The Philosophical Society of Texas

PROCEEDINGS

1992

The Philosophical Society of Texas

PROCEEDINGS
OF THE ANNUAL MEETING
AT DALLAS

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THE PHILOSOPHICAL SOCIETY OF TEXAS
1993

THE PHILOSOPHICAL SOCIETY OF TEXAS FOR THE COLLECTION AND DIFFUSION OF KNOWLEDGE *was founded December 5, 1837, in the Capitol of the Republic of Texas at Houston by* MIRABEAU B. LAMAR, ASHBEL SMITH, THOMAS J. RUSK, WILLIAM H. WHARTON, JOSEPH ROWE, ANGUS MCNEILL, AUGUSTUS C. ALLEN, GEORGE W. BONNELL, JOSEPH BAKER, PATRICK C. JACK, W. FAIRFAX GRAY, JOHN A. WHARTON, DAVID S. KAUFMAN, JAMES COLLINSWORTH, ANSON JONES, LITTLETON FOWLER, A. C. HORTON, I. W. BURTON, EDWARD T. BRANCH, HENRY SMITH, HUGH MCLEOD, THOMAS JEFFERSON CHAMBERS, SAM HOUSTON, R. A. IRION, DAVID G. BURNET, and JOHN BIRDSALL.

The Society was incorporated as a non-profit, educational institution on January 18, 1936, by George Waverly Briggs, James Quayle Dealey, Herbert Pickens Gambrell, Samuel Wood Geiser, Lucius Mirabeau Lamar III, Umphrey Lee, Charles Shirley Potts, William Alexander Rhea, Ira Kendrick Stephens, and William Embrey Wrather. On December 5, 1936, formal reorganization was completed.

The office of the Society is located at 2.306 Sid Richardson Hall, Austin, 78712.

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One hundred and sixty-one members, spouses, and guests gathered at the Loews Anatole Hotel in Dallas on December 4, 5, and 6 for the Society's 155th anniversary meeting. President William D. Seybold had organized a timely program with plenty of opportunity to enjoy the many seasonal events in Dallas. The Friday reception and dinner was held at the Dallas Country Club, during which President Seybold introduced 14 distinguished Texans as new members of the Society and presented them with their certificates of membership. The new members are Daniel C. Arnold, Houston; Frank N. Bash, Austin; John B. Connally, Houston; Terry Hershey, Houston; Diana Hobby, Houston; Kay Bailey Hutchison, Austin; Marguerite Johnston, Houston; Tom Luce, Dallas; Thomas R. Phillips, Austin; Harry Reasoner, Houston; Walt Whitman Rostow, Austin; Roy F. Schwitters, Dallas; Marilyn Wilhelm, Houston; and Paul Woodruff, Austin.

Working with Dr. Roy F. Schwitters of the Superconducting Super Collider Laboratory, a newly elected member of the Society, President Seybold had organized a thought-provoking program for Saturday on the Superconducting Super Collider. Lunch was served in the Peacock Terrace Room, and the reception and annual banquet was held that evening in the Wedgwood Room of the Loews Anatole Hotel.

At the annual business meeting, First Vice-President Robert Krueger announced the names of the eight members who had died during the past year: Edward A. Clark, Ballinger Mills, Howard Boyd, J. R. Parten, Mark Andrews, Newton Gresham, Thomas Sealy, and Zollie Steakley. Vice-President Krueger also announced that the topic for the Society's 156th anniversary meeting would be the "North American Free Trade Agreement" and that the site for the meeting would be Laredo on December 3-5, 1993. He also announced the 1993 President's Award of $2,000 to be given to the senior or graduate student in a Texas college or university presenting the outstanding original essay on the topic of the annual meeting. The following officers were elected for the coming year: Robert C. Krueger, president; Steven Weinberg, first vice-president; William H. Crook, second vice-president; James Dick, treasurer; and Ron Tyler, secretary.

President Seybold declared the annual meeting adjourned following the Sunday morning discussion, to be reconvened on December 3, 1993.

ATTENDANCE AT THE 1992 MEETING

Members registered included: Miss Hayes, Hill; Mesdames Hutchison, Johnston, Lancaster, Lee, McDermott, Randel, Rhodes, Rostow, Wilhelm, Isabel Wilson; Messrs. Anderson, Arnold, Ashby, Atlas, Paul G. Bell, Bryan, Caldwell, Calgaard, Christian, Conger, Cook, Crim, Cunningham, Curtis, Doyle, Dunagan, A. Baker Duncan, John Duncan, Fehrenbach, Durwood Fleming, Jon Fleming, Galvin, Gordon, Greenhill, Hackerman, Hargrove, Harrison, Hay, Hill, Howe, Inman, Dan Kilgore, W. J. Kilgore, Krueger, Lawrence, Levin, Locke, Margrave, Mark, McCombs, McGinnis, McKnight, Moseley, Mullins, Randall, Reavley, Reynolds, Rostow, Rutford, Schwitters, Seybold, Shuffler, Frank C. Smith, Jr., Sparkman, Sprague, Storey, Sutton, Trotti, Tyler, Wainerdi, Woodruff, Wozencraft, Charles Wright, James S. Wright

