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and
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OVERVIEW OF THE CONFERENCE

The 1989 Particle Accelerator Conference was the 13th in the series of such conferences. It was also the silver anniversary of the first meeting of the Organizing Committee to begin planning the conferences. In the intervening years, the conference has grown enormously, with the field. It is now the most frequently used place of publication for North American accelerator engineers and scientists. In addition, our colleagues from all over the world now attend and use the conference as an important means of communication and publication. Because of the breadth and detail of the material presented, the Particle Accelerator Conference and its European counterpart compete with the International Conferences for technical interest.

The 1989 Conference was held at the Hyatt Regency Hotel in downtown Chicago. Approximately 1100 people attended (about the same as the 1987 Conference) and 656 papers are included in this Record. These papers covered a vast scope of effort on many different aspects of particle accelerators and their applications in many branches of science, medicine, and industry. It is, in fact, impossible for us to pick out any single paper or topic and label it the "outstanding" part of the conference. There were simply too many outstanding papers and topics. Superconducting cyclotrons, linear accelerators and synchrotrons, storage rings, synchrotron-radiation devices, free-electron lasers, rf systems, and beam dynamics all had significant advances to be discussed.

Over the years, the conference has also grown in length. The Program Committee struggled to fit the papers that they accepted into four days. It was finally possible only by having three parallel sessions on one day. The third session covered work on one of the burgeoning fields of accelerator work, free electron lasers. The Organizing committee has always taken the view that parallel sessions should be held to a minimum in order that attenders can avoid too many agonizing decisions. It is clear from the trends of the past that our field will continue to expand in interest and in numbers of active people. The resulting crowding of papers has caused the Organizing Committee to explore ways to ease the problem, including possibly lengthening the conference.

The Conference banquet was held at the Field Museum of Natural History, in surroundings that added considerably to the elegance of the affair. A high point of the evening was the presentation of the annual award of the Nuclear Physics and Plasma Sciences Society of the Institute of Electrical and Electronics Engineers to L. Jackson Laslett, whose contributions to accelerator science have spanned and added insight to many different aspects of the field over many years (in fact, since the earliest days. After his graduate work with Ernest Lawrence, Dr Laslett was one of the builders of the first cyclotron in Europe just before World War II). He is active to this day in accelerator work, a career that has spanned almost a half century and still continues.

A new feature of this conference was a forum sponsored jointly by us and the Topical Beams Group of the American Physical Society (now becoming a division of the Society). This lively evening was devoted to consideration of the future of our field. A more detailed account of the forum is included in this volume. The collaboration with the Topical Beams Group and the forum were fruitful and we can hope for continued collaboration at future conferences.

The Conference was organized under the auspices of the Organizing Committee by people from the Argonne National Laboratory and the Fermi National Accelerator Laboratory. Their names are listed on the opposite page. The groups worked so hard and so well that a mere listing does not do justice to their contribution. Knowing that we speak for all attenders, we give them heartfelt thanks for their dedicated work.

The 1991 Conference will be held in San Francisco. Matthew Allen of SLAC is the Chair. The 1993 Conference will be held in Washington, D.C.. Christoph Leeman of CEBAF is the Chair. There is a tentative plan to hold the 1995 Conference in the area of Waxahachie, Texas.

Donald Young and Francis Cole
Conference Co-Chairs

THE 1989 PARTICLE ACCELERATOR CONFERENCE AWARD

March 22, 1989

TO PARTICIPANTS OF THE 1989 PARTICLE ACCELERATOR CONFERENCE:

At this conference we are seeing a new feature -- an award is being given for "Outstanding Contributions to the Development of Particle Accelerator Technology." The selection committee received names of a number of outstanding candidates for this first prize. An award to any of them would be a credit to our profession.

It was the unanimous opinion of the selection committee that the award should go to L. Jackson Laslett.

