical fields. MSU's five most recent accelerator physics graduates from the past three years are now employed at MIT, Fermilab, Argonne National Lab, Jefferson Lab, and in industry. In each of these cases, the student had taken at least 2 and sometimes 3 or 4 USPAS courses while at MSU.

As well documented through such publications as DOE's *Accelerators for America's Future*, the demand is high for a well-trained accelerator workforce and MSU offers one of the nation's premiere graduate programs for accelerator science. The USPAS continues to play a vital role in the MSU academic program geared toward meeting these needs, and the new accelerator facility being constructed at MSU is already competing for the future workforce resources in this field and will continue to do so for years to come.

Other Remarks

Two of the greatest strengths of the USPAS are its consortium of laboratories and universities as well its roaming format. The consortium generates "buy in" from its members thus providing motivation to provide a highly-skilled set of instructors and motivated students flowing through the USPAS sessions. Should the consortium structure go away, it is highly likely that USPAS enrollment would suffer, as would the quality of instruction. Additionally, by having the USPAS sessions take place at various locations around the country the students gain access to the various laboratories and universities that they might otherwise not have. Attendees of a USPAS session hosted by a prominent university (from which they receive credits) that are also able to tour a nearby major laboratory facility during the middle of the two week stay often acquire a great boost to their self esteem and have their careers enhanced in ways that cannot easily be attained through their normal workplace or university setting.

In all, perhaps the most important aspect of the USPAS is that of pooling resources and creating access across institutional boundaries. This provides depth and breadth beyond what would realistically exist or be maintainable for any single university program.

OAK RIDGE
National Laboratory

PO Box 2008
Oak Ridge, TN 37831-6462
(865) 241-6794 | joneskw@ornl.gov

March 10, 2015

Professor Andrew Lankford
Chair, High Energy Physics Advisory Panel
University of California at Irvine
Physics & Astronomy Department
4129H Frederick Reines Hall
Irving, CA 92697

Dear Professor Lankford:

Oak Ridge National Laboratory (ORNL) has a long and proud tradition of building and operating accelerator facilities to support innovative research in fundamental and applied science. These facilities include the Oak Ridge Electron Linear Accelerator (ORELA), the Holifield Radioactive Ion Beam Facility, and, most recently, the Spallation Neutron Source (SNS) which is a flagship facility for the Department of Energy Office of Science (DOE/SC), and is funded through the Office of Basic Energy Sciences (BES).

The SNS is home to the world's first (and currently only) high power superconducting proton linear accelerator which routinely operates at a beam power of ~1 Megawatt (MW) and has demonstrated reliable operation up to just over 1.4 MW, making it jointly the highest average power hadron machine in the world together with the proton cyclotron at the Paul Scherrer Institute in Switzerland. The SNS is also home to the world's highest power accumulator ring, which holds the world record for protons per pulse delivered by any particle accelerator complex.

Facilities such as the SNS rely on unique combinations of advanced technology to perform their function of reliably, predictably and efficiently enabling fundamental scientific research. Accelerators, if well engineered and maintained, can last indefinitely and must continue to evolve as technology evolves. This is most obvious at facilities such as Fermi National Laboratory (FNAL) and the Centre for European Nuclear Research (CERN), where machines built over 50 years ago still support the operation of the new Large Hadron Collider (LHC). It is therefore essential that laboratories such as ORNL that operate, maintain and improve DOE research accelerators such as the SNS have access to highly qualified researchers and practitioners in particle accelerator science and technology to sustain their effectiveness in support of the DOE mission.

ORNL is proud to be one of the core members of the governing board of the U.S. Particle Accelerator School (USPAS), a longstanding partnership between several DOE laboratories and the Office of Science. USPAS is essential to the development of the skilled and diverse workforce that continues to establish the SNS as a premier scientific research facility driven by cutting edge accelerator technology. ORNL staff members have received instruction in thirteen

Professor Andrew Lankford
Page 2
March 10, 2015

of the fourteen topical areas offered by USPAS, and have participated as instructors in more than a third of the topical areas offered. Over 125 individuals from ORNL have benefitted from USPAS courses since 1987.

It is quite difficult to obtain a degree in accelerator science and technology in the United States, particularly an advanced degree. Approximately 80% of the doctorate degrees in the field are granted by 9 academic institutions, all of which are top tier universities. Unfortunately, most universities are not well equipped to provide the breadth of course work in topics that underpin the field, especially at the advanced level, and for the most part do not have complex accelerator facilities for hands-on training. The DOE accelerator community recognized this vulnerability in the pipeline and has worked tirelessly to address it through what has become the very successful USPAS program. The program is unique in the sense that it enables highly technically qualified staff from the national laboratories to bring their expertise to the classroom to supplement the academic staff at universities throughout the country. It also permits students at universities around the country to obtain rigorous academic credit to support both undergraduate and graduate degrees in accelerator science and technology. The partnership between the laboratories, USPAS and universities is exceptionally cost effective, and students always rate the content of the classes and the quality of instruction as being of the highest caliber, often well exceeding that of their home institutions.

USPAS is an essential part of workforce development and training for ORNL staff that support accelerator science and technology, of which only a very small fraction have degrees in accelerator science and technology. Most have received education in related scientific or educational disciplines, or technology training obtained through regional colleges or service in the armed forces. The challenge then is to provide these individuals with specialized education and training in the specific topical areas that are of importance to accelerator science and technology. One way to accomplish this is through on-the-job training. While this is useful for the specifics of a particular facility, it does not expose the individual to broader concepts within the specific sub-field of activity. This is where USPAS makes a critical difference. Sending an early-career electrical engineer with limited experience in high-power radio-frequency (RF) technology to an intensive topical course in RF technology can provide a foundation for that individual to make important contributions to system developments that transcend what can be learned in-house. Similarly, exposing a good mechanical engineer to a course on magnet systems can provide the organization with an individual who could then, with further skill enhancement, develop creative and novel physical designs for magnets that meet challenging beam optics or other applications. The current director of the ORNL Research Accelerator Division began his career as an experimental nuclear physicist, but attending the first demanding USPAS course on instrumentation and beam measurement at the Massachusetts Institute of Technology over twenty years ago had a profound foundational effect on his successful transition to the field of accelerator science and technology. These are real examples of the profound positive influence of USPAS in support of accelerator science and technology at ORNL.

Professor Andrew Lankford
Page 3
March 10, 2015

Also, as with many technical fields, the number of women and minorities who have such backgrounds and interest is limited. USPAS has provided the opportunity for ORNL to considerably strengthen its demographics within accelerator science and technology. Key female employees who are "graduates" of USPAS include the group leader of our Controls Systems Group, two accelerator operations shift supervisors, and one of our best mid-career accelerator physicists. This latter individual has transitioned from being a graduate student attending USPAS to a course instructor for USPAS, and has now been asked to serve a term as the chair of the USPAS curriculum committee. She is also the first member of the SNS team to obtain a non-BES grant (from OHEP) for an accelerator physics initiative related to improving operation of the SNS facility. She embodies the success of the USPAS concept. ORNL has also been able to develop and diversify the technical careers of a number of other minority staff through attendance at USPAS.

ORNL anticipates a continuing need for individuals with strong fundamental skills in the areas of accelerator science and technology. Many individuals who were key to the successful construction of SNS are nearing the end of their careers. Succession planning and skill development are critical both to the ongoing needs of operating and maintaining the current accelerator capabilities at ORNL, as well as developing and extending those capabilities to support the SNS Second Target Station initiative and the doubling of the SNS beam power to ensure long-range competitiveness for the United States when the European Spallation Source becomes a reality. Over the next ten years ORNL management estimates that it will need to hire approximately 100-150 new staff with relevant skills to offset natural attrition and to support new accelerator capabilities envisioned at the laboratory. USPAS will be an essential element of the education of this new generation of accelerator scientists and technologists at ORNL.

The quality of the accelerator science and technology staff at ORNL is high. Many key contributors at new facilities under construction such as the Facility for Rare Isotope Beams (FRIB) at Michigan State University and also at the ESS were drawn from ORNL. ORNL staff members are sought after as technical advisers for and reviewers of accelerator initiatives around the world. It is imperative for the future success of the BES mission at ORNL that our laboratory be able to sustain the ability to attract and develop staff of similar quality. USPAS will be a key part of that strategy.

Accelerators are tools that have extensive application in fundamental research, industry and medicine. However, unlike many mainstream academic disciplines, formal university-level instruction in topics specific to accelerator science remains limited. USPAS provides a valuable, unique and cost-effective bridge between skilled staff at national laboratories, the academic environment of university courses for credit toward undergraduate and graduate degrees, programs that provide students with opportunities for research at national laboratories, and staff at national laboratories that can benefit from topical instruction. USPAS will continue to be an

Professor Andrew Lankford
Page 4
March 10, 2015

important element of the continued success in delivering on the accelerator-based mission for the Department of Energy at ORNL.

ORNL management unreservedly endorses the continued operation of the USPAS and the unique aspects of education and workforce development that it brings to the field of accelerator science and technology.