Guests included: Mrs. Thomas D. Anderson, Mrs. Dan Arnold, Mrs. Lynn Ashby, Mrs. Morris Atlas, Charles Barnes, Joe Barton, Mr. and Mrs. Dick Bass, Mrs. Paul G. Bell, Mrs. J. P. Bryan, Tom Bush, Mr. and Mrs. Trammell Crow, Mrs. Clifton Caldwell, Mrs. Ron Calgaard, Mrs. Roger Conger, Mrs. C. W. W. Cook, Connie Copley, Mrs. Billy Bob Crim, Mrs. Greg Curtis, Mrs. Gerry Doyle, Gerald Dugan, Mrs. J. Conrad Dunagan, Mrs. A. Baker Duncan, Mrs. John Duncan, Mrs. T. R. Fehrenbach, Mrs. Durwood Fleming, Mrs. Jon Fleming, Peter Galison, Mrs. Charles Galvin, Eli Glatstein, Mrs. William E. Gordon, Mrs. James W. Hargrove, Mrs. Jess Hay, Mr. and Mrs. Ross Hemphill, Mrs. John P. Howe III, Ray Hutchison, Raphael Kasper, Mrs. W. J. Kilgore, Mrs. Dan Kilgore, Mr. and Mrs. Don Koons, Mrs. Robert Krueger, Olin Lancaster, Mrs. Lee Lawrence, Mrs. William Levin, Mrs. John Locke, Mr. and Mrs. Bill Magee, Mrs. John L. Margrave, Mrs. Red McCombs, Mrs. Robert C. McGinnis, Mr. and Mrs. Peter McIntyre, Mrs. Joe McKnight, Morton Meyerson, Tony Montgomery, Mrs. John D. Moseley, Jon Mosle, Mrs. Charles B. Mullins, Peter O'Donnell, Jr., Mrs. Risher Randall, Mrs. Tom Reavley, Mrs. Herbert H. Reynolds, Alec Rhodes, Mrs. Robert H. Rutford, Mrs. Roy F. Schwitters, Mrs. William D. Seybold, Mrs. Frank C. Smith, Jr., Mrs. Robert S. Sparkman, Mrs. Charles C. Sprague, Louise Spurgin, Mrs. Charles Storey, Mrs. John F. Sutton, Jr., Mrs. Robert S. Trotti, James C. Wainerdi, Mr. and Mrs. Peter Wiggins, Wallace Wilson, Ellen Wilson, Mrs. Frank Wozencraft, Mrs. James S. Wright, Mrs. Charles Alan Wright, Mrs. H. B. Zachry

WELCOME AND INTRODUCTION

WILLIAM D. SEYBOLD

WELCOME TO THE 155TH ANNIVERSARY MEETING OF THE PHILOSOPHICAL SOCIETY of Texas. I am William D. Seybold and I have the honor to be President of the Society in 1992. The theme of our program today is Discovery—the discovery of new knowledge about the structure of our universe, the structure of minute particles that make up the whole of it—more specifically about the role of the Superconducting Super Collider (SSC) in that quest.

Nineteen ninety-two is the year we are also celebrating two discoveries that changed our world: the 500th anniversary of the discovery of the New World by Christopher Columbus in 1492 and the 400th anniversary of the appointment of Galileo to the faculty of the University of Padua. Columbus set out to discover a new route to India. What he found was infinitely more valuable. Galileo set out to study the motion of a few planets. Along the way he invented the telescope and made discoveries about our universe that changed our concept of the world completely. Such is the great excitement about the search for truth. In that search unexpected rewards are commonplace, and mankind always comes out ahead.

The work of Galileo is having a direct effect on our attendance today. On this very weekend, Doctor Steven Weinberg, our second vice-president, Nobel Laureate in Physics, is at the University of Padua for a celebration of Galileo's appointment to its faculty in 1592. He is there to give the keynote speech and to receive an honorary degree from that venerable institution. I might add that he was a great help in planning this program and in recruiting some of the outstanding scientists and educators who are to address you. He regrets that he is not here.

The perpetual promise of the rewards of new knowledge, of new understanding, is what brings the Superconducting Super Collider into being. It is the largest, most complex, and most ambitious scientific instrument yet conceived. It is under construction right here in our midst.

The WHY, the WHERE, the WHO, and the WHAT of the SSC, as described for us today by some of the foremost men in the endeavor, constitute our program today.

It promises to be a fascinating, stimulating presentation, one that should provoke great interest and lively discussion.

There are four panels. Our first panel deals with the WHY of the SSC. Dr. Roy F. Schwitters, who's one of our new members, by the way, is the director of the laboratory. And he's been most helpful to me in putting this program together. As a matter of fact, without him, we wouldn't have the fine program we have today. He is a former professor of physics at Harvard. He is the former associate editor of the *Annual Review of Nuclear and Particle Science* and a fellow of the American Physical Society, the American Association for the Advancement of Science, and the Academy of Arts and Sciences. He was awarded the 1980 Allan T. Waterman Award of the National Science Foundation. He is an eminent physicist, and I present him with great pride as our moderator this morning and our keynote speaker for this conference on Discovery. Dr. Roy Schwitters.

