Report on the Panel Discussion on Future R and D Cooperation

Andrew M. Sessler
Lawrence Berkeley Laboratory
University of California
Berkeley, CA 94720, USA

I. Introduction

On May 17, 1984 there took place a panel discussion on Future R and D Cooperation, with members of the panel G. Brianti, Y. Kimura, M. Tigner, G-A. Voss, V.A. Yarba and chairman A.M. Sessler. In this brief report I will describe the main points covered in the presentation and, then, the audience response to that presentation.

The meeting opened with the chairman remarking that the primary purpose of the ICFA Seminar was, in fact, cooperation. Not, he hastened to add, cooperation for its own sake, but because some of us feel that it is good for high-energy physics. Is this really true ? Is cooperation good, or does it cut down on competition which is essential to the health of our science ? Thus, it was proposed that the first topic to be addressed be just this of whether or not more cooperation was called upon.

It was noted that in industry, where the product is money, not new knowledge, it appears that cooperation is advantageous and most of the governments of the world have regulatory agencies to prevent undue collision: "trust breakers", "cartel destroyers". Yet the balance is delicate: forced cooperation doesn't appear to work and undue competition can be counterproductive.

So, first it was necessary to examine R and D on accelerators so as to judge whether, or not, more cooperation is called upon. All of us would agree that the competition of the past has been beneficial, even essential, to our field, but perhaps it has been, or is now excessive.

Thus, the first three items were placed upon our agenda. (Items II, III, IV in the Outline)

Our examination of the past suggested the need for new mechanisms and a particular scheme was proposed. (Item V and the Appendices) But, of course, the Panel only consisted of five people and it was very important to obtain the audience reaction to the proposal. This reaction is covered in the final section (Item VI).

II. A Brief Look at the Past

Each of the Panel Members, in turn, gave a 5' to 10' presentation of anecdotal information concerning R and D cooperation experiences in his country. This information was not comprehensive, often personal in nature, but served to illustrate the extent, variety, and effectiveness of past cooperation.

In this report we will not include this material; for, as I have noted, it was not comprehensive in nature. It did, however, perform a useful purpose in the overall presentation; for it gave the audience a good "feeling" for the present degree of cooperation.

III. A Survey of R and D Activities in the US

In order to understand the extent and nature of R and D on accelerators, the "advanced" portion of accelerator R and D in the US was presented. The "advanced" reseach is not that research, both theoretical and experimental, which is directed towards improving the day-to-day operation of accelerators or storage rings. This work tends to be the development of solutions to specific facility-related problems. Rather, "advanced" research is that which is directed towards solution of general problems and hence the extension of accelerator technology.

Thus the following list, which only includes "advanced" items, tends to be a bit arbitrary, because there is no clean line between accelerate R and D and advanced accelerator R and D.

National Laboratories

Argonne National Laboratory

Advanced R&D on H^- sources, wakefield effects, and phase space cooling (electron and stochastic). Development of advanced superconducting magnets for use in high energy beam transport systems has been done and the laboratory supports an advanced capability in superconducting RF acceleration under its program in nuclear physics.

Brookhaven National Laboratory

Advanced R&D capability and facilities to support all phases of superconducting magnet and wire development. Special R&D capability in H^- sources, laser accelerators (inverse free electron and grating accelerators), radio frequency quadrupole, large cryogenics systems, RF systems, ultrahigh vacuum technology, beam instrumentation, and advanced computer control systems.

Cornell University - Wilson Synchrotron Laboratory and Newman Laboratory of Nuclear Studies

Development of advanced superconducting RF systems, special beam instrumentation, and theoretical studies of collective effects and wakefields in electron positron storage rings and advanced devices such as grating accelerators.

Fermi National Accelerator Laboratory

Advanced R&D capability and facilites to support all phases of superconducting magnet and wire development. Special R&D capability in phase space cooling of particle beams (stochastic and low and intermediate energy electron cooling), H^- ion sources, antiproton source technology, large cryogenic systems, RF systems, advanced power supply systems, and advanced computer control systems.