Laslett's work has extended over nearly all aspects of accelerator development. Among these topics are linear and nonlinear forces in both transverse and longitudinal motion, magnet design and the effects of field errors on the motion, space-charge forces, and collective instabilities. As an integral part of this work, he has made unique contributions to computational methods in most of these topics.

Throughout his career, Laslett has been an effective teacher and valued collaborator. He has been an inspiration to all who know him or of him by virtue of his hard work, insight, great care and accuracy, and as a person with unshakeable integrity, honesty, and unfailing good will to his associates.

It is a great pleasure to present to Jackson Laslett this award plaque from IEEE NPSS and a check for $1500.

Mark Q. Barton

Mark Q. Barton

Chairman, IEEE-NSPS
Technical Committee on
Particle Accelerator
Science and Technology

A. Summary (Mel Month)

During the Particle Accelerator Conference on March 22, 1989 in Chicago, the Beam Physics Topical Group of the American Physical Society, in association with the Particle Accelerator Conference, organized a Forum designed to foster a dialogue between members of our growing community and the institutions that represent it. The panel consisted of:

Richard J. Briggs, Associate Director, Lawrence Livermore (LLNL)
Timothy Coffey, Director of Research, Naval Research Laboratory (NRL)
Helen T. Edwards, Head, SSC Accelerator Division
F. Russell Huson, Director, Texas Accelerator Center (TAC)
Michael Knotek, Chairman, NSLS, BNL
James E. Leiss, Former Director Office of High Energy and Nuclear Physics (DOE)
Andrew M. Sessler, Vice-Chair, APS Beam Physics Group
Moderator: Robert L. Gluckstern, Physics Dept., University of Maryland

In addition to short statements, panel members responded to a wide variety of questions and comments which on the whole tended toward two issues, the appropriate role for beam physics in university education and the need for direct funding to support research in the physics and technology of beams. For a variety of reasons, mostly connected with accidents of history, universities and funding agencies for the most part have not supported beam physics directly but only through other scientific areas where beams are necessary for experiments. The panel and the audience spoke for change, sometimes with a great deal of passion. We should certainly have more such dialogues. In addition the Topical Group Executive Committee, as well as the PAC organization, should develop plans to foster more direct activities of universities and the funding agencies in our field.

B. Introduction (Robert L. Gluckstern)

This is the forum on issues facing the accelerator community. We have a distinguished panel of leaders in the community with considerable experience in such matters. They will each make approximately 5 minute statements, following which we will take questions and comments from the audience.

There are many issues about which there is considerable concern and interest. Among these are the following, which I hope will be addressed by the panelists:

1) What are the needs for manpower over the next decade?

2) What training/skills are needed?

3) Where is this training to be obtained? At universities? At national laboratories in collaboration with universities? At Accelerator Schools?

4) How can we expand the activity at universities? How can we address and change the present perception that accelerator physics is an applied (second rate) activity in the hierarchy of university research in physics and engineering?

5) What should be the role of the accelerator community in the American Physical Society? What should be the interaction with various APS divisions? What are the implications of divisional status?

6) There is a need for more research (separate from building machines) in accelerator physics. What should be the proper balance between these two activities?

7) What is the proper role for industry to play in support of research in accelerator physics?

8) There is some dissatisfaction with the current publication practices in accelerator physics. How might these practices be changed?

C. Comments by Andrew M. Sessler

The development of university programs, in engineering and in physics, depends upon an appreciation by our colleagues of the intellectual content of the field of beam physics. We know that the field has intellectual content, but that fact is not widely known, partly because we have been busy building things rather than giving seminars and writing papers.

As a small step in the direction of better identification of the intellectual content of our field, we have petitioned the American Physical Society to create a Division of the Topical Group on Particle Beam Physics, on a par with Nuclear Science, Particles and Fields, Astrophysics, Condensed Matter Physics, etc.

Marty Perl argued our case before the APS Council and his remarks were so persuasive that I would like to read most of them:

1. Introduction

Officers and members of the Particle Beam Physics Topical Group have petitioned the Council to form a Division of Beam Physics, replacing the present Topical Group.