THE SUPERCONDUCTING SUPER COLLIDER WHY?

I

Roy Schwitters

Some 200 feet beneath the prairies and farms of Ellis County, Texas, a tunnel is under construction that, when completed a few years from now, will stretch 54 miles in circumference to house the world's largest scientific instrument, the Superconducting Super Collider, or SSC. Large even by Texas's standards, such a scale is normally associated with mankind's largest structures, like highways encircling major metropolitan centers, rather than the smallest distances that can be imagined. Yet the SSC is being built to explore the structure of subatomic matter and the nature of forces at distances far smaller than a single proton.

When completed at the end of this decade, the SSC will become the principal research focus for a major fraction of the 2,000 American high energy physicists and many more from abroad. Its detectors and accelerators will provide unique scientific opportunities well into the next century. The SSC is already developing and will continue to develop as a resource for science education at all levels.

Befitting its huge scale, the story of the SSC has reached epic proportions. The stakes—scientific, economic, and political—are high. For the past generation, the scientific need for the SSC has been clear, but the worldwide competition to discover new physics beyond our current understanding is stiff. For the past decade, the U.S. high-energy physics community has placed the SSC at the top of its priorities, but institutional imperatives at existing laboratories and harried researchers in other areas of science view SSC funding as a threat. For the past five years, the SSC has been a presidential initiative and many states offered to host the new laboratory, but recent budget pressures felt by Congress have created shortfall and uncertainty in funding. For somewhat less than four years, the SSC Laboratory has been in existence; and despite all the many challenges, technical and otherwise, excellent progress is being made toward constructing this great machine. It is entirely appropriate that the Philosophical Society of Texas examine this story.

SCIENTIFIC IMPERATIVE

High-energy physics is the ultimate extension of mankind's curiosity about what things are made of and how they work. The main goals of this science are to find the most basic building blocks of all matter and to describe quantitatively the forces and interactions between the building blocks. Progress in high-energy physics takes place through the interplay of theoretical insight, experimental discovery, and advances in technology. The development of accelerators and particle detectors during the twentieth century has been crucial to our current understanding of the subatomic world. Accelerators of ever-increasing energy have been used to collide subatomic particles, such as protons and electrons, to reveal underlying structures and forces. Detectors record and analyze the collisions. It is generally agreed that major new accelerator facilities like the SSC are required to explore beyond the horizon of current knowledge.

Today, physicists are on a remarkably broad and rich plateau in the understanding of the physical world. Discoveries of the past 30 years have resulted in a great synthesis known as the standard model, which describes matter in all its diverse forms as composed of just two classes of building blocks called quarks and leptons. The standard model then explains all interactions of everything in the universe in terms of a few fundamental forces acting among the quarks and leptons.

To current experiments, quarks and leptons appear structureless and indivisible, the modern embodiment of the ancient idea of atoms. It is thought that there are six different kinds of quarks and six different kinds of leptons. In ordinary matter, quarks reside in atomic nuclei and are responsible for most of the mass. The sizes and chemical properties of atoms and molecules are due largely to electrons—the most familiar of the leptons—orbiting the nucleus.

For over 50 years, physicists have recognized four basic forces that govern the interactions and motions of material objects: gravity, electromagnetism, the weak force responsible for certain radioactive decays, and the strong force that binds atomic nuclei. Two great triumphs of today's standard model were the recognition of electromagnetism and the weak force and, the successful description of the strong force in a mathematical framework similar to the electro-weak force.

The apparent range of validity of the standard model is astounding. It is consistent with all existing observations ranging from high-energy accelerators to more familiar laser and atomic physics laboratories. Indeed, the standard model is thought to have played a major role in the biggest laboratory of them all, the evolution of the entire universe from the first moment of creation, the Big Bang. The experimental conditions studied in today's accelerator experiments are thought to be similar to those that dominated the universe fifteen billion years ago when it was roughly one nanosecond old.

Despite its great successes, the standard model revealed important questions at its inception that we are no closer to resolving today than we were then, and new questions continue to arise. A key idea in the standard model is that of symmetry, a special symmetry that would have all particles massless. But the world we live in evidently violates this symmetry. Our theories can accommodate this breaking of symmetry, but the mechanisms by which nature actually accomplishes the task of giving mass to objects is of paramount interest to our understanding of the physical world, yet completely outside what guidance the standard model can give us. Other crucial questions, such as how many quarks and leptons there are and why the constituents and forces have the particular properties they possess, are also beyond the scope of the standard model. Such questions can only be reconciled by a more fundamental theory. Further, beyond the standard model, we want to know: if there are new kinds of matter, not built out of quarks or leptons, are they themselves composite objects built out of a smaller number of even more fundamental constituents? Can all known forces be interpreted within some super-unified force? The standard model may be the most successful theory thus far in the history of science, but we know it is incomplete and even inconsistent when extrapolated to high enough energies.