Los Alamos National Laboratory

Special R&D capability in theory and hardware development of radio frequency quadrupoles. Special R&D capability in H^- ion sources, beam instrumentation, RF systems, laser accelerators (inverse free electron laser and beat wave acceleration), RF systems and specialty electronics.

Lawrence Berkeley Laboratory

Advanced R&D for superconducting magnets and wire development with special emphasis on very high field ($B > 8$ T) magnets and on the use of super-fluid helium cooling of magnets. Theoretical studies and hardware development of stochastic cooling of particle beams. Special capability in superconducting materials, beam instrumentation, RF systems and computerputer control. Theory group is particularly strong in magnet lattice design for accelerators and storage rings, long-term orbit tracking, nonlinear beam dynamics, and collective phenomena.

Stanford Linear Accelerator Center

Advanced R&D capability and facilities to support all phases of electron linac development with special emphasis on iris loaded wave guide structures. R&D

in high power RF sources with extensive special tube fabrication capability. Active program of high power klystron technology. Special R&D capability in surface physics of conventional and superconducting RF structures, superconducting RF acceleration systems, beam instrumentation development, advanced computer control, RF systems, advanced power supplies, electron gun development, and high gradient accelerating structures. Special program of R&D on large linear collider technology. Theory group has special capabilities in nonlinear beam dynamics, beam-beam interaction, wakefield phenomenon, numerical computation and simulation of electron guns, advanced magnet lattice and beam transport system design, and polarization phenomenon in storage rings.

Special Research Projects

Brookhaven National Laboratory - C. Pellegrini
Theoretical and computer simulation studies of the inverse free electron laser and the similar "two wave" device. The study includes the development of conceptual designs of these devices.

University of California at Los Angeles - C. Joshi and F. Chen
Theoretical and experimental study of the laser beat wave accelerator.

University of California at Santa Barbara - J. Fontana
Theoretical study of the physics of laser acceleration of charged particles via the inverse cerenkov effect including the use of analytic and computer simulation techniques to study the effects of multiple scattering, breakdown discharge threshold, and laser power density.

Clarkson College - T. Bountis
Theoretical study of the nonlinear dynamics of particle beams in electron-positron storage rings with special emphasis on applying the analytic techniques of current nonlinear mechanics research to the development of comprehensive models of the beam-beam interaction. The research includes a comparison of computer simulations with actual storage ring performance.

Columbia University - W.Y. Lee and R.R. Wilson
Study of the accelerator and storage ring requirements for an electronproton

colliding beam facility with special emphasis on accelerator physics problems effecting luminosity and electron beam polarization and on problems related to carrying out physics experiments with such a facility.

Cornell University - L. Hand
Theoretical study of accelerator physics issues involved in the design of an isochronous storage ring free electron laser and its use as an intense source of radiation.

Cornell University - J. Nation
Theoretical and experimental study of the acceleration of positive ions using slow space charge waves propagating on weakly relativistic, high current electron beams. The theoretical studies involve extensive simulation by Cornell and by Mission Research Corporation as a subcontractor to Cornell. The experimental apparatus provides a demonstration of staging in a collective effect accelerator.

Georgia Institute of Technology - J. Ford
Theoretical and computational investigations of the mechanisms of slow diffusion in undamped and damped oscillating systems. This work uses the techniques of theoretical nonlinear mechanics to study the effects of diffusion and storage ring parameters on stability questions related to the beam-beam interaction in electron positron storage rings.

Houston Area Research Center - R. Huson and P. McIntyre
Design studies of superferric magnet technology and associated support systems and accelerator physics questions in support of the U.S. National study of the proposed Superconducting Super Collider. Houston Area Research Center is the management and contracting representative for a consortium of unversities and U.S. national laboratories formed for the purpose of carrying out this particular R&D study.

University of Illinois - R. Dowing
Development of special circuits, software and protocols for the Fastbus instrumentation standard developed for high energy physics.