2. Beam Physics

Beam physics comprises the study and use of particle and photon beams: the formation of beams, the properties of beams, the interactions of beams with matter and with other beams. At one energy boundary are beams in the electron volt range, beams of molecules, atoms, and ions. Uses of such beams range from fundamental atomic physics studies to ion implantation procedures. At the other energy boundary are the GeV and proposed TeV beams of high energy particle accelerators and colliders. Spread over the particle beam energy landscape are accelerators for medical use, nuclear physics accelerators, neutron beam facilities, and industrial electron accelerators. The photon beam energy landscape is also rich with instruments such as synchroton light sources, free-electron lasers, and high energy photon beams.

One area of beam physics research concerns the formation of the beam. For charged particle beams this involves basic research, development, and invention in methods of charged particle acceleration. For neutral beams basic research, *development, and invention is required in the production of such beams from the interactions of charged particles with matter and electromagnetic fields.*

A second area of beam physics concerns the properties of beams as a special state of matter. The physicist studies the self-interaction of beams, means for changing the properties of beams, and the interactions of beams.

3. The Basic Physics in Beam Physics

There are so many applications of beam physics that we sometimes forget the basic physics subfields that are interwoven with beam physics. First, of all there is classical and quantum electrodynamics. In these subfields beam physics brings forth new and beautiful problems in areas such as coherent phenomena and nonlinear dynamics. Second, the quantum mechanics of molecules, atoms, and ions is often involved. Third, statistical physics, often nonequilibrium statistical physics, occurs as a major component in much beam physics research. For example, the physics of the collision of two dense bunches of charged particles brings up deep problems in nonlinear dynamics and in statistical physics. Finally, many aspects of plasma physics are important in beam physics.

Today few physics departments give courses or award degrees in beam physics. And even in the accelerator laboratories there is often a perceived hierarchy with theoretical physicists first, experimenters second and accelerator physicists third. Divisional status for beam physics would help build a stronger position for that field in academic physics departments and would help give beam physics its rightful status in laboratories.

Another benefit of divisional status would be to improve publication habits and traditions in beam physics. At present much basic and applied beam physics is published only in internal notes, preprints, or conference proceedings. This makes it difficult for young physicists or physicists from other disciplines to enter the field. It also inhibits academic recognition for achievements in beam physics. A Division of Beam Physics would be able to work on the publication problem.

Paradoxically the importance of applied beam physics in the energy range from eV to TeV has inhibited funding for basic beam physics. The need is often great to design, build, operate, and improve accelerators and other beam physics facilities. Consequently, almost all available funding goes into these activities, and little funding is left for basic and long range research in beam physics. Through a division of the American Physical Society, beam physicists could strengthen the case for broader support for basic beam physics research.

The Council approved in principle the formation of a Division and enjoined a Task Force to draw up By-laws, Proposed Activities for the next few years, and a Transition Plan. Our Task Force did just that on Sunday. I urge you to maintain your membership in the Topical Group this year. That is non-trivial, as it will cost you $5 this year as the APS is changing its rules. But if membership drops off, we are dead in the water.

So, please pay your $5 and tell your friends to do the same.

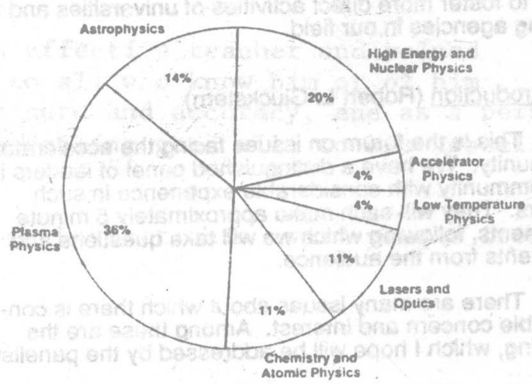
D. Comments by Richard J. Briggs

The accelerator community is carrying a very large share of the responsibility for constructing the scientific facilities needed by the USA science community. Projects underway include the SSC (for HEP), CEBAF (for Nuclear Physics), and several synchrotron light sources. In addition, commercial and national defense accelerator applications are rapidly increasing; examples include space-based neutral particle beams, free electron lasers, medical accelerators, and x-ray lithography.