Sincerely,

Kevin W. Jones
Director, Research Accelerator Division

KWJ:lbe

SLAC and the USPAS

Alex Chao, Roger Erickson, Zhirong Huang

SLAC National Accelerator Laboratory

March 10, 2015

SLAC has been strongly involved with the US Particle Accelerator School (USPAS). Since its inception in 1987, SLAC has contributed 146 instructors and 420 students to the USPAS program (see attached information sheet on SLAC attendance at the USPAS). At each school session, SLAC sends close to 3 instructors and about 8 students on average. The school curriculum has been consistently excellent and rigorous, on par with top US graduate school curriculum program. Both instructors and students work very hard during the school session. Lack of sleep time is pretty common during any of these sessions. The consistence of school curriculum and its academic rigors make the USPAS an effective vehicle for workforce development and training at SLAC.

SLAC has been a renowned center of accelerator research (especially in electron and photon beams). The USPAS program contributes tremendously to its success. SLAC accelerator staff members teach regularly in the USPAS. Preparing and lecturing these courses help staff members systematize their accelerator knowledge and sharpen their professional skills. Many course lecture notes become standard learning materials in the accelerator communities. For students, postdocs and junior staff members, participating in the USPAS courses prepares them with the basic accelerator theory and also a more complete set of accelerator courses for their career development and advance. For some staff members that obtained their advanced degrees in fields other than accelerator physics, USPAS exposes them for the first time the formal training of accelerator physics and even some first hands-on experience. In addition, many US and international students who participated in the USPAS get in touch with SLAC instructors and students at the USPAS and afterwards. Some of them eventually apply and come to work at SLAC or other US laboratories. This channel has been a constant source of SLAC postdocs in the accelerator research division.

The USPAS has been a critically important part of the workforce training of staff members who carry out the day by day operation of the accelerators at SLAC. Over the years, most accelerator operators have come to SLAC directly after completing a bachelor's degree in physics, although in some cases they arrived with master's degrees or limited industrial experience. In nearly all cases, they arrived with a solid background in undergraduate level physics, but with no knowledge of accelerators. For those who have been motivated, the USPAS has provided the educational opportunity to rapidly advance their careers at SLAC, and it has helped provide SLAC with a steady source of skilled manpower. In the past 25 years, about 80 entry level accelerator operators have attended one or more USPAS courses, and many of these attended two or three times to take progressively more advanced courses. Of these, about 35 have advanced within two or three years to become Operations Engineers, a role in which they direct the activities of the control room. In that same time period, approximately 25 of the operators who attended the USPAS have gone on to engineering, control software, or other jobs at SLAC in which some knowledge of accelerator physics is essential. A few of these individuals now have management responsibilities at SLAC, and several have major responsibilities in the LCLS-II construction project. Two have gone on to new jobs at other DOE laboratories and twelve have gone on to graduate school Ph.D. programs. Of those who have finished Ph.D. degrees, two have returned to SLAC to work in other parts of the laboratory.

In the next few years, we anticipate the need to send about five operators per year to the USPAS course on introductory accelerator physics. In addition, we anticipate an urgent need for courses in superconducting RF linac technology and could send 25 or more control room staff over the next three years if the courses are available. There are many opportunities for SLAC to contribute to the USPAS as well, as SLAC continues its tradition in accelerator research, operation and maintains it leadership in x-ray free-electron laser facilities.

SLAC attendance at the USPAS
1987-2015

session	# of students	# of instructors	instructor name								
1987	1	2	Karl Brown	Perry Wilson							
1988	5	0									
1989	12	0									
1990	6	0									
1991	4	2	Ronald Ruth	Karl Brown							
Jan-92	4	2	Perry Wilson	John Seeman							
Jun-92	12	2	Robert Siemann	Michiko Minty							
Jan-93	4	1	Pisin Chen								
Jun-93	7	1	Kwok Ko								
Jan-94	3	3	John Seeman	Spencer Hartman	Thomas Himel						
Jun-94	2	5	Helmut Wiedemann	Michiko Minty	Max Cornacchia	Ronald Ruth	Scott Berg				
Jan-95	7	2	Ronald Ruth	Haitham Hindi							
Jun-95	22	2	Haitham Hindi,	Haitham Hindi							
Jan-96	3	3	Karl Brown	John Seeman	Alan Fisher						
Jan-97	22	4	Michiko Minty	David Whittum	Haitham Hindi	John Fox					
Jun-97	5	2	Gennady Stupakov	Vinay Srinivas							
Jan-98	6	3	Dennis Palmer	Perry Wilson	Christopher Nantista						
Jun-98	21	6	Michiko Minty	Pisin Chen	Robert Phillips	Glenn Scheitrum	Arnold Vlieks	Sami Tantawi			
Jan-99	2	4	David Whittum	Xintian Eddie Lin	Dennis Palmer	Tor Raubenheimer					
Jun-99	6	3	John Irwin	Michiko Minty	Frank Zimmermann						
Jan-00	7	1	John Seeman								
Jun-00	7	4	Cecile Limborg	Kwok Ko	Zhenghai Li	Brian McCandless					
Jan-01	5	2	Yiton Yan	Andrei Terebilo							
Jun-01	3	1	Uli Wienands								
Jan-02	14	4	David Whittum	Sami Tantawi	Richard Cassel	and Paul Bellomo					
Jun-02	3	3	Kwok Ko	John Irwin	Andrei Terebilo						
Jan-03	13	0									
Jun-03	8	8	James Sebek	Andrei Seryi	Peter Tenenbaum	Mauro Pivi	Robert Hettel	Zhirong Huang	James Safranek	Roger Jones	
Jan-04	8	1	John Fox								
Jun-04	22	5	Alexander Chao	Gennady Stupakov	Paul Bellomo	James Sebek	Sayed Rokni				
Jan-05	20	3	Zhirong Huang	Jeff Corbett	Andrei Terebilo						
Jun-05	14	7	James Sebek	Kwok Ko	Zenghai Li	John D. Fox	Robert Ruland	Catherine LeCocq	Roger Jones		
Jan-06	5	2	James Safranek	Sayed Rokni							
Jun-06	5	1	Zhirong Huang								
Jan-07	6	3	Alex Chao	Mauro Pivi	ndrei Seryi						
Jun-07	9	4	Gennady Stupakov	Zhirong Huang	Paul Bellomo	Antonio de Lira					
Jan-08	15	7	Zhirong Huang	David Dowell	John Schmerge	Jeff Corbett	Alan Fisher	Andrei Terebilo	Andrei Terebilo		
Jun-08	1	3	Juhao Wu	James Safranek	Chungming (Paul) Chu						
Jan-09	3	8	Sami Tantawi	Muralidhar Yeddulla	Alex Chao	Yunhai Cai	Eric Colby	Eric Colby	Craig Burkhart	H.-Ulrich (Uli) Wienands	
Jun-09	4	2	Gennady Stupakov	Dan Van Winkle							
Jan-10	16	5	Paul Bellomo	Jim Sebek	Jeff Corbett	Alan Fisher	John Fox				
Jun-10	7	1	Zhirong Huang								
Jan-11	4	1	Mauro Pivi								
Jun-11	5	4	Gennady Stupakov	Craig Burkhart	Mark Kemp	Juhao Wu					
Jan-12	15	1	Eric Colby								
Jun-12	4	8	Alex Chao	Yunhai Cai	Mauro Pivi	Paul Bellomo	Fernando Rafael	James Safranek	Xiaobiao Huang	Claudio Rivetta	John Fox
Jan-13	6	0									
Jun-13	8	1	Zhirong Huang								
Jan-14	6	0									
Jun-14	9	4	Uli Wienands	Eduardo Marin Lacom:	Gennady Stupakov	Erik Hemsing					
Jan-15	14	5	Xiaobiao Huang	Paul Bellomo	James Sebek	Craig Burkhart	Mark Kemp				
	420	146									

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

Hugh E. Montgomery
Laboratory Director and Jefferson Science Associates President

March 5, 2015
Phone: (757) 269-7552
e-mail: mont@jlab.org

Professor Andrew Lankford
Chair, HEPAP USPAS Review Subcommittee
University of California at Irvine
Physics and Astronomy Department
4129H Frederick Reines Hall
Irving, CA 92697

Dear Andy,

This document summarizes Jefferson Laboratory's response to your e-mail query of February 18, 2015 regarding our past and future needs for manpower development through the United States Particle Accelerator School (USPAS). This note will document some aspects of Jefferson Lab's participation in the USPAS, followed by some general comments about the school itself. As an early summary of our main conclusions: since Jefferson Laboratory's inception only slightly after the beginning of the USPAS there has been significant and important utilization of USPAS courses to train and develop Jefferson Lab Staff, both as students and participating faculty. Presently, we regard this program as an essential element in our future training plans.

Aside from the direct support provided USPAS from our operating budget, Jefferson Lab participates in the USPAS principally through the students and faculty sent to the school. Between 1987 and 2015 Jefferson Lab has sent students to USPAS on 324 separate occasions, and between 1992 and 2015, Jefferson Lab has sent 55 instructors to the school. The majority of the participants (77% and 64%) completed full two week stays at the school. Figures 1 and 2 provide year-by-year tallies of participation.