The strategy for addressing these questions is to seek new experimental data outside the current range of validity of the standard model. To understand how new experimental results can advance theory, it is useful to recall the situation in physics at the end of the last century. At that time an extremely successful theoretical picture encompassed most existing physical knowledge. We now call it classical physics. Classical physics accounted for everything as being composed of the 92 or so chemical elements interacting through gravity and the recently unified electromagnetic theory of Maxwell and Faraday according to the mechanical laws of Newton and Galileo. While the patterns of the periodic table and certain phenomena such as spectral lines of the elements could not be understood within classical physics, many eminent scientists of the day believed that classical physics completely incorporated the fundamental laws of nature and that further work in physics would be reduced to understanding the "last few decimal places." Then within the few years around the turn of the century came a series of astonishing experimental discoveries revealing such phenomena as x-rays, electrons as indivisible subatomic particles, radioactivity, and superconductivity. These experimental discoveries revolutionized physics, leading to the "modern" foundations of twentieth-century physics, quantum mechanics and relativity, and ultimately the standard model. We now believe that the path beyond the standard model to a more complete understanding is obscure and that experimental guidance is again required. The SSC is the most technically certain and cost-effective means to acquire this necessary data in a timely way.

THE MACHINE

In the SSC, beams of very high-energy protons are brought into head-on collision and the debris of these collisions is studied with large detectors. The protons can be pictured as loose bags containing three quarks and particles related to the strong force known as gluons that hold the quarks in their proton bags. When the protons collide, occasionally a quark or gluon in one proton will suffer a violent collision with one in another proton. These very violent collisions of quarks and gluons are what physicists want to study; the proton collisions per se are of lesser interest. New forms of matter may be created out of the energy of collisions, and internal structures or forces will affect the pattern of scattered debris. By examining many examples of these violent collisions, the underlying physics can be discerned. It is a general property of nature that the more energetic the collision, the more deeply a measurement probes the structures of the colliding particles. Requirements concerning the energy of the quark and gluon collisions needed to observe new phenomena specify the *beam energy* of the colliding protons.

The interesting aspects of high-energy particle collisions take place over immeasurably small distances, but the scattered objects eventually give rise to hosts of stable or nearly stable particles that emerge from the inner reaches of the proton beams and can be detected by the tracks they leave in sensitive materials in much the way a high-flying jet aircraft can be "seen" by its contrail alone. While the detected secondary particles give a faithful representation of collisions of quarks and leptons, measurement errors and ambiguities dictate the need for statistical analyses of collision data. To collect enough collision events to make meaningful conclusions within a reasonable period of time puts requirements on the rate of collisions, which in turn specifies the *luminosity* of the device providing the proton-proton collisions.

Beam energy and luminosity are thus the key parameters controlling the design of any high-energy physics collider. In the case of the SSC, the beam energy requirement is the most critical determinant of the overall size and cost of the facility. The SSC's beam energy will be 20 TeV, 20 times that of the highest energy accelerator in the world today, the Fermilab Tevatron. This energy was chosen to ensure that some experimental manifestation of the symmetry-breaking or mass generation phenomena anticipated by the standard model will be observed. A sharp threshold where such phenomena appear is not expected, but judgment and the desire to have as wide an opportunity as possible for detecting totally new and unexpected physics dictated the large increase over today's accelerators.

To achieve the desired beam energy, the SSC will employ superconducting magnet technology that was pioneered at the Tevatron. Because of engineering limitations on the field strength of accelerator magnets, the extraordinary size of the SSC is required to contain the 20 TeV proton beams within the racetrack-shaped rings of magnets. There are two such rings housed in the underground tunnel already mentioned, one placed 80 cm above the other. The beams circulate in opposite directions at the speed of light within a vacuum in 5-cm-diameter pipes running through the centers of the magnets making up the collider rings. Accelerator magnets bend and focus the beams so that they stay within the beam pipes. At four locations around the rings, two on the east side and two on the west, the beams are made to cross through each other at a small angle so that they collide. These collision points are where experimental detectors are mounted to observe the products of the proton-proton collisions. We expect at least two and as many as four detectors to be operated simultaneously at the SSC.

The proton beams will continue to circulate and collide for periods of about a day until their intensities diminish and it is necessary to replenish them. This is accomplished with an injector system consisting of several lower-energy accelerators cascaded together to supply beams that can be injected into the collider rings at 2 TeV energy. The collider rings then accelerate the beams to full collision energy. A complete injection-acceleration cycle is expected to take one to two hours. Experiments will operate around the clock for periods of months to years. Even though 100 million collisions will take place every second in a typical experiment, the yield of events telling us something radically new may be mere handfuls per year.

THE PROJECT

The SSC Laboratory was formed in January 1989 when Universities Research Association (URA), a not-for-profit consortium of 79 universities in the United States and Canada with research programs in high-energy physics, contracted with the U.S. Department of Energy to manage and operate the new laboratory in Texas. Earlier design studies, demonstrating the technical feasibility of the SSC and providing the conceptual plan for its construction, had been carried out by a central design group in Berkeley under the aegis of URA.