With such a heavy burden for "deliverables", the accelerator community must be particularly sensitive to the need for maintaining and enhancing the long-term intellectual health and vigor of the field. The proposal for divisional status of the Beam Physics Topical Group in the American Physical Society is a very positive step in this regard. A serious shortcoming of the particle beam physics and technology disciplines is the extremely scanty academic base. The accelerator community and the government agencies responsible for applications of this technology (DOE, NSF, DOD) must share the blame for allowing this to happen. We have, in effect, "stolen" our scientific and engineering talent from people trained in other scientific fields. We should share with them the responsibility for attracting young people into science and engineering.

As an example, I offer the attached data representing the 30 Beam Research Program physicists at LLNL (a group involved in induction linac technology and applications such as FELs and relativistic klystrons). The message is clear: accelerator science should "grow up" and establish itself in the academic realm as a discipline with exciting intellectual content and job opportunities. Funding agencies must provide support for this to be successful.

Professional training, Beam Research Physicists



E. Comments by Timothy Coffey

While we do face serious problems regarding personnel and funding, we are also confronted with a marvelous set of opportunities such as those presented by the free electron laser, the high intensity synchrotron light sources, interest in compact accelerators, and so forth. These should open new horizons in accelerator physics and in the application of accelerators. I would also point out that all of the interesting problems do not lie in the area of large accelerators. There are many very challenging scientific and technological problems connected with designing accelerators for compact systems, such as broadband moderate power radiation sources, which might be useful for example in electronic countermeasures applications. There are many exciting and challenging accelerator and beam physics problems which can be undertaken at a small scale, which would assist in advancing science and technology and also assist in the training of the scientists and engineers needed to address the nation's accelerator and beam physics requirements. The major problem which NRL faces with respect to accelerator physics is our inability to recruit and retain high quality pulse power engineers and RF engineers. Over the years, the Laboratory has seen a significant fraction of its capabilities in this area suffer attrition through retirement. The Laboratory has been unsuccessful in replenishing this capability. We have also been unsuccessful in getting the serious attention of universities with regard to training pulse power and RF engineers. We have also found industry to be less than enthusiastic about undertaking high risk innovative programs which would lead to rebuilding the nation's RF power engineering capability.

For some reason, we do not seem to be able to convince youngsters that the accelerator physics business is an exciting, innovative business. This is puzzling, since we have a number of marvelous opportunities emerging. For some reason, we are doing a poor job in making our case. I think this syndrome manifests itself in a far broader sense than beam physics and accelerator physics. As a nation, we do not seem to be doing an adequate job in convincing youngsters to go into the fields of science and engineering. We at NRL, and I am sure most of you in the audience, have programs which are geared towards convincing high school students and college students to enter scientific fields of interest to us, and to consider employment at our institutions. While this is desirable, I do not think it goes far enough. By the time a youngster has entered high school, he or she has already made a number of decisions which may have foreclosed opportunities for them to move into scientific or engineering careers. I have become convinced that we need to begin our programs in the elementary schools before the youngsters have really made up their minds, or perhaps have inadvertently made some decisions which preclude scientific and engineering careers. I believe the federal laboratories need to undertake a program to bring their considerable collective capabilities to bear upon reaching elementary school children with the intention of convincing a larger number of them that scientific and engineering careers are fulfilling.

F. Comments by James E. Leiss

There is at present a very real shortage of trained scientists and engineers and of accelerator design knowledge for the many growing applications of accelerators in scientific research, national defense and industry. This problem has been brought about by the rapid growth in the application of accelerators in recent years, and by the fact that many of the communities using accelerators are not contributing a fair share to the development of the necessary people and basic knowledge.