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

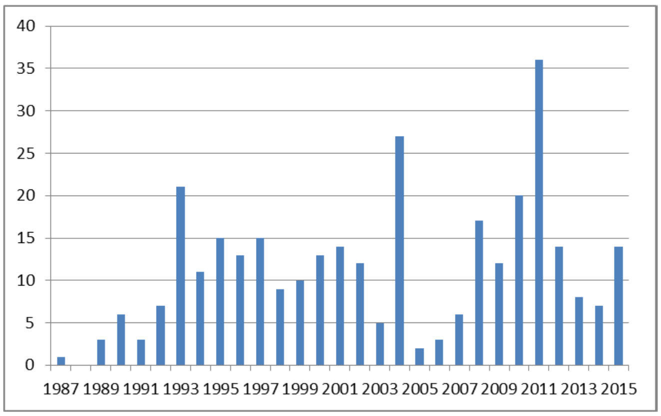


Figure 1: Jefferson Lab Staff Student Participation

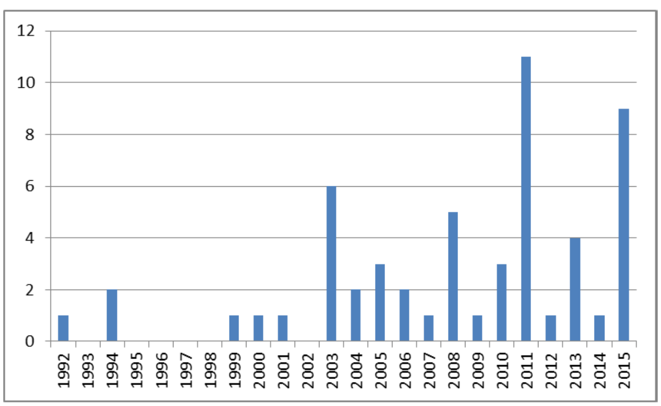


Figure 2: Jefferson Lab Staff Faculty Participation

In quantifying our participation we will follow the basic classifications present in the USPAS courses themselves: [1] Basic Accelerator and Beam Physics; [2] Specialized Topics; and [3] Accelerator Technology, Safety, and Management. Courses under category [1] are regularly presented and usually considered as a prerequisite for other courses. Courses in categories [2] and [3] are less frequently presented (with the

12000 Jefferson Avenue, Newport News, VA 23606 • • www.jlab.org
Jefferson Lab is managed by the Jefferson Science Associates, LLC for the U.S. Department of Energy Office of Science

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

exception of the microwaves measurement course which has high demand), and even when organized by USPAS on a national level, relatively infrequently have participation with a large number of students. Accelerator physicists within the laboratory would typically attend courses in categories [1] and [2] and engineering staff tend to concentrate on courses within topics [2] and [3]. Because the expertise in topics in categories [2] and [3] tend to reside mainly within the DOE national lab system, the instructors for these courses are usually drawn from the national lab system.

Student Participation

In the early years of Jefferson Lab (1987-1991) there were 13 students at USPAS, 12 of whom attended the Accelerator Fundamentals (Group [1]) courses present at the time. This type of utilization, new staff at a new lab being trained in what accelerators are and how they work, was quite natural and helpful in Jefferson Lab's initial period. Since that early period Jefferson Lab has continued to utilize the fundamentals course sequences at a rate of about 5 students/year, representing about 37% of the total utilization. Typical students in these courses in the earlier days were young PhD-level scientists and junior to mid-career engineering staff, newly hired into the lab and who needed to be trained in accelerator fundamentals in order that they can understand at a higher level what the Jefferson Lab accelerators are and how they operate. Even to the present day, this model is followed when a new staff scientist or engineer is hired on who does not have prior experience in particle accelerators; the introductory USPAS Accelerators Fundamentals sequence is almost a "rite of passage". Recently, our utilization of the introductory courses has been dominated by operations staff: both operators and operations software staff, who benefit in their day-to-day work by having a clear picture of how accelerators are built and operated. In addition, during the last decade and a half, four graduate students in particle accelerator topics have gone through the accelerator fundamentals sequence.

Jefferson Lab's largest demand, at 44% of the total, is in the Group [2] specialized topics courses. Such courses, usually presented by university or national lab experts in the field, are highly useful in assuring that our staff has access to state-of-the art ideas and accelerator science. In particular, the USPAS is one of the only places to regularly present courses on Superconducting Radio Frequency science and technology. This science and technology, pioneered by Jefferson Lab on the large scale, is absolutely essential to what we do. Our staff can be brought more quickly up to the state-of-the-art through training and courses presented at the USPAS. Students in these courses are typically junior to mid-level scientists and engineers whose normal work activity involves the topic of the course. Occasionally, technical staff will attend courses to achieve better grounding in their chosen field and more senior scientists and engineers will attend these courses in order to rapidly obtain information on forefront topics, e.g., if a new job

12000 Jefferson Avenue, Newport News, VA 23606 • • www.jlab.org
Jefferson Lab is managed by the Jefferson Science Associates, LLC for the U.S. Department of Energy Office of Science

assignment requires one to rapidly develop competence in an area not recently or previously trained in. The major part of our graduate student participation occurs in this category; the student can be introduced to topics at the state-of-the-art as they plan and execute their thesis work.

Seventeen percent of our students participate in various accelerator technology, safety, and management courses (Group [3]). The largest share of these have participated in the Microwave Measurements Lab or its predecessor courses. This particular course is highly useful to us because Jefferson Lab's electron beam is created, measured, controlled, and directed to our experimental users through a vast array of microwave equipment. Such a course, which is unique in that it is focused on accelerator applications and measurements with microwaves, can be found at no other venue. The course instructors are world-leading scientists on the topic, usually from within the DOE national lab complex.

To conclude this section, it is worth pointing out the names of several individuals listed as students in our student summary list have gone on to prominence within the field: Arne Freyberger is now Director of Operations at Jefferson Lab, Curt Hovater is now Low Level RF Lead for the new LCLS II project, Will Oren is now Director of Engineering at Jefferson Lab, Lia Merminga is now the Director of Accelerators at TRIUMF, and Karen White is now Controls Group Leader at the Spallation Neutron Source. The peaks in student and faculty participation in the USPAS in the years 2011 and 2015 are at least partly due to the fact that the school came to Old Dominion University and was held in Hampton, Virginia in those years.

Faculty Participation

Jefferson Lab has provided support for 55 instructors to the USPAS. On ten occasions (18%) the course was in Group [1], on 24 occasions (44%) the course was in group [2], and on 21 occasions (38%) in Group [3]. All of the Group [1] (Accelerator Fundamentals) courses have been presented starting in 2008, perhaps an indicator that the general accelerator physics program at Jefferson Lab has "aged" over the years, leading to greater chances for scientists in this effort to make courses. Again, a major share of the faculty participation has been in the Group [2] category. In this category the major topics presented have been RF superconductivity, recirculated and energy recovery linacs, RF systems, and accelerator laser systems. Isolated courses have been presented on injectors and cathodes. In all of these topics Jefferson Lab activity has been world-leading, and it is quite natural that authors of these courses were from Jefferson Lab. Compared to the student group, a much greater share of the faculty participation has been in the Group [3] category. In this category the major topics presented have been the microwave measurements lab, safety systems, and the beam measurements lab. An isolated course on laboratory management was the first one presented by a Jefferson Lab instructor. In this group too, Jefferson Lab provides world-leading instructors.

Because the course content is so closely linked to particle accelerators, Group [2] and Group [3] topics themselves are not of the character that, e.g., a course in a university would provide equivalent training. Because Jefferson Lab staff is making presentations, Jefferson Lab technology is highlighted, as are the particular contributions to the subject of the staff involved. Therefore, we regard teaching a USPAS course as a valuable staff development activity for the instructors too. The instructors find the experience teaching to be a rewarding one and are generally eager to accept courses when asked.

General Comments

Now that our usage of the USPAS has been summarized and many of the main values we receive from the school have been documented, it is worth making some general comments. First, the USPAS is the unique institution available in this country for obtaining much of the training mentioned. A few universities do have introductory courses in accelerator and beam physics. But because the demand for the more specialized courses in the USPAS curriculum within a single university is generally not sufficient to justify regularly presenting a course, the specialized courses will not be attractive curriculum elements of a typical university physics or engineering department. One could imagine a single university or a consortium of universities presenting the full USPAS curriculum, but only if the university or consortium has access to the present student demand, which is distributed throughout the country and to some extent, the world. Because we have a continuing need to access the specialized courses, continued use of the USPAS is an essential element of our future training needs.

Next, the field of accelerators is growing with many applications, so there will be a continuing and growing need to introduce new practitioners to the field and to continue providing specialized training for national lab scientists and engineers. Therefore, there is a continuing and possibly growing need for the USPAS. The USPAS is supported directly by all the main accelerator laboratories in the United States and is perhaps a singular instance of a recognized need of the national lab system as a whole being supported by the national lab system as a whole through contributions of direct assistance and instructors. We agree generally with the idea that obtaining equivalent training utilizing only Jefferson Lab resources would be impossible in most cases, and very much more expensive in cases where courses could be reproduced internally.