Also that January, the formal Record of Decision by the Department of Energy confirmed the Texas site for the SSC, completing a national site competition that had started two years before and involved 43 proposals from 26 states. The proposals were evaluated against criteria such as geology and tunneling, regional resources, environment, setting, regional conditions, and utilities. The Texas site was selected from a group of seven proposals that a National Academy of Sciences site evaluation committee had judged as best qualified.

A unique aspect of the proposal was the establishment of a state commission, the Texas National Research Laboratory Commission, with authority to issue up to $1 billion in bonds to support the SSC. TNRLC has since become a vital partner in the SSC. The independent funding provided by the State of Texas has already proven invaluable by permitting increased flexibility in the management of the project and supporting educational and university research programs on a national basis. A great strength of our national laboratories, starting with Los Alamos, is the federal government-private sector partnership embodied in the government-owned, contractor-operated concept on which these laboratories are managed; with the partnership of the state in the SSC, we are seeing a new model for scientific, research, and development laboratory management that will almost surely become more important in the future.

The laboratory staff has now grown to about 2,000, close to the eventual size when operations begin. The staff is housed in temporary offices on the southern edge of Dallas, a large converted warehouse in Ellis County, and in new laboratory buildings constructed on the site. About one-half the staff consists of scientists, engineers, and technicians, while the remainder provides the necessary administrative support. There are 193 Ph.D.'s on the staff, and more than 18 nationalities are represented among our scientists.

The main task during our first year was to adapt the conceptual design to the specific Ellis County site and to new developments in accelerator design. That effort indicated that a number of substantial changes in design would be required to meet the scientific goals, and it was clear that the proposed changes would increase the total cost of the project. After careful review by the Laboratory, the scientific community, and government, it was agreed to raise the total project cost ceiling to $8.249 billion from $5.894 billion. This has been the only substantive increase in the total projected cost of the SSC, despite many reports to the contrary.

The State of Texas, through TNRLC, has acquired essentially all of the 16,299 acres of land needed for the SSC. Where surface access to technical systems or campus buildings is not needed, underground easements were secured so that the collider rings will pass under existing farms and other properties with no impact on the surface environment. Civil construction on our first building, the magnet development laboratory, began in the fall of 1990. The MDL and several other buildings are now occupied. The tunnel housing the collider rings will be 14 feet in diameter and 54 miles in circumference at an average depth of about 200 feet below the surface. Over one-half of it is now under contract, with three large tunnel-boring machines set to go early in 1993. We are currently one of the largest civil construction projects under way in the country, and we are receiving very favorable bids for new construction.

Development of the superconducting accelerator magnets has been the most important and challenging technical activity for the new laboratory. The magnets use special superconducting cable that must be maintained at a temperature just four degrees Celsius above absolute zero; very high magnetic forces are present and tolerances of a thousandth of an inch over the fifty-five-foot length are required. The effort involves collaboration with Fermilab; Brookhaven National Laboratory; Lawrence Berkeley Laboratory; the Saclay Laboratory outside Paris; KEK High Energy Physics Laboratory in Tsukuba, Japan; and contracts with major U.S. companies. The scientific principles for the magnets were established by the success of the Tevatron and the recent commissioning of a new accelerator, HERA, in Hamburg, Germany. Our job has been to engineer magnets to the more demanding specifications of the SSC, especially in areas of reliability and manufacturability, at a cost we can afford. The sheer size of the SSC dictates that industry produce our magnets. Prototypes of the various kinds of magnets needed have been built by industrial workers, and they meet or exceed our specifications. On August 14, 1992, six weeks ahead of schedule, a major milestone of the project was met when we successfully tested a string of magnets and associated systems that represents the basic building-block of the collider rings. Where just two years ago there was only poor grazing land, we now routinely operate a 100-yard-long, supercold prototype of the SSC.

Physicists from across the United States and abroad will carry out scientific experiments on the SSC. Proposals for detectors and experiments are made to the laboratory and reviewed by an international program advisory committee. Much attention is focused now on plans to construct two large, complementary detectors to be ready when the collider begins operation in late 1999 or 2000. The international consortia proposing these detectors already comprise over 700 U.S. scientists and comparable numbers of foreign physicists. A tremendous amount of prototype and development work is already in progress to prepare the way for the building of these enormous instruments that will each weigh more than 10,000 tons and use approximately 1,000,000 channels of sensitive electronics to record the tracks from the products of the SSC's colliding protons. We expect to make commitments to begin constructing the large detectors in 1993; smaller experiments are also being planned, but final decisions need not be made until we are closer to the startup date for the SSC.

BENEFITS OUTSIDE HIGH-ENERGY PHYSICS

Construction of the SSC is a scientific imperative for high-energy physics, but its large cost must be justified by the overall scientific, technical, economic, and cultural return to our nation and to those who join with us in this endeavor. The principal arguments for supporting the SSC are: 1) possible long-term revolutionary changes in science and technology that emerge directly from major scientific discoveries; 2) enhancement of the nation's overall capabilities in science and technology that derives from the exceptional cadre of scientists and technologists drawn by the challenges of the SSC and its research potential; and 3) scientific and technological spin-off to other sciences and high-technology activities.