In the period just after the second World War a major supporter of accelerator research was the Department of Defense, mainly through the Office of Naval Research. Other agencies including the National Science Foundation and particularly the Atomic Energy Commission-Department of Energy contributed substantially, especially in their High Energy Physics and Nuclear Physics programs. However the number of agencies participating in general accelerator research and training has fallen substantially during the last decade or so, and at present the principal support which is not specific project related comes from the Department of Energy High Energy and Nuclear Physics research programs. The Department of Defense through its SDI program is also supporting advanced accelerator development, but very little support goes toward the training of new accelerator scientists and engineers. Also, very little support is provided by American industry to the training of people or for advanced accelerator development.

The above situation is in sharp contrast to the present and growing trends in the applications of accelerators. The High Energy and Nuclear Physics programs continue to need advances in accelerator science and newly trained people; however several other fields are now actively using very advanced accelerators. Consider some examples. The number of synchrotron light sources for research in a number of fields of science and in industry is growing rapidly. Furthermore, the sophistication of these sources in their intensity, brightness, and use of undulators and wigglers is also growing. The development of free electron lasers and their many application is another example. The accelerators for these devices require very high beam quality, and for many defense applications very high accelerator currents and beam power. Similarly, applications of neutral beams for strategic defense require beams an order of magnitude improvement in emittance and brightness compared to most other applications.

The situation described above illustrates the growing shortage of trained accelerator scientists and engineers and in development of advanced accelerator concepts. The problem is actually much more severe than generally recognized when the age of the work force is considered. A large number of the most talented accelerator scientists and engineers are nearing retirement age and within the next decade will no longer be active in the field. Very little is being done to provide replacements for these individuals. The increased sophistication of many advanced accelerators requires considerable research effort and in some projects there exists the risk that performance will fall short. Yet in many cases projects are funded without funding the necessary parallel research efforts and developing the necessary accelerator science support groups.

It is clear that many agencies should be concerned that the situation described above be corrected. Some of these agencies such as the National Science Foundation, the DOE Basic Energy Sciences programs, the National Institutes of Health, the Department of Defense, and American industry have not been supporting the general accelerator development efforts and scientist and engineer training which is needed. It is in the vested interest of these agencies to consider what they should do to correct this situation.

G. Comments by Michael Knotek

I would like to make the following points upon which one could now act:

1) There is a decided shortage of accelerator scientists and engineers, even in the absence of major new projects. Somehow this needs to be remedied if we are to mount these new projects without massive disturbances to the community. It will require a new strategy and concerted action of all the major laboratories.

2) The educational institutions have done a miserable job of putting out students. Whether it is ultimately the fault of the HEP management is not clear, but someone must

start to fill the pipeline soon and keep it full for the next decade or so.

3) The major professional societies have a role in advertising the opportunities and making the young and not-so-young aware that they can get on board.

4) Industry can be enlisted to help solve the skill gap and solve some of the manpower peaking problems over the next decade. It could also help to redress our poor technology transfer performance over the past couple of decades.

5) Most of these strategies require putting more money into the educational system at several levels. In particular the leaders of HEP and Synchrotron Radiation need to demonstrate their interest by putting their money where their problems are.

H. Comments by Helen Edwards

Over the years we have tried to build, operate and improve high energy accelerators with a scientific staff of individuals who have been recruited (co-opted) primarily from the high energy physicist community. This transition is made usually in an individual's career after completion of the Post Doctorate stage. Thus, most people start their accelerator career a number of years after their Ph.D. and with no formal education or experience specific to accelerators. Though this approach has a certain charm in attracting mavericks and those truly interested because of the difficulties involved in the transition from high energy physics, obviously it is not optimized for producing sufficient numbers of physicists well grounded in the fundamentals of accelerators.

We should set up a system for attracting physicists and engineers into the accelerator field earlier in their careers or academic training. A fellowship program starting with 1st and 2nd year graduate students which would provide recipients with financial support without the burden of assistantship work, would be a start to try to attract people who would in all probability then go on to get their degrees in Accelerator Physics. The program should involve summer work at the national labs where students could get hands-on laboratory experience working under supervision of physicists and engineers there. It would also include attending Accelerator Summer School courses.