Jefferson Lab
Thomas Jefferson National Accelerator Facility
Exploring the Nature of Matter

The main source material for this document comes from the USPAS Records themselves. The school has been quite open and expeditious in sharing their records to allow this report to be prepared quickly. Likewise, we are comfortable with the subcommittee citing any information in this document in its final report.

Sincerely,

pp Mont & Andrew

12000 Jefferson Avenue, Newport News, VA 23606 • • www.jlab.org
Jefferson Lab is managed by the Jefferson Science Associates, LLC for the U.S. Department of Energy Office of Science

Appendix H. Letters from Universities

Colorado State University

Electrical and Computer Engineering
1373 Campus Delivery
Fort Collins, Colorado 80523-1373 USA
(970) 491-6796
MOBILE: (708) 638-6813
biedron@engr.colostate.edu
www.engr.colostate.edu/ece

February 26, 2015

Dear Dr. Lankford:

Thank you for soliciting my input for the USPAS review. I have included the general comments of the other CSU Professor's (Stephen Milton's) comments here as well. Please feel free to contact him directly as well if you prefer individual input. He can be contacted at Milton@engr.colostate.edu.

I would have loved to be part of this important analysis. It seems a bit rushed? I am happy to call in or be present for the meeting in March if you need something more.

I need to start by saying that my own career has greatly benefitted from the USPAS. I worked at Argonne while getting my Ph.D. and the USPAS courses counted as elective courses for me during my graduate studies. Further, since the USPAS is set up much like a Systems Engineering or Executive MBA suite of courses for graduate students (special times for the working person), it allowed me to work while studying.

I have participated in USPAS courses since 1997 as an attendee; as an instructor; as a combined co-course developer and teaching assistant (with my former Argonne supervisor and colleague Lee Teng in 1997 and again in 2000); and now, as a Professor sending students to these courses.

Here are my responses to "For instance, what do you find is the effectiveness, impact, quality, and breadth of the USPAS program?"
Effectiveness – This modern-day approach to education, offering students world-class graduate courses with world-class instructors twice a year along with credit for these courses from accredited universities is outstanding. It reaches out to those working in the field so they can broaden their expertise. For myself - USPAS helped immensely in providing me the theoretical, simulations-based, and experimental techniques required to go on and produce concepts, equipment, and deliver experiments and/or facilities. I have been fortunate enough that my work along with that of my colleagues has been featured in high-impact journals such as PRL, PRST-AB, Science, Nature Photonics, Proceedings of the IEEE, IEEE Transactions on Nuclear Physics, and Nuclear Instruments and Methods. I can attribute these successes in substantial part to USPAS.

Impact - Without USPAS, my students and I would not have had the opportunity to learn accelerator specialties from the world experts. Without USPAS, my students and I would have not had the opportunity to expand the scope of our coursework. Further, my students and I would not have had the opportunity to become acquainted with the instructors as well as other students, many of whom are now close collaborators.

Quality – Again, world-class instructors and credit from accredited universities. AND world-class coursework.

Breadth – There is NO WHERE else in the world to get the breadth of courses in accelerator and beam physics and the engineering of peripheral systems. Accelerators are a suite of complex systems that interact. USPAS addresses all related topics.

Here are some short answers to your questions:

"How, in the past and now, does the existence of USPAS benefit your academic program?
Since we only have presently 8 students in our organization, it is IMPOSSIBLE for us to organize the number and breadth of courses in accelerators that USPAS does. Further, we are not expert in all of the fields that USPAS teaches. In fact, we would not have started the program here at CSU if USPAS did not exist. It would not be fair to students. Our students can transfer 6 USPAS course credits into the program.

"To what extent does USPAS complement your graduate program; to what extent is it redundant with your program?"
It only complements our program. There is no redundancy. We designed our program around the USPAS.

"What unique and essential capabilities are provided to the program through the involvement of the DOE laboratories?"
Without the involvement of DOE laboratory personnel as teachers, since these are many of the world experts, the USPAS effectiveness would be diminished. Just as we document systems and sub-systems, procedures, and commissioning and operations plans, we need to document knowledge that is based at the DOE labs. Their involvement documents this knowledge for present and future researchers, technicians, operators, physicists, and engineers.

Further, I know lab personnel that are operators, engineers, scientists, beamline scientists, technicians, etc… that have taken the courses and this has enhanced the performance of the person. In almost all other fields there exists continuing education. The USPAS serves as the continuing education for the DOE lab system in accelerators, beams, and peripherals. USPAS continues to update its coursework to keep with disruptive technologies that change our accelerator systems, this is why most attendees take more than one course in their graduate or work careers. Further, the modern reality is that most people need or want to work and use their work for their theses or dissertations. USPAS permits such a work-study synergy, especially for DOE laboratory employees.

"What fraction and how many of your students enroll in USPAS courses?"
All. We require it.

"How many USPAS courses does a typical PhD student take during their graduate program?"
At least two.

"Do you grant course credit for USPAS courses?"
I am taking this question to mean – do we allow transfer of credits. Yes – the same as the accredited institution. We want to do more for USPAS and we are thinking of ways to cross-list them at CSU. This is the best win-win situation.

"How are your past graduates in accelerator science and technology employed?"
Two at national labs, one at a foreign lab, one at Seagate, one at Cymer. All of our present students want to work at the national labs once graduated. We are already starting to transition some of them.

"What changes in the USPAS program could you envisage that would enhance its benefit to your graduate program?"
On the CSU side (not USPAS) it would be great to cross list all courses so our students could take more for credit.
On the USPAS side there are only a couple things I can think of. I do a lot of work with the DOD and I think a couple of systems engineering courses might be interesting for USPAS. I am very involved also with the Systems Engineering program at CSU and teach for this tract. Some of the techniques would help with large DOD projects, even small ones in fact. Also, I believe that the USPAS might be expanded to include a few more HEP style courses as well as radiation. I say this as I know the detectors course is a hit as were the HEP and radiation courses at CSU's sponsoring of the USPAS in 2013.

I am also very appreciative that the USPAS joins with CERN school and other schools occasionally to have very specialized international schools.

At the Erice school in April 2011, for example, we taught as well as were able to meet and discuss topics with colleagues as well as recruited students from a NATO country (Turkey). Without this school, we would not have been able to capture two students who wish to remain in the United States after their Ph.D.s.

Further, the recent school "Beam Loss and Accelerator Protection," I am aware that the topics have already helped many including the DOE laboratory folks at Fermilab working on the high power proton goals. This was an excellent topic since so many programs are now pushing high power.

I would strongly suggest you reach out to several students, industry and other national and international laboratory colleagues (some of which were either students or teachers at USPASes) listed below for their input as well. I am aware that they would be willing to write a letter for you directly. Please let me know if I can help facilitate this.

Nate Moody LANL - nmoody@lanl.gov
Patrick O'Shea - poshea@umd.edu
Jon Edelen - jedelen@engr.colostate.edu
Auralee Morin - auralee.l.morin@gmail.com
Josh Einstein - jeinstei@gmail.com
Jamie Santucci - santucci@fnal.gov
Trudy Bolin - bolitru@aps.anl.gov
Chris Hall - chris.Hall@colostate.edu
Pierpaolo Stabile - pierpaolo.stabile@gmail.com
Dave Douglas douglas@jlab.org
Georg Hoffstaetter gh77@cornell.edu
Robert Wilson bob.wilson@colostate.edu
Simone DiMitri simone.dimitri@elettra.eu
Alex Murokh <murokh@radiabeam.com>

Also for the record, the classes I took are below my salutation.

Please let me know if I can help in any other way.

Very truly yours,

Sandra G. Biedron, Ph.D.
Associate Professor

USPAS/IU (Held in Tuscon) – Management of Scientific Laboratories, 3 credit hours [2000]
USPAS/IU/University of Chicago – Hard X-ray Synchrotron Radiation Optics, 1.5 credit hours [1999]
USPAS/IU/University of Chicago – Digital Signal Processing Fundamentals with Applications to Accelerators, 1.5 credit hours [1999]
USPAS/IU/Vanderbilt University - Medical Applications of Accelerators, 1.5 credit hours [1999]
USPAS/IU/Stanford University - Microwave Measurements, 3.0 credit hours [1998]
USPAS/IU/University of Texas Austin - Linear Accelerators, 3.0 credit hours [1998]
USPAS/IU/Massachusetts Institute of Technology - Intense Pulsed Electron and Ion Beams, 1.5 credit hours [1997]
USPAS/IU/ Massachusetts Institute of Technology - Electromagnetic Radiation, 1.5 credit hours [1997]
USPAS/University of California Berkeley - Beam Experiments: Methods and Theory, 3.0 credit hours [1997]

Cornell University

Dr. Georg Hoffstaetter
Professor of Physics Newman Laboratory
Head of SRF group and
Director of ERL R&D at CLASSE
gh77@cornell.edu

Newman Lab
Cornell University
Ithaca, NY 14850
607 255 4951
March 10, 2015

Cornell Laboratory for Accelerator-Based Sciences and Education

Letter of support for the United States Particle Accelerator School (USPAS)

To Whom It May Concern:

Cornell's graduate program in accelerator-physics has on average somewhat above 10 graduate students. Each of these students usually participates in one or more USPAS schools during their time as PhD students, and we have often also sent post docs or your research associated to this accelerator school. The accelerator-physics faculty at Cornell University continue to send students to the USPAS because it fills an essential need in preparing our students for research, and it provides opportunities for networking that have proven beneficial for many research projects and for many young careers.