Lawrence Berkeley Laboratory - A. Sessler

Theoretical and computational studies of the "two beam" accelerator concept in which one beam of low energy very high current electrons is used to generate one intense RF pulse which is in turn used to accelerate a high energy low current electron beam. Work is in collaboration with Lawrence Livermore National Laboratory (LLL) and is expected to lead to an experimental test of the two beam accelerator concept.

Los Alamos National Laboratory - S. Singer

An experiment using the Helios laser to generate space charge waves in a plasma and a search for "hot" electrons emitted by such a plasma. Also includes theoretical computations and simulations. This work is part of the R&D effort to study the plasma beat wave concept.

University of Maryland - A. Dragt and R. Gluckstern

Task A, Dragt - Theoretical and computational studies of charged particle beams in transport lines, accelerators and storage rings using Lie Algebraic techniques. Includes further development of the Lie algebra method, which was pioneered by Dragt in this application for the purpose of developing a new, more effective method of handling nonlinear phenomena in magnet optical systems.

Task B, Gluckstern - Development of advanced methods for the computation of electromagnetic fields in cavities and permanent magnets and their application in transport systems, accelerators, and storage rings.

University of Maryland - M. Reiser

Task A - Experimental and theoretical study of instabilities and emittance growth of low energy, space charge limited particle beams in periodic focusing channels.

Task B - Experimental and theoretical study of collective ion acceleration in slow wave structures and in pulse powered plasma focus devices.

Massachusetts Institute of Technology - Y. Iwasa

Development of acoustic emission diagnostic techniques and associated instrumentation and methodology for analyzing the performance of high field, high current density superconducting magnets.

Mathematical Sciences Northwest - J. Slater

A study of laser and related technology as applied to the acceleration of charged particle beams. The purpose is to assess the suitability of present laser technology for use in various proposed laser acceleration schemes, identify and describe special devices or techniques of particular interest and indentify special problems and shortfalls which require R&D.

National Bureau of Standards - L. Costrell

Development of the new interface and instrumentation standard for high energy physics known as "Fastbus". (cf. DOE/ER-0189, "Fastbus, a Modular High Speed Data Acquisition and Control System for High Energy Physics and other Applications", December 1983.)

National Bureau of Standards - A. Clark

R&D in support of the development of "consensus standards" for the properties of superconducting materials.

Naval Research Laboratory - P. Sprangle and C.M. Tang

Theoretical studies of the laser beat wave and inverse free electron laser concepts. Development of fully-relativistic, nonlinear one dimensional model of the formation of plasma waves in the beat wave device and extension of this model to include stimulated two-dimensional processes. Study of the special problem of focusing of intense laser beams over extended distances and application of this to the inverse free electron laser concept.

Physical Dynamics - R. Helleman

Theoretical study of the long term stability of particle orbits and beams in accelerators and storage rings. A combination of numerical particle tracking with recently developed analytic methods involving the concepts "invariant tori" and "basins of attraction" used in the study of stochastic systems.

Supercon Inc. - J. Wong

Development of the metallurgy, fabrication processes, and quality control methods for the development of an advanced Nb_3Sn superconducting wire for application in very high field dipole magnets for high energy physics.

University of Wisconsin - D. Cline

Experiments and theoretical study of the problems of "intermediate energy" electron cooling of particle beams in storage rings at proton energies above 1 GeV. Being carried out in collaboration with Fermilab (F. Mills) and the National Electrostatics Corporation (M.L. Sundquists).

University of Wisconsin - D. Larbelestier

A study of the basic relationships which exist between fabrication processes, the metallurgy, and the resulting critical current density in NbTi superconducting composite materials. The purpose of the study is to raise the critical current density of NbTi materials used in the fabrication of superconducting magnets for high energy physics. An extensive interaction with U.S. superconducting wire manufactures to understand the impact of production processes on wire performance and to improve quality control is part of the study.

IV. A Categorization of R and D

Recently, there was convened a Technical Sub-Panel on International Cooperation in High Energy Physics. That Panel, following the suggestion of Burton Richter, produced a categorization of R and D cooperation which is helpful to those thinking about the subject.