The scientific goal of the SSC, as we have seen, is to gain a deeper and more complete understanding of the structure of all matter and the nature of all forces. There are many examples of similar basic exploration seemingly far removed from ordinary experience that have led to profound innovations and benefits to all mankind. Indeed, most of today's technology is based on fundamental discoveries made in the nineteenth and early twentieth centuries. A characteristic of this kind of advance is the long time scale, running years to decades, between the basic scientific discovery and its practical application.

No one can predict the impact on future generations of discoveries made at the SSC. It can be anticipated, however, that the SSC will open up uncharted waters in our understanding of the subatomic world with new lands that await the first explorers. If these lands hold anything like the riches previously found, the rewards of launching the SSC will far outweigh all investments.

On a more certain and immediate level, the "doing" of the SSC enhances the nation's posture in science and technology to an extent that fully justifies the costs. The very high scientific potential of the SSC attracts the best scientific talents worldwide, who, in turn, will assemble the technology necessary to achieve their scientific goals. By this process, the nation acquires a highly motivated, talented, and productive team of scientists, engineers, and technical staff who work together with foreign partners in solving some of the most fundamental and difficult problems in all of science and technology. The ability of the nation to form and deploy such teams and to find solutions to problems of this kind is essential if we are to interact effectively in the modern technical-industrial world.

The SSC has an important education and training role that benefits our country as well. The great machine presents the kind of dramatic appeal that inspires young people to enter careers in science and technology. For the graduate students who participate in the research program, there will be unparalleled opportunities to work with top scientists, other students, and first-rate technical people on challenging problems in instrumentation and analysis, and to participate in major scientific discoveries. This can be an outstanding training ground for such students, many of whom will go on to positions of leadership in our universities, industry, and government. Well before commissioning, the SSC is already a resource for science education at all levels because of the broad range of technical activities under way that are being opened to interested educators and the public. These activities will only grow to meet the demand. We believe that being a resource for science education at all levels is so important that it, along with becoming the premier international high-energy physics laboratory in the world by the year 2000, is one of the two principal goals of the SSC Laboratory.

The tools and methods of high-energy physics have been applied to many other areas of research, development, and manufacturing. The pattern continues with the SSC. Examples include the development of synchrotron radiation sources, uses of accelerators in medical and energy-conversion processes, and applications of high-speed data-acquisition systems to process control. In addition to detection methods and magnet technology, some of the basic ideas of data analysis and large solid-angle detection arising in high-energy physics have found their way into modern medical diagnosis instrumentation such as

CAT and MRI scanners. The very large scale of the SSC means that industrial quantities of superconducting materials and other equipment must be produced, and these will be available to other applications previously hampered by the higher prices associated with availability in only small quantities. The SSC Laboratory is engaged in a joint program with the Southwestern Medical Center of The University of Texas to use excess protons from the linear accelerator of the injector system in cancer research and therapy. Achieving the high quality-assurance standards required of vendors to the SSC improves the ability of those companies to compete in other markets.

Much is made of "technology transfer" in debates over U.S. R&D policy. I believe it is important to distinguish the "science-pull" kind of development that is taking place at the SSC from what I would call the "technology-push" development that is characteristic of much technology-transfer activity today. The clear scientific challenges of the SSC demand that new inventions and developments be made. Subsequently, the new tool or idea, which is already known to be useful, can often find application outside high-energy physics. In contrast, the technology-push approach seeks to find uses for technologies thought to be useful, but at least partially developed without a specific need. Of course, the most effective technology-transfer activity of them all is drawing talented young people into exciting technical programs, educating them to meet high standards, and having them move into leadership positions in other research, teaching, or commercial activities.

The fundamental questions addressed by high-energy physics are basic to all science. Hence, the research findings of the SSC will benefit other sciences. Some of the strongest ties are with cosmology, where SSC results will be used in studies of the evolution of the universe. The quark structure of the nucleus is of direct relevance to nuclear physics. There is strong synergism between theoretical activities in high-energy physics and areas such as mathematics and condensed-matter physics. High-energy physics has been one of the first experimental sciences where large collaborative efforts are required to make progress. SSC experimental collaborations may involve up to a thousand scientists. New management and scientific procedures are being developed to ensure that the best science is performed with proper accountability for the large expenditures of public funds. The lessons learned about maintaining opportunity for individual creativity and high scientific standards in large groups can be applied elsewhere as other experimenters increasingly turn to large facilities.

OUTLOOK

Large colliders where forefront research is carried out today include Fermilab's Tevatron, the Large Electron-Positron (LEP) facility at the CERN laboratory near Geneva, Switzerland, and HERA at Germany's DESY laboratory in Hamburg. The Tevatron and LEP have been operating for several years, and various upgrades have been proposed or carried out that will extend their productive lives for at least several more years. HERA is just beginning its research program. At one-twentieth the energy of the SSC, the Tevatron is likely to remain the world's highest energy collider until the SSC era. LEP is the largest collider in the world today with a tunnel circumference about one-third that of the SSC. However, technical differences between electron and proton accelerators result in a maximum energy for LEP about one-two-hundreth that of the SSC. CERN is considering placing superconducting magnets in the LEP tunnel to permit proton-proton collisions at energies up to about one-third that of the SSC. This is known as the LHC project, but no decision has been made to go forward to construction, nor is one expected before the end of 1993 at the earliest. LHC magnet research and detector plans are at preliminary stages. HERA is a novel electron-proton collider providing collision energies intermediate between LEP and the Tevatron. All three of these operating colliders provide important new data that test the Standard Model and could discover new physics. Any scenario where new phenomena are discovered at one of these machines predicts a rich and exciting program for the SSC.