I have taught the graduate accelerator-physics class at USPAS twice and can attest to the excellent quality of students that are attracted to this school. All students have been extremely motivated, come well prepared, and leave with a substantial knowledge of basic accelerators science. Considering that national laboratories have recognized the need for the education of more accelerator scientists, maintaining the strength of the USPAS is very important for the accelerator field in the US.

Students come from Universities, national laboratories, industrial companies, and international research institutions and often return much better prepared for their research. This broad orientation of USPAS has prepared for the centers where many students later find employment. Cornell students, who usually all participate in the USPAS since its first classes in 1987, are now employed by FNAL(4), TJNAF, Oak Ridge National Lab, BNL, SETI institute/NASA, Cornell University(5), Stanford University, Vanderbilt University, University of Colorado, UC Davis, Colorado State University, PSI/Switzerland, Helmholtz Zentrum Berlin and the University of Siegen, Center for Excellence in Basic Sciences, Mumbai and University of Mumbai, Raytheon(2), Euclid Techlabs, McKinsey, Outcome Referrals, Bechtel, TJ Watson research center IBM, and Teledyne Technologies.

The origin of students from a wide variety of institutions contributes much to the character of the school, it broadens the horizon of participants, increases the potential for networking, and challenges the lecturers to design comprehensive classes. I have been a member of the USPAS curriculum committee for many years and it has been helpful that also this committee draws members form a variety of backgrounds, bringing suggestions of a broad variety of classes.

As a graduate student in the 90s, I participated in one USPAS as a student and in another one as TA. Both experiences were important for me. What I learned and the research contacts I made at these schools has been very beneficial to my career.

I therefore strongly recommend the continuation of a financially health USPAS program and recommend that its current form be maintained, serving students in national labs, university, and industrial companies.

Sincerely,

From S.Y.Lee - Indiana University

Introduction

When CERN organized the first Accelerator School (CERN yellow report 77-13) in 1977, high energy physicists in USA recognized the importance of training accelerator scientists on future high energy physics and organized the first US Particle Accelerator School in 1981 at Fermilab (AIP conference proceedings 87) edited by Dr. M. Month. Since 1982, Dr. Month organized annual USPAS program until 1989. Conference proceedings were published in AIP conference proceedings 87, 105, 127, 153, 184; and Springer-Verlag Lecture notes 246, 296, etc.

Dr. Month recognized the limit of conference style particle accelerator school programs on graduate student training. There were few US Universities having "accelerator physics programs," and the accelerator sciences involve many branches of sciences and engineers. In 1990, Dr. Month introduced accelerator school following the model of graduate program of Universities. A 3 credit-hour course in the USPAS program has to have a minimum of 45 contact hours. This model fills the vacuum of the accelerator science education in Universities, and provides opportunities for technicians working at National Labs and Industries to enrich their career. Dr. Month played key role in the development of the USPAS.

Effectiveness,

USPAS course is intensive, focused, and limited in time. There are counter arguments that people commonly considered.

1. There are arguments that students may not have enough time to absorb course materials during such a short time for a course that covers the entire semester. During a semester, students have time to carry out detailed calculations and difficult assignments. On the other hand, during the USPAS program, it is difficult to assign difficult assignments.
2. In counter argument, each USPAS course is short and intense so that students can focus their study in one subject within two weeks.

I have taught students both in the USPAS and IU courses. My observation is that their effectiveness is similar. Actual learning of a subject depends additional work after the class. There is no way for students to absorb a course during the course time of two week.

Impact,

1) Necessity for University programs: USPAS is the only resource for graduate students in Universities without accelerator physics program. Even for Universities having accelerator physics program, it is difficult to offer accelerator physics course because very few graduate students in each University, and there is not sufficient number of students to offer a graduate level course. At IU, I have offered a total of 10 graduate level accelerator physics courses in 36 years.
2) All AP graduate students in IU group need to take "beam measurements" courses. Between 2000 and 2008 and after 2010, there is no experimental facility at IU and IU graduate students have to attend the "beam measurement Lab courses." Other University programs may have slightly different focus, and they may need USPAS for different reason.

3) Since the accelerator sciences involve many branches of sciences and most of these experts are in National Labs, University programs cannot offer technology courses. USPAS fills the vacuum of many essential accelerator science courses that cannot be offered in Universities.
4) USPAS programs serve as a training ground for leaders of future accelerator scientists. When a course is assigned to young scientists in National Labs, they will spend about at least five months to prepare the course. The best way to learn a subject is to teach that subject. Thus USPAS will provide training ground for the next generation young accelerator scientists.
5) The USPAS Master of Science program provides a platform for technicians in industry and National Labs to enrich their knowledge and incentive in receiving promotion in their career.

Quality and breath

Each USPAS course is taught by scientists from National Labs or faculty from Universities. USPAS has course evaluation for each class. The USPAS program committee serves a function of discovering young scientists for the USPAS programs.

The USPAS courses also encourage teachers to write textbooks for "accelerator sciences". For example, "Measurement and Control of Charged Particle Beams" by Michiko G. Minty and Frank Zimmermann was intentionally organized for a teaching a course at USPAS to complete this "intermediate accelerator physics;" The "Iron Dominated Electromagnets: Design, Fabrication, Assembly and Measurements" by Jack T. Tanabe was also planned on purpose to write a textbook.

Other specific Questions:

1. How, in the past and now, does the existence of USPAS benefit your academic program?

   As explained earlier, none of the "accelerator programs" in US universities can cover the scope of accelerator sciences. The most important course IU accelerator physics group is the "microwave instrumentation and beam measurement lab." Other important courses are technology courses.

   Other University AP programs may have slightly different requirements.

2. To what extent does USPAS complement your graduate program; to what extent is it redundant with your program?

   As explained in the item #1, all IU AP graduate students need to take "microwave instrumentation and beam measurement Lab". There is little redundant with my program. It is difficult for IU to offer "accelerator physics" core course, and thus all students need to take the core accelerator physics course. Our weekly group meeting provides an opportunity to rectify mis-concepts and enrich the understanding of essential physics.

3. What unique and essential capabilities are provided to the program through the involvement of the DOE laboratories?

   Funding of USPAS is a very difficult problem. It is a difficult subject to handle money. USPAS offers about 900 credit hours (or 300 students) annually, which correspond to about $360,000 in University graduate school in-state students. I stress the importance of the USPAS, but the funding of the USPAS programs should be resolved by your committee and funding agency.

4. What fraction and how many of your students enroll in USPAS courses?

   All students from IU AP program takes about 3-4 courses.

5. How many USPAS courses does a typical PhD student take during their graduate program?

   All students from IU AP program takes about 3-4 courses. In particular, they have to take "Microwave instrumentation and beam measurement Lab."

6. Do you grant course credit for USPAS courses?

   IU grants credits to all USPAS courses, except the "accelerator fundamental," which is for undergraduate students.

7. How are your past graduates in accelerator science and technology employed?

   All students were employed. Several foreign students return to their home country to serve.

8. What changes in the USPAS program could you envisage that would enhance its benefit to your graduate program?

   The USPAS fills the need of IU accelerator physics graduate students. I do not see the need of changes.

Andrew J. Lankford

From: Richard G Milner <milner@mit.edu>
Sent: Friday, March 6, 2015 13:04
To: Andrew.Lankford@uci.edu
Subject: Re: Reminder: Request for input to HEPAP review of USPAS

Dear Dr. Lankford,

USPAS has been an important means to facilitate graduate education in beam physics at MIT. While at MIT there are faculty who pursue research in beam physics, there are no faculty in the area of beam physics MIT Department of Physics. We are fortunate that Dr. Bill Barletta, the USPAS Director, holds an adjunct faculty position in our Physics Department. He has initiated an undergraduate course at MIT which has proved successful. I provide answers to your questions as follows:

How, in the past and now, does the existence of USPAS benefit your academic program?
Our graduate students attend the school and take the courses for MIT credit. Some of our students have been TAs. The experience has been very positive for all.

To what extent does USPAS complement your graduate program; to what extent is it redundant with your program?
It certainly complements our program in that we have no faculty or courses in t eh area of beam physics.

What unique and essential capabilities are provided to the program through the involvement of the DOE laboratories?
Certainly, Fermilab hosts the Director and the labs regularly provide support.

What fraction and how many of your students enroll in USPAS courses?
About 20%.