Students could then select thesis topics that would be pursued at one of the National Labs, and have adjunct advisors from that lab. Support for this phase might be possible from the labs or DOE.

The potential pool of students might come from many universities including those university members of organizations such as AUI, URA, SURA, TAC, etc. as well as universities involved in a variety of accelerator based activities such as in light sources, etc. We would need the backing of the Universities and their engineering and physics professors to get the candidates identified and into the program. The program would be most healthy if there were free competition and cooperation from all the labs as to where students could go.

Support for such a program should be sought not only within the academic, national lab and federal areas, but also from industrial sources which have specific interest in accelerators such as the light sources.

A program directed at the graduate level is by no means sufficient. We must take every opportunity to interest young people as early as possible. High school is usually the time when people really get interested in science. Tours, summer programs, courses, self-motivated science displays, etc., all need as much personal support as we can give.

I. Comments by F. Russell Huson

The U.S. is faced with a shortage of accelerator physicists. There are many large accelerator projects on the horizon. Examples are, CEBAF in Virginia, Advanced Light Source in Berkeley, SSC in Texas, RHIC Project in Brookhaven, 7 GeV Light Source at Argonne National Laboratory, upgrade at FNAL, SLC at SLAC, a variety of other projects in high energy and nuclear physics, and smaller accelerator projects in medicine, industry and defense. One day the military could become an important factor; for example free electron lasers and a high power linac for tritium production. Most U.S. universities, particularly the top universities, have not implemented accelerator physics into their physics departments. Even though modern accelerator physics was started by E.O. Lawrence at Berkeley, the University of California has never had an official accelerator program. Stanford University has had SLAC accelerators nearby for many years and yet has not instituteded an accelerator course in physics. MIT and Harvard have had an accelerator laboratory nearby but have not initiated accelerator programs in their departments. Accelerator programs have existed at Cornell University as well as at Maryland and Wisconsin.

During the past five years the Texas Accelerator Center has been able to establish an accelerator physics program connected with four major Texas universities: Texas A&M University, Rice University, University of Houston, and The University of Texas at Austin. Fifteen PhD students are now working on thesis projects and one student has completed a PhD. This program is about equal to all other programs in the U.S. The university administrators in the southwest are very receptive to adding an accelerator physics program to their curriculum.

It has been found at TAC that industry is anxious to collaborate with the university based research laboratories. TAC has had successful collaborations with General Dynamics Corporation on long superconducting magnets; on linear accelerators with Grumman Corporation; on superconducting magnet research with Bechtel, General Electric, and General Dynamics; on Superconducting Magnetic Energy Storage with General Dynamics; on high field superferric magnets with General Motors; and with Baylor Medical Center on development of new superconducting magnets for MRI.

I would strongly recommend that the Office of Research in the Department of Energy set up a separate group for funding accelerator research and education of students. Accelerator Technology and related subjects cover many of the U.S. government's missions; examples are high energy physics, nuclear physics, free electron lasers, synchrotron light sources, SDI accelerators, heavy ion accelerators, etc. It has been recommended by high level DOE high energy physics committees that DOE put 4% of its operating budget into accelerator research. If this were done in general at DOE, approximately $50 million a year would be available for general accelerator research and education of students in accelerators. Approximately 10 laboratories such as ours could be funded. This would provide 40 or 50 PhD students per year after an initial five year investment. It would take another five years just to produce the accelerator physicists required for the SSC!

J. Comments by Hermann A. Grunder (who was unable to be present at the panel discussion).

Accelerator Physics as a Profession: Accelerator physics has become a scientific profession in its own right. Besides its complex and intriguing uses of classical and quantum mechanics, electromagnetism, and statistical mechanics, this field has a unique combination of intrinsic characteristics: it is both interdisciplinary and international. It is naturally interdisciplinary in that it encompasses a mixture of science and engineering. Through its connection with sciences and advancing technologies around the world, it is naturally international. What follows is my view of the status of, and outlook for, accelerator physics as a profession.