So we are building the SSC, and its scientific promise is, if anything, greater today than when the project was proposed a decade ago. Unfortunately, continued funding for the SSC is uncertain. On June 17, 1992, the House of Representatives voted to eliminate essentially all funds for fiscal year 1993. Funds were eventually restored by Senate and joint Congressional actions, but the international scientific community and many others were shocked that a project so advanced and so important to science could face the threat of cancellation largely because of political considerations. Continued chronic shortfalls in planned funding and uncertainties over the very existence of the project will have deleterious effects on the overall cost and schedule of the project, on our ability to recruit and retain qualified staff, and on our ability to secure commitments from international partners who have been invited to join in the scientific program and construction of the accelerator. When costs are being considered, it is important to include the costs of lost opportunities and the lost vision of national purpose should we stop building the SSC after already investing so much capital, both financial and human.

The major engineering and management challenges presented by the SSC are being met. Its construction is going well. People have left their farms and homes to make way for the SSC, while many scientists from around the world have moved to the new laboratory, drawn by its scientific importance. Now, with a new administration coming to Washington and the great progress and promise already realized, the time is here to reaffirm our commitment to this great resource of science and education for the next century.

II
David Gross

Steve Weinberg called me about a year ago and asked me to stand in for him at this meeting. I was very pleased to do so. I thought I would have about an hour to explain to you in great detail the theoretical imperative for the SSC. And then last week, Roy informed me that I had ten minutes. So I realized that I would have to cut out my usual jokes, which is a great loss.

As Roy explained, we have succeeded in this century in constructing a successful theory of matter and force. We have done this by exploring nature with experiments that probe down to distances of a billionth of a billionth of an inch. Based on these discoveries, we have constructed a theory which identifies the constituents of matter as quarks and leptons, and explains the forces between them. This theory is called the standard model. It's called a model, by the way, because when it was first proposed, the physics community was only tentative about its truth, so we covered ourselves by calling it a model. I've been trying to get people to call it the standard theory, but it's very hard to change terminology.

Now this model, this standard theory, is extraordinarily successful. It appears to be consistent with all present-day observation as the precursors of the SSC, and it has passed all experimental tests. It is, in fact, an incredible intellectual achievement. But this success does not make us very happy. You have to realize that physicists don't really like success. Success is nice, but we really appreciate problems. And, so far, the standard model hasn't presented us with many direct problems or paradoxes.

This success does not leave us happy for other reasons as well. In fact, we can identify within the standard model the seeds of its own destruction. The very success of the theory prompts us to ask new questions that were previously unthinkable. The progress of physics or any science can be measured by the nature of the questions that we ask. First, when we explore a new scientific area, we ask *what* questions. What is the phenomenon? What's going on? Once we understand what's going on, we ask *how*. How does it work? How is it put together? And once we understand how it works, we began to ask *why* questions. Why is it so?

Now, in elementary particle physics, we've arrived at this last stage. The standard model certainly deals with the what questions and with most of the how questions, but it is powerless to answer the new why questions. As for the how questions, the most important remaining how question relates to the origin of mass which was already discussed by Roy; namely, what is the precise mechanism of symmetry-breaking that gives a mass to the electron and to the quark? Now I don't have an hour to describe to you symmetry-breaking, but there's one analogy about symmetry-breaking that might be useful. You all know what a symmetry is; for example, if you're seated around a lunchroom table and napkins are placed between the plates, there's often a symmetry between the clockwise and the counter-clockwise direction. In fact, you will often look around and you're not sure whether to choose the napkin on your left or the napkin on your right. So that's a symmetry. The laws of nature, the pattern, are symmetrical. But that symmetry has to be broken; otherwise, you can't eat. Someone chooses a napkin, say the one to his right, and then it's clear everyone has to choose the napkin to his right and the symmetry pattern is broken. Everyone has chosen the one on the right.

That's what happens in the real world. Much of the structure of the world, the laws of nature, has an incredibly large symmetry, but the actual pattern of how they are manifested in the world we see around us breaks the symmetry. It is the breaking of the underlying symmetry that is one of the most important ingredients of the standard model. This symmetry-breaking produces the very mass of all or most of the particles in the universe. Now, we're pretty sure that we understand how that symmetry is broken, the mechanism that produces the mass, but it has not been thoroughly tested by experiment and surprises might await us.