How many USPAS courses does a typical PhD student take during their graduate program?
1.

Do you grant course credit for USPAS courses?
Yes.

How are your past graduates in accelerator science and technology employed?
We have no graduates in accelerator science and technology from LNS. Rick Temkin in PSFC has produced some excellent students in this area.

What changes in the USPAS program could you envisage that would enhance its benefit to your graduate program?
None. I think that it is an excellent program.

I trust that this is useful to you.

sincerely,
Richard Milner
Director, Laboratory for Nuclear Science

Andrew J. Lankford

From: philippe.piot@gmail.com on behalf of Philippe Piot <piot@nicadd.niu.edu>
Sent: Wednesday, March 11, 2015 18:55
To: Andrew.Lankford@uci.edu
Cc: Philippe Piot
Subject: Re: Request for input to HEPAP review of USPAS

Dear Andrew,

Below are my answers to you six questions. Let me know if any of my answers need clarification or elaboration.

Best regards, -- Philippe.

1- To what extent does USPAS complement your graduate program; to what extent is it redundant with your program?

Our university has an accelerator-science program consisting of two general classes in beam physics and a "placeholder" class for special topics in Beam Physics. Given the small number of graduate students these classes are one per year offer provided enough student enroll in them. Some years there are not offer and we rely on the USPAS to provide the general student training in Accelerator Science (our student generally take the "Fundamentals of Accelerator Physics and Technology" class. In addition some of our students who already started their research are often sent to USPAS to enroll to a special topics. The latter type of class is an important element of the USPAS as it enables the students to get educated in a very specific topic
-- this turns out to be very valuable at the early stage of the research work.

2- What unique and essential capabilities are provided to the program through the involvement of the DOE laboratories?

I think the lab have the set of expert not generally available in Universities especially in area such as radiofrequency and beam diagnostics.

3- What fraction and how many of your students enroll in USPAS courses? How many USPAS courses does a typical PhD student take during their graduate program?

I try to send ensure one student attend at least one USPAS class during his/her phD research work. My preference is generally to have the student attend our local beam physics class to get trained in the general aspects of beam physics and then send him/her to the USPAS to gain experience in a field closer to the research being carried as part of his/her phD. So typically a student will take one course at the USPAS over the PhD period.

4- Do you grant course credit for USPAS courses?

Yes, since our graduate catalog has several classes in beam physics we are usually mapping classes taken at the USPAS in one of this classes. The general two-week class is generally mapped to our "Beam Physics" class while the other advanced and more specialized classes are usually mapped to our "Special Topics in Physics-Beams Physics" course.

5- How are your past graduates in accelerator science and technology employed?

PhD: One is no a staff scientist at SLAC. the others have moved to finance or insurance companies.
Terminal master: The only terminal master I had joined the Argonne's ATLAS operation group.

6- What changes in the USPAS program could you envisage that would enhance its benefit to your graduate program?

I think the USPAS should make an effort to increase the universities representation in their curriculum committee as the need for class on specialized topics is mainly driven by the current poll of graduate students and their topic of research. If not possible the curriculum committee should at least seek input from active faculty members and graduate advisers in Accelerator Science at least within the US. Likewise the teaching load should be distributed among a larger community, this could benefit to students as newcomer could refresh the part of the program. To be specific, I think for instance most of the people teaching the "Fundamentals of Accelerator Physics"
class use materials developed by Wiedemann back a decade ago and follow an "old-fashion" syllabus mainly along the history of accelerators development.

Philippe Piot,
http://nicadd.niu.edu/~piot/wiki/pmwiki.php

Northern Illinois University, Dept of Physics and Northern Illinois Center for Accelerator & Detector Development
DeKalb, IL 60115, USA
Tel: 815 753 6473, Fax: 815 753 1772
Web: http://www.physics.niu.edu/physics/

Fermi National Accelerator Laboratory,
Accelerator Physics Center, MS 306
PO Box 500, Batavia, IL 60510, USA
Tel: 630 840 8128/6291, Fax 630 840 5231
Web: http://apc.fnal.gov/

OLD DOMINION UNIVERSITY

Dr. Gail E. Dodge
Professor of Physics
Old Dominion University
Norfolk, VA 23529
(757) 683-5854
gdodge@odu.edu

Dr. Andrew Lankford
Chair, High Energy Physics Advisory Panel

March 7, 2015

Dear Dr. Lankford:

Thank you for soliciting my input on the important charge facing your committee to evaluate the effectiveness of the United States Particle Accelerator School. ODU hosted USPAS in January 2011 and again in January 2015. In both cases I was involved in preparing for the USPAS and so I have gained some familiarity with what USPAS offers and how it functions. I will answer your specific questions below, but first I will include some background on the situation at ODU in order to provide some context to my answers.

Old Dominion University established its Center for Accelerator Science (CAS) in 2008 in partnership with Jefferson Lab. We have hired three faculty in connection with the center, including the director, Jean Delayen. In addition we have three Jefferson Lab professors in the area of Accelerator Science – these are Jefferson Lab scientific staff who have faculty privileges at ODU and who are occasionally available to teach a course. In establishing the center, ODU and Jefferson Lab were reacting to the well-documented shortage of trained personnel in accelerator science, which affects not only the future workforce at laboratories such as Jefferson Lab, but also the rapidly growing industrial sector that depends on workers skilled in this area. It has been widely understood that increasing the availability of accelerator science as an academic discipline at universities would be one important way to increase the number of people trained in this area. I note that the National Science Foundation has begun accepting grant proposals in accelerator science as an academic discipline within physics. As chair of the physics department at ODU when we established CAS, and now as the Deputy Director, I can speak to the importance of USPAS in our ability to effectively train and educate students in this area.

Since accelerator science is interdisciplinary and extremely broad in scope, it is not possible for most universities to provide all the necessary courses in accelerator science to adequate train graduate students in the field. ODU is a mid-size department (~22 tenure/tenure-track faculty) – we use our regular faculty to teach the base undergraduate and graduate courses, with the occasional topical course in accelerator science for undergraduates or graduate students. We rely on the USPAS to provide additional courses for our M.S. and Ph.D. students.

Below I answer your questions in more detail.

What do you find is the effectiveness, impact, quality, and breadth of the USPAS program?
The USPAS courses are very intensive. From talking to students I have the impression that the quality of the teaching in these courses is very high. The two-week format is very efficient, and very effective for teaching courses that are focused and technical in nature. As far as I can tell USPAS

Dr. Gail E. Dodge
Professor of Physics
Old Dominion University
Norfolk, VA 23529
(757) 683-5854
gdodge@odu.edu

has found the right balance between offering the "core" courses often (once or twice per year) and including specialty courses every few years. In this way, a Ph.D. student has a good chance of taking any necessary, specialized courses during the course of his/her studies. USPAS has had a clear impact on our ability to offer a high-quality graduate program in accelerator science. I can only guess that the impact has been similarly noticeable at other universities. Of course national laboratories can comment more knowledgably about the impact on their workforce needs.

How, in the past and now, does the existence of USPAS benefit your academic program?
USPAS enables us to provide our graduate students with a broad array of courses that we cannot offer. In order to best prepare our students for careers in industry, national labs, or academia, it is important that they be exposed to a wide range of topics outside the expertise of our own faculty. An USPAS-like school would probably be beneficial in any academic program, but since accelerator science is so broad and interdisciplinary, it is particularly necessary.

To what extent does USPAS complement your graduate program; to what extent is it redundant with your program?
The USPAS courses are almost entirely complimentary. We do occasionally offer an undergraduate survey course in accelerator physics and a graduate elective course, both of which are part of the USPAS standard courses. We cannot offer these two courses very often because of pressures to teach core courses. On the other hand, USPAS offers many other courses which benefit our students and which we cannot ever offer.

What unique and essential capabilities are provided to the program through the involvement of the DOE laboratories?
The DOE laboratories influence the USPAS program in several ways. First of all, laboratories such as Jefferson Lab can provide facilities for hands on training as part of some USPAS courses. The courses are very popular and are invaluable in training that meets specific workforce needs. For example, in January 2015 USPAS offered a course titled "SRF Technology: Practices and Hands-on Measurements," which was very well received. Also, USPAS offers the occasional course in project management because the laboratories need their staff accelerator scientists to be trained in that subject. Finally, the national laboratories provide most of the instructors for USPAS – they are invested in the training that USPAS provides for the current and future workforce.

What fraction and how many of your students enroll in USPAS courses?
In January 2015, six ODU graduate students enrolled in USPAS courses. Five were physics Ph.D. students and one was a Mechanical Engineering Ph.D. student who works on an interdisciplinary project with physics faculty. The five physics students are roughly half of our accelerator science Ph.D. students and roughly 10% of all physics Ph.D. students. These statistics are typical for a local USPAS. When travel is required to another university, we typically send about 2 students. Over time all of our accelerator science students (which includes those working in interdisciplinary research groups related to computational physics, atomic physics and plasma physics) attend at least one USPAS.