They defined three classes of R and D work:

A Parallel R and D

No joint funding, no formal coordination.

Information exchange through meetings, reports, visits (this has been highly effective and represents 94±5% of our collaborative effort. Examples: Accelerator design, strong focusing, superconducting magnets, accelerator theory)

B Collaborative R and D

Two or more groups pool resources (money, people, installations) (e.g. superconductive rf work between DESY, CERN, Karlsruhe).

C Coordinated R and D

Work gets divided among participating group.
(Sometimes formal agreements are made, but more often there are informal agreements such as that on superconducting rf between CERN-DESY-Univ. of Wuppertal).

V. A Proposal: ICFA Sponsored Standing Panels

It was the view of the panel that a more formal system of cooperation is called for. We proposed that ICFA sponsors such a mechanism, which could take the form of groups of working scientists, meeting on a regular basis, to share information, to exchange results, to divide up (on a voluntary basis) tasks, to motivate particular research, etc.

The specifics will vary from activity to activity. Note that we didn't propose setting up one group, a super HEPAP or Wood's Hole, but rather many groups. How this might be done, in some example working groups, was discussed by members of the panel and is included, here, as Appendices A through E.

VI. Audience Reaction

The audience reaction was quite favorable to the proposed scheme. A number of important points were, however, raised in the discussion:

It was emphasized that publication of information was an important activity. The various panels must inform others of their existence, and where various activities are underway, especially as to include new people in their work.

It was pointed out that a panel on New Acceleration Schemes should not restrict, or dampen, crazy ideas.

There was considerable discussion about "facilitation" vs. "planning". It was difficult for me to clearly understand this difference, but it was very clear to me that the audience did not want the proposed panels to become "heavy handed" and restrict the initiative of the various laboratories. Of course, we agreed with this, but noted that the active participants on one of the ICFA Panels might well agree to have certain groups carry out some work, while other groups carry out different work: i.e., engage in "planning".

There was discussion of commercialization, both a recognition of the problems this presents and a hope that the proposed panels might, especially by setting standards, facilitate this process.

There were some remarks, on a very high plane, concerning the fragility of the present human condition and the hope that the proposed panels, although small steps, indeed very small steps, in the direction of international cooperation were, nevertheless, in the correct direction and that they should be taken. This spirit was echoed by a number of other participants from the audience and the discussion closed on this very positive note.

Appendix A: Development of Superconducting Magnets and Cryogenics

G. Brianti

After two decades of development of superconducting magnets, a number of very important achievements have been made in the last few years. The most significant of these is the Tevatron at Fermilab. Very successful prototype magnets have been built for HERA, UNK and the proton ring of Tristan. All this work demonstrates that large superconducting magnet systems can be built and operated. This permits not only to increase the beam energy in a given tunnel, but to reduce the investment cost per Tesla meter, and even more the power consumption. The magnet systems mentioned above operate at field levels of 4 to 5 T. The development should continue toward higher fields of 8 to 10 T with adequate current density. It is indeed very important for small bore magnets (40 to 50 mm inner diameter of coil) to achieve overall current densities in the coil cross-section as high as possible (300 to 500 A mm^{-2}), which in turn implies current densities in the non-copper part of the wire of 1,300 to 2,000 A mm^{-2}.

Two lines of development are open here: Nb_3Sn of ∿ 4.5°K and NbTi at ∿ 2°K. In principle the most promising material is Nb_3Sn because of its higher critical field and temperature (more relaxed cryogenic system). Its drawback is brittleness and fragility, which requires either final reaction of the composite to obtain the superconducting state after winding, or else magnet coils wound with relatively large radii using pre-reacted material. The alternative line of development is to use NbTi conductors at lower temperatures (∿ 2°K). The advantage is that the material can be wound in the reacted state, but the disadvantages fall on the cryogenic system. An assessment should be made as to whether or not a 2°K cryogenic system is practical and economically acceptable for multi-Tev hadron colliders.