In the six decades since Lawrence first accelerated protons to 80 keV in a device that could be held in the palm of a hand, accelerators have grown and proliferated. So have the opportunities and challenges for those who study them, design them, and build and operate them - not to mention those who use them. Table 1, an informal compilation, gives a sense of the variety and scope of major accelerator initiatives worldwide. Each line of the table represents, roughly, a region of the globe.

Table 1
Accelerator Initiatives Worldwide

High Energy Physics

LEP, HERA, CLIC, LHC
Tevatron, SLC, SSC, TLC
TRISTAN, BEPC, JLC
UNK, VLEPP

Nuclear Physics

SIS, Frascati, SIN, Mainz, NIKHEF, ALS
CEBAF, MIT/Bates, RHIC, KAON Factory
BEP/VEPP2M, Moscow Meson Factory, Kharkov/PSR, Troitsk

Dedicated Light Sources

Aladdin, NSLS, ALS, LSY, APS
BESSY, Daresbury (2 GeV), ESRF, Trieste
Photon Factory, Taiwan (1.3 GeV), Korea (2 GeV), Japan (8 GeV)
VEPP-3, Moscow

One can also gain a sense of the variety and scope of present-day accelerators by noting what this table does not even try to reflect: the many smaller research machines as well as FELs, medical accelerators, and industrial synchrotron radiation sources.

A useful distinction can be made between two types of accelerators for physics research. One type includes world-class facilities with unique characteristics and capabilities. At any one time we can have only a few of these, and experimenters may travel great distances to use them. The other type is the regional "workhorse" facility, providing valuable research opportunities to greater numbers of experimenters.

Accelerator capabilities determine which experiments can and cannot be done. The diversity of beam requirements for experimental physics offers unique challenges for designers of storage rings and colliders, linacs and linear colliders, lights sources, and FELs. And just as accelerator capabilities determine possible experimentation, the state of the technological art determines which capabilities are achievable. The challenges for the profession of accelerator physics are therefore not only scientific, but technological. Table 2 is my list of today's technological frontiers for accelerator physics.

Table 2
Technological Frontiers

Superconducting magnets	Beam cooling
Superconducting rf cavities	Rf power sources
Wakefield acceleration	Polarized beam sources
Instrumentation & control sources	High-intensity beam
Lenses	Positron production

My experience suggests that accelerator builders should be keenly aware of how much expansion they are demanding on the technological frontiers. It is good to push one or two technologies to the limit, but not more. At the same time, it is good for an accelerator initiative to strive for significant improvements over the performance of previous machines. The focus must remain fixed on the physics to be done - that is, on the requirements of the user and every effort should be made to build a machine that is understandable. By "understandable" I mean a machine of manageable intellectual complexity.

With these general requirements setting the context, I would suggest the following as the specific elements needed for successful accelerator development:

- Bright, enthusiastic people who know what they are doing.
- Close collaboration between accelerator designers and experimentalists.
- Innovative technologies.
- A direction and a plan.
- Adequate funding through the commitment of government.

The last of these is least in our own hands as accelerator physicists and engineers. At the same time, however, as members of a scientific profession with a growing record of significant successes and contributions, it is not at all beyond our reach to influence this commitment.

The way to ensure that these successes and contributions continue is to strengthen accelerator physics as a scientific profession. By deciding in principle to establish a Division of Beam Physics, the American Physical Society is recognizing the importance of moving in this direction. As with any science, however, a strong professional community must also have formal training programs and independently funded research. It is encouraging to see accelerator physics curricula now being initiated in the universities; one hopes to see more. Independently funded research programs - in the universities and major laboratories, as well as the smaller laboratories, possibly in cooperation with industry in some cases - will also strengthen the profession. With new Ph.D.-level specialists and with strong programs of basic research in accelerator physics, the field will continue to flourish.

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