OLD DOMINION UNIVERSITY

Dr. Gail E. Dodge
Professor of Physics
Old Dominion University
Norfolk, VA 23529
(757) 683-5854
gdodge@odu.edu

How many USPAS courses does a typical PhD student take during their graduate program?
Ph.D. students doing something related to accelerator science take anywhere between 1 and 5 USPAS courses. On average each student takes ~2 courses. Some of our students have served as teaching assistants when USPAS is local.

Do you grant course credit for USPAS courses?
Yes.

How are your past graduates in accelerator science and technology employed?
We have eight students who have graduated with a Ph.D. in accelerator science and technology. Three are employed as staff members at a national laboratory (Jefferson Lab and Brookhaven), one is a senior research scientist at NASA, one is a postdoc, one is a university lecturer, one is in industry, and one is unemployed because of visa issues.

What changes in the USPAS program could you envisage that would enhance its benefit to your graduate program?
I think it would be helpful if the core USPAS courses would have a standard syllabus. I know this is difficult since different instructors teach them each time. However, we would like to keep these courses in our catalogue and it is important that the description of the course in our catalogue matches the actual content delivered. Another idea worth exploring is the possibility of offering some courses on-line over a full semester. The two-week session in January overlaps with the regular Spring semester, so students cannot take an USPAS course as well as a regular full semester course because they would be away from regular classes for two weeks. Perhaps the "normal" USPAS school could take place once per year in June and other online courses could be offered as part of the fall and spring semesters.

At ODU we have been working with USPAS to develop a master's degree in accelerator science that would enable students to use USPAS courses to complete part of a degree. The program would be similar to what was previously offered at Indiana University. We believe there is a strong demand for such a master's program and that it would only be possible in partnership with USPAS.

In summary, I think the USPAS is an effective way to increase the number of students who have access to a high quality graduate program in accelerator science and to enhance the training of those already working in the field.

Sincerely yours,

Gail E. Dodge

Gail E. Dodge

Stony Brook University

Department of Physics and Astronomy
State University of New York
Stony Brook, NY 11794-3800
Vladimir Litvinenko
Professor and Deputy Head at BNL
Jacobus Verbaarschot
Graduate Program Director and Professor
e-mail: vla@bnl.gov, jacobus.verbaarschot@stonybrook.edu

March 11, 2015

Prof. Andrew Lankford,
Chair HEPAP,

Dear Prof. Lankford,

Stony Brook graduate students have been advised by BNL accelerator physicists for many years (for example by Ilan Ben-Zvi and Vladimir Litvinenko). More recently we have established the Center for Accelerator Science and Education (CASE) with Vladimir Litvinenko as director, while Ilan Ben-Zvi and Sergey Belomestnykh have been appointed as a Brookhaven Professor (which is a 0 percent adjunct appointment). Since 2011 we have had 3 PhD defenses in accelerator physics, two were advised by Vladimir Litvinenko and one be Axel Drees. Currently, CASE scientists supervise ten graduate students. We have currently a search for a junior faculty member in accelerator physics, and with two faculty positions in this field, we expect that the total number of graduate students in accelerator physics will increase. The establishment of accelerator physics in the Stony Brook Physics Department was spear headed by Paul Grannis, and nuclear physicists Tom Hemmick and Axel Drees are active in this field as well. In addition to the PhD program we have the Master of Science in Instrumentation Program, which is a terminal degree, and it also graduates about one student every other year.

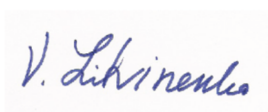
For a long time we have been offering an advanced course in accelerator physics every two or three year taught by Vladimir Litvinenko and Stephen Peggs. Two specialized courses on Super-Conducting RF were recently taught by Sergey Belomestnykh. Since hiring Vladimir Litvinenko as professor of physics, the department has been offering "Fundamentals of Accelerator Physics". In its initial offering during Spring 2014 it had an enrollment of 6 Stony Brook students and five operators from BNL. In Spring 2015 we offered the "Advanced Accelerator Physics Laboratory" course with an an enrollment of 11 students. This course counts toward the "laboratory" requirement for all graduate students. In Fall 2015 we will offer the course of Advanced Accelerator Physics. Even though we have a large graduate program, the number of graduate student pursuing accelerator physics is relatively small. Hence, more specialized accelerator physics courses will certainly not be viable or justifiable to teach as part of the regular curriculum.

Graduate students in accelerator physics typically take 3-5 USPAS courses during their graduate career. Participation in these courses is strongly recommended by their advisors, and it is the only way to receive instruction on specialized topics in this field. Thus, USPAS is critical for sustainability of accelerator physics and, more generally, accelerator science education and research at Stony Brook University.

Currently Stony Brook students are not able to take USPAS courses for credit, and they do not appear on the transcript of the students. However, we have been working with the Dean of the Graduate School to change this, and he recently approved that starting with 2016 Winter USPAS session SBU students can take them for credit.

Our graduates in accelerator physics are doing very well and many of them have found jobs at National Labs, Universities or in Industry. From three recent PhD recipients in accelerator physics, one of them became Research Scientist at Tech-X, one of them is Deputy Group Leader at BNL and the third one, who graduated last Fall, is still looking for a postdoc.

Sincerely,



Vladimir Litvinenko
Professor of Physics and Deputy Head at BNL

Jacobus Verbaarschot,
Graduate Program Director and Professor of Physics

UCLA - Jamie Rosenzweig

How, in the past and now, does the existence of USPAS benefit your academic program? To what extent does USPAS complement your graduate program; to what extent is it redundant with your program?
The UCLA Particle Beam Physics Laboratory currently has, despite the participation of ~12 graduate students at any given time, only two ladder faculty. Thus we offer an advanced undergraduate course (textbook "Fundamentals of Beam Physics" by J. Rosenzweig, Oxford 2003) and one graduate course with varying subject matter per year. This is augmented by the year long course in plasma physics. For many specialty courses, however, the USPAS is extremely useful. These may be practical lab courses, such as the comprehensive microwaves course, or advanced topics, e.g. free-electron lasers. While these may be eventually covered in our graduate courses, the twice-yearly option provided by USPAS is extremely convenient, and also provides the students with the opportunity to learn from other professionals in the field. With the wide variety of courses offered, it is straightforward to tailor the classroom preparation of the students as they enter into research.

What unique and essential capabilities are provided to the program through the involvement of the DOE laboratories?
The specialized expertise provided by dedicated professionals from the national labs provides a dynamic counterpoint to the fundamental physics emphasis of the on-campus courses. The DOE labs provide lecturers, further, that are per definition interested in student training and outreach. Contact with these lab scientists is often very useful in opening future career options for our students.

What fraction and how many of your students enroll in USPAS courses? How many USPAS courses does a typical PhD student take during their graduate program?
Essentially all of the students in our group take at least one USPAS course. I would estimate the average number of USPAS courses for each student is two.

Do you grant course credit for USPAS courses?
This is not a necessary component of the USPAS offerings; typically neither our undergraduate or graduate students do not need the course credit.

How are your past graduates in accelerator science and technology employed?
Nearly all of PhDs produced by our program are employed in the accelerator field in the national labs (I have sent six to SLAC in the past seven years alone) or in industry. In regard to the final point, there is a successful spinoff company produced by the UCLA program, RadiaBeam, which employs a number of graduates).

What changes in the USPAS program could you envisage that would enhance its benefit to your graduate program?
I would put more effort into developing a laboratory program that is site independent [*i.e. a laboratory course independent of the site at which the School is being held - ajl*], for hands on hardware and observation/data taking/analysis training. I would put less effort into management and safety courses (which are of course useful for post-graduate training of national lab employees.

Appendix I. Letter from APS Division of Physics of Beams

Argonne NATIONAL LABORATORY

Stuart D. Henderson
Project Director, APS Upgrade
Advanced Photon Source

Argonne National Laboratory
9700 South Cass Avenue, Bldg. 401
Argonne, IL 60439-4803

1-630-252-7828 phone
1-630-252-1133 fax
hendersons@aps.anl.gov

March 11, 2015

Andrew J. Lankford
Professor, Dept. of Physics and Astronomy, UC Irvine
Chair, High Energy Physics Advisory Panel

Dear Professor Lankford,

As Chair of the American Physical Society (APS) Division of Physics of Beams, I represent more than 1,000 members, from universities, national laboratories, industrial firms and medical facilities, who are passionate about the field of particle accelerator science and technology and the role that accelerator technology plays in the scientific and economic health of our Nation. On their behalf, I am honored to contribute to the U.S. Department of Energy (DOE) High Energy Physics Advisory Panel assessment of the U.S. Particle Accelerator School (USPAS), and to take this opportunity to underscore the essential role that USPAS plays in training the workforce of accelerator scientists and practitioners and assuring the ongoing vitality of our field.

USPAS was created to address our nation's critical shortage of top-quality, undergraduate and graduate-level accelerator science training. Since its inception in 1987, USPAS has provided crucial support to the U.S. accelerator science community by offering rigorous, highly specific training to more than 4,000 scientists, engineers and accelerator operators –training that is available nowhere else. USPAS has become a fundamental part of our nation's scientific enterprise, offering the initial and continuing workforce training required to assure the safe, efficient and productive operation of today's accelerators and to enable design, development, construction and commissioning of tomorrow's forefront accelerator-based scientific facilities.