The development of high field magnets consists of different phases:

1) definition and production of new enhanced superconductors and their testing
2) model work on coil packages, force retaining structures, etc.
3) prototypes for a given well-specified project.

The international coordination, or eventually collaboration, would be most profitable and probably easier to organize for phase 1) and, possibly, for phase 2) than for phase 3).

Proposal to ICFA

To encourage the formation of an international group of people active in the field to:

i) review progress, enhance exchange of information, etc. (Parallel R and D)

ii) promote sharing out of work and attempt to avoid duplication (Coordinated R and D)

iii) constitute the possible frame-work for collaborative R and D.

Appendix B: Uses of rf Superconductivity

M. Tigner

As we struggle to find ways of making economical but very high energy accelerators, the understanding of how we might exploit rf superconductivity for this purpose is important. Our understanding of this technology is now such that it will be used extensively in the generation of electron storage rings now being built. In looking beyond these machines to make higher energies, there are two major questions which must be answered about the further potential of rf superconductivity: How might we exploit it and can we achieve its theoretical peak performance in large apparatus. These break down into number of scientific and engineering questions which must be addressed. Under the rubric of scientific questions are those having to do with performance limits: to what basic and proximate causes can we attribute the socalled residual losses which limit Q's, what is the nature of the high field surface losses and, is there a fundamental limit to Q's below the critical fields, what is the physical and chemical nature of the magnetic breakdown centers that are observed. Spanning the categories of scientific and engineering questions are questions about materials: can we improve the quality of the niobium we use, can we exploit the potentially even more effective materials such as niobium-tin and other A15 components, can we learn to engineer complex surfaces to produce a stabilized homogeneous current-carrying layer exhibiting only the BCS losses. Engineering questions of great weight are: what are appropriate modes of exploitation such as storage rings, linacs, hybrids excited either continuously, or in a pulsed fashion; what are the best structures and rf circuits, what are the best fabrication and repair methods, what are the best surface preparation methods. In addition to these issues there remains the need to develop much better instrumentation for dealing with surface phenomena in a cryogenic environment.

All of these are difficult questions whose resolution will require the devotion of significant resources, particularly physicist manpower resources. Currently there are a number of groups around the world, each addressing some of the substantive issues. They are in good contact with each other and frequently exchange manpower and material resources. Of great utility have been ad-hoc Workshops arranged by verbal agreement among the participating groups, the next one to be held at CERN this year. Also of considerable help have been special sessions of the various accelerator conferences. There have been a few semiformal and formal collaborative efforts which have been and continue to be useful.

Voluntary association of institutions carrying out this work, into a standing ICFA panel on exploitation of rf superconductivity could serve in two ways. The panel could formalize the ad-hoc workshop activities to promote the widest possible participation in this branch of AARD and could serve as a forum for discussion of voluntary coordination of R&D activities to enhance effectiveness of resources used in the work.

While it is clear that the best possible information exchange and cooporation are absolutely necessary, we must not lose sight of the fact that many of the problems to be addressed are of great scientific difficulty. Thus in carrying out our duty to minimize wasteful duplication of efforts and facilities, we must take care to cultivate individual initiative and ingenuity.

Appendix C: Surface and Material Physics Related to Accelerator Technologies

Y. Kimura

Recently research on surface and material physics is most relevant to accelerator technologies such as UHV beam chambers, high gradient accelerating structures, high power tubes, and rf superconducting devices, which are vital to raising the possibilities and removing the limitations of high energy accelerators. The followings are some examples of such subjects.

1) Preparation of low out-gassing surface for UHV applications.
2) Preparation of surface which stands very high field gradient in UHV.
3) Surface phenomena associated with irradiation by particle beams and synchrotron radiation.
4) Ceramics for UHV and high power rf devices.

These items are associated with different fields of research, but in some sense they face common problems. Those are, for example, gas adsorption and desorption, field emission, secondary electron emission, surface glow discharge, and so on. Resolving those problems will require technical developments in preparation of new materials, heat, chemical and/or electrical treatments, and surface coating.