It is nearly impossible to overstate the importance of accelerators in today's scientific and technological landscape. Particle accelerators are essential tools for scientific discovery; since 1939, two dozen Nobel Prizes in Physics have recognized work that was directly connected to accelerators. Over the past 75 years, discoveries at accelerators have driven transformational new technologies that have an enormous impact on Americans' daily lives. Today, there are more than 9,000 medical accelerators operating around the world, providing diagnoses and treatments to tens of millions of patients each year. Particle accelerators are operating daily at ports and border crossings, scanning cargo for dangerous materials. More than 20,000 industrial particle accelerators are incorporated into the manufacturing chain of products ranging from microchips to automobile tires to sterilized food products, for a total commercial value of $500 billion each year.

Despite the enormous scientific and industrial value that accelerators create, the opportunities for university-based study of accelerator science and technology are quite limited. The number of U.S. universities offering graduate-level training in accelerator science and technology is quite small – about a half-dozen nationwide – and only about a dozen Ph.D.'s in accelerator science are granted in the United States each year. Even those universities that do offer accelerator science education are not able to support the full suite of coursework required for comprehensive training.

In large part, the limited number of university-based courses reflects the interdisciplinary nature of accelerator science, which incorporates advanced topics that bridge traditional departmental boundaries of physics, applied physics, computational sciences, and electrical and mechanical engineering. As a result, the vast majority of accelerator scientists, engineers and other professionals working in the field were not trained in accelerator science during their university studies. Instead, their expertise has been developed on-the-job, and through training provided by USPAS.

The impacts of USPAS training are felt throughout DOE. The DOE Office of Science operates 11 particle accelerator-based scientific user facilities, which draw more than 15,000 academic, industrial and laboratory researchers each year. More than half of USPAS attendees are current or former employees at DOE national laboratories. Past participants in USPAS include more than 250 researchers who today are considered leaders in the field, including two dozen who have gone on to become program managers within DOE. USPAS also plays a critical role in professional development both inside and outside the DOE complex; several hundred accelerator operators received their initial training through USPAS, along with hundreds of accelerator staff who rely on USPAS offerings for their professional continuing education in health physics and radiation protection.

Through the fulfillment of its workforce training mission, the USPAS helps to produce the expert men and women who design, build and operate accelerators for scientific discovery, medical applications and industrial uses, as well as the university and laboratory researchers who are extending the reach and impact of particle accelerators by working to make them more compact and less costly. This function is increasingly important in the field of accelerator-based high energy physics where the demands of the science require significantly advancing the state-of-the-art. Well-trained researchers with new innovative ideas are critical to developing these next generation accelerators. Many of the leaders in the field have participated in the USPAS as either students or instructors, or both.

In addition to its role in workforce development, USPAS has been an engine in developing the discipline of accelerator science itself, making an ongoing contribution that is critically important to the members that I represent. Lecture notes developed by USPAS instructors have been expanded into several canonical textbooks in accelerator science and technology, helping to power the development of a new body of scientific literature in the past two decades.
For almost three decades, USPAS has been meeting the needs of the particle accelerator community – and of the American scientific enterprise – by providing workforce training that is top-quality, relevant and affordable. Thanks to USPAS, our accelerator scientists, engineers and

technicians continue to have access to the professional training they need to remain at the cutting edge throughout their careers.

USPAS and its instructors fill a critical gap in accelerator education, serving as a vital national resource by presenting information and techniques that are typically not offered through the American university system. The APS Division of Physics of Beams, whose members I am proud to represent, consider USPAS to be a crucial element of our nation's scientific infrastructure – one that is necessary to our present and future global competitiveness.

Sincerely,

Dr. Stuart D. Henderson
Argonne National Laboratory
Chair, American Physical Society Division of Physics of Beams

Appendix J. Letter from USPAS Board of Governors

Rodney E. Gerig
Senior Advisor

Argonne National Laboratory
9700 South Cass Avenue, Bldg.401
Argonne, IL 60439-4803

1-630-252-7366 phone
1-630-252-4599 fax
gerig@aps.anl.gov

March 5, 2015

Professor Andrew Lankford
Chair HEPAP
University of California at Irvine
Physics & Astronomy Department
4129H Frederick Reines Hall
Irving, CA 92697

USPAS BOG Perspective for HEPAP Subcommittee

Thanks for giving me this opportunity to comment on the importance of the US Particle Accelerator School from the perspective of the USPAS board, and to provide background into the management and governance of the school.

I have served on the board as Argonne's representative since 2002. Regarding directors, I briefly overlapped S.Y. Lee, and then served during the tenure of Helmut Wiedemann, and William Barletta. I was elected the chairman of the board in 2013, when Derek Lowenstein, then chairman, resigned from the board.

It has been stated that the USPAS serves the needs of its members, namely the consortium partners and that "if the members of the USPAS Board of Governors, representing the relevant scientific disciplines and national laboratory organizations, decide that a given school is needed for training personnel," then the relevant Office of Science ADs support that decision.

The board has met regularly, often at the school's sessions, allowing the board members to visit classes and talk with students. This has given us good first hand experience into the functioning of the school.

I would like to address the panel in two main areas: firstly the importance of the school to the United States accelerator S&T community, and secondly a bit about the way the board is involved in managing the school.

The case for the importance of the school in providing the necessary workforce has been made in many of the documents provided to this panel. I can only underscore what has been already said. Each board member will have their own stories to tell. From an Argonne perspective, USPAS has been the only avenue to build a workforce within the local area. In spite of the many good universities in the Chicago there are simply not enough students for any of them to adopt a regular program within their departments. Occasionally there have been special topic classes taught for credit, but little on a regular basis. Thus when we get interested students, either through our efforts at the undergraduate level, or when we have accelerator physics staff members who desire to take on a graduate student from a local university, USPAS is the only way to get the necessary courses in accelerator related areas. I also wish to note that this problem also applies to engineering programs.

Professor Lankford
March 5, 2015
Page 2

There are numerous areas of engineering that are unique to accelerators that simply are not taught in typical university engineering programs. Examples are high level (power) radio frequency systems, large-scale ultra-high vacuum systems, and high precision magnet design and measurement. The laboratories are also dependent on USPAS for sending our own staff, both degreed and non-degreed to get the needed instruction for areas that were not included in their educational experience.

I also note that Argonne, as much as any of the Office of Science laboratories has active accelerator programs funded by HEP, NP and BES. Within the laboratory we function as an accelerator S&T community. When it comes to workforce development we have worked closely together, and USPAS is a very big part of that combined activity, with students and staff working together... students to study, and staff to help develop curriculum.

Moving on to management and governance issues I note that the board has met regularly throughout the time I have been on it. In years that it has not met in person, we have held teleconferences, and have had e-mail discussions and votes on any issue that impacts the way the school is being managed.

The board receives a yearly comprehensive report on the status of the school. This report heavily emphasizes financial issues, but also looks at attendance, diversity, and course content. We are heavily involved with the choice of instructors, and to that end review all school evaluations from students.

The consortium also provides the membership of the curriculum committee (some of the BOG members also represent their institutions on the curriculum committee). In general the curriculum committee determines the courses, however the board approves the curriculum, and regularly discusses any changes or additions that reflect the needs of the community. In general the curriculum consists of a few fundamental courses held every session, a second set of very basic courses that are held at an interval which would allow a student to take it during their course-taking years, and finally a set of courses that reflect the needs of the community. As an example, when a new project is forthcoming, we will generally schedule a course that meets the needs of that project in order to help draw young people into the necessary area of expertise, and help other working accelerator S&T staff make the transition into the area of emphasis. These are not simply job training classes, but true academic classes; for instance the physics of accelerating heavy ions is quite different from the physics of accelerating electrons for light sources; and the science and engineering of superconducting rf systems is a very challenging academic and practical problem deserving a number of courses.

The point I am making in the above paragraph, as a laboratory representative is that the entire focus of the curriculum of the school is set by the consortium (DOE and NSF laboratories) to meet the needs of the entire US accelerator community. (Of course the courses need to meet the qualifications of the credit granting university as well).

The BOG selects and oversees the performance of the school director, who may have any member of the Consortium as his/her home institution. As the director is responsible to the board for all aspects of USPAS operations, the chairman of the Board provides written evaluation which also serves as input into the director's performance appraisal as administered by his home institution.

Professor Lankford
March 5, 2015
Page 3

Finally, as a laboratory manager with responsibilities for providing a trained workforce to innovate new accelerators and improve existing ones, I cannot imagine where we would be today if not for the USPAS. It is not hard to look through the lists of scientists and engineers working on our existing accelerators, and developing new ones, and see many who have received significant education from the school. USPAS is a national resource that is essential for the future of US science and technology.

Sincerely,

Rod Gerig

Rodney E. Gerig
Chairman USPAS Board of Governors