Research on such subjects has, however, been done on a small scale, and rather independently in each laboratory, or separately in each research field, so far. Then, we propose that ICFA plays a role of finding a way to promote an international exchange of informations and peoples on those subjects.

Appendix D: Beam Dynamics

G-A. Voss

In the past accelerators were built with rather limited understanding of all the effects which might have an influence on their performance. The result was, that in almost all new machines new effects were observed which needed careful experimental and theoretical analysis in order to solve the problems they posed for machine performance. As individual bunch currents increased, with the introduction of sophisticated new machine optics, with the increase in size of these new accelerators and storage rings, a host of new phenomena appeared: Instabilities, resonances, beam-beam interactions and many others. It often took a very large effort to understand these new phenomena and it was not always possible, despite great efforts, to reach the original design goals of the new machines. The description of these effects in analytical terms is often quite difficult. On the other hand modern computers have reached capabilities, which make it possible to simulate particle bunches, calculate exactly the fields they produce and which after interaction with the accelerator environment may act back on the particle bunches. This mutual interaction can be simulated over many turns. This then gives a very realistic picture of the beam behaviour.

Computer simulations may be the only way to analyze complex phenomena such as:

i) Chromatic corrections and their effect on acceptance.

ii) Effects of nonlinear field errors (to establish, for example, the required quality of superconducting magnets).

iii) Beam-beam interactions in storage rings (An area which, for example, is widely unexplored is the incoherent beam-beam interaction limits for bunched beams in a crossing geometry).

iv) Instabilities (single bunch instabilities of a new and unexpected kind have begun to plague electron storage rings, as their size increased). Coupled synchro-betatron resonances (They seem to assume more and more importance in circular electron machines, as bunch currents and radiofrequency voltages increase).

This is only a small sample of the problems, which need to be solved before a very large new project is started bacause the remedies for these problems may be too expensive to be installed after such large machines are completed. The problems cited are important to many laboratories and to many new projects (SSC, HERA, TRISTAN, LEP, UNK etc.) On the other hand computer simulations require a large amount of computer time, particularly for proton machines, for which many turns have to be calculated. A collaboration in this area would therefore be very beneficial. In a collaborative R&D effort momey and people should be pooled, to do these calculations on the most suitable computer. A coordinated program might help to get work divided among the participating groups.

Almost as important as computer simulations are experiments on existing machines to check the validity of these calculations. An agreed-on multinational and multi-laboratorial program will carry more weight and will have a better chance of being made part of a laboratory's machine program.

Other areas for an ICFA sponsored panel on beam dynamics might be beam dynamics in linear colliders and work on beam polarization. The effect of common R&D effort in these areas might be better communication and avoidance of uncoordinated parallel work.

Apendix E: New Acceleration Schemes

G-A. Voss

Theoretical and experimental work on new accelerator ideas is going on in many places. Some of these are listed in Table I.

At present there are many workshops and special meetings which make the communication in these areas quite good. Despite this there is a valid reason to suggest an ICFA sponsored panel to further work in this areas.

Much of this new work is going on in small groups at universities or small laboratories. The contributions from these small groups are most important. Very often though these groups do not have the equipment and the unique facilities which are necessary for experimental work and which large laboratories have at their command. (for example, high power lasers, rf equipment). A panel on new acceleration schemes might help to coordinate these efforts and be a link between small university groups and large laboratories.

Table I

New Acceleration Schemes

	Exp. work (in progress)	Theoretical. work
Wake field	DESY	DESY
		Japan
		Virginia
		Stanford
Inverse free electron laser		BNL
		NRL
		Stanford
Laser beat wave	NRL	Stanford
	Chalk River	CERN
	Los Alamos	Rutherford
	UCLA	Mission Reseach
	Washington	
	Japan	
Two beam	LBL/LLNL	
Near field (grating LINAC)		BNL
		Cornell
Very high power tubes	Maryland	
	Stanford	
	KEK	