The standard model also raises many why questions. Why are there three families of quarks and leptons? Atoms are made of protons, neutrons, and electrons. The proton is made out of two kinds of quarks and in addition we have the electrons (which are leptons) rotating about it. What we discovered was that this pattern of quarks and leptons repeats itself three times. There are particles just like the quarks that make up the proton and the electron, but they're different. We call these "families." When the muon, the first of the new leptons was discovered, I I. Rabi asked, "Who ordered that?" And we're still asking, who ordered that? Why are there these repetitions? We have no explanation. The families of quarks and leptons come in a very strange pattern of masses, for which we have no explanation.

So why are there these families of quarks and leptons? Why this strange pattern of masses? Why are the various numbers that come into the theory? Why? Why? Why?

Most of these questions relate to the 19 parameters that enter into the standard model. So far, all of these numbers have to be fixed by experiment. The theory itself cannot determine these numbers nor answer these why questions.

Now it is a fundamental article of faith among physicists that questions like this are answerable. And that our understanding of nature will not be complete until we understand the origin of these numbers and answer these why questions. The standard model, therefore, cannot be the final fundamental theory of nature.

In addition, our understanding allows us to begin to ask even more profound questions. For example, the forces that we've identified and understood; the electroweak force, which is responsible for electricity and magnetism on the one hand and radioactivity on the other, and the strong nuclear force are, so far, treated separately. But they show many, many similarities, which cry out for greater unification.

How does this unification occur? We don't know. The specific pattern of matter and forces that embodies the standard model must have a reason, a simple and rational origin. What specifies this pattern? We don't know. The origin of matter itself is an interesting question. One component of matter is essentially the matter that is responsible for force. For example, the quanta of light, the photons that we observe around us, are responsible for and connected with the origin of the force of electricity and magnetism. These elements of nature, the particles associated with forces, photons, light rays, and their heavier partners, W and Z bosons recently discovered at CERN, as well as the gluons, the partners of the light rays that provide the nuclear force, are understood. For these particles and these forces, we have a reason for their existence. We have a symmetry principle which is responsible for the existence of these forces. For matter, electrons and quarks, we have no such principle. They exist, of course, but for no good reason from a theoretical point of view. We need a more comprehensive theory, with greater symmetry, that can explain the origin of quarks and leptons.

We expect that the SSC will enable us to transform some of these why questions into what questions and how questions. And that's how we will begin to answer them. At the SSC, in a sense, we're in a no-lose situation. We can compare our situation to that of Columbus, as our chairman started to do, starting out on his voyage of discovery 500 years ago. At that time, there were three theories of the world. The first theory, the standard model, was that the world was round and Columbus would end up in India, although many people thought that he couldn't make it because it was too far and Congress threatened to cut off his funds. The second theory was that the world was indeed round, but Columbus was mistaken and there were many New Worlds between Spain and India and he would discover new worlds. Finally, the third theory was that the world was not round and that Columbus would come to its edge.

Now, I think we're in a similar situation. I actually believe in the first theory, that the world is round, and we will find the mass-producing mechanism as predicted by the standard model, in roughly its expected form. However, it is conceivable that the standard model is wrong and then the mechanism is much more complicated. All the more interesting. You see, we're guaranteed to discover something, either America or the edge of the world, with the SSC. The trip cannot be boring. Beyond the shores of the standard model, I, and many of my colleagues, have reasonable hopes that new continents will be discovered with the SSC. What might these look like?

In the construction of the standard model, we have discovered that so far all of the forces of nature emerge as consequences of profound symmetries. Most of those symmetries are broken or hidden, which is why it's so hard to discover them. But they turn out to underlie everything we have learned to understand.

This really is the primary lesson that we have learned in our voyage of discovery. The secret of nature is symmetry. This notion is also at the heart of Einstein's theory of gravity which governs the dynamics of space and time and remains to be integrated with the standard model.

Now, in attempting to understand more, to answer the why questions posed by the standard model and to achieve further unification of the forces of nature, theorists have invented many new things. Let me just describe briefly one of my favorites—a new kind of symmetry called supersymmetry. (Notice how physicists love the superlative "super." Everything is super—supersymmetry, superconductivity, supercollider.) Supersymmetry represents a beautiful extension of the ordinary notions of space-time symmetries. Most importantly it offers a possible answer to one of the why questions I posed before—why does matter exist? It also answers another fundamental question—what sets the scale of masses in the universe?

However, if supersymmetry exists, then it's badly broken, like the right-left napkin symmetry, in the microscopic world we have already explored. The only way we can hope to see this supersymmetry and its implications is by building powerful microscopes to explore smaller and smaller distances. And the most powerful microscopes we build today are particle accelerators.

If supersymmetry is to play its imagined role in nature, then we expect its traces to be visible precisely at the scale of distances to be explored at the SSC. The discovery of something like supersymmetry would be incredibly profound. Now if I had five more minutes, I could explain to you how supersymmetry arises from the existence of new dimensions of space. The tricky part is that these new dimensions are not exactly the same as the ordinary dimensions that you are acquainted with. This inner space, by the way, is called superspace. Thus, the discovery of any one of many, many particles predicted by supersymmetry would greatly enlarge our conception of the world, much more so than the discovery of America. It would be very nice, in fact, if the supercollider would reveal the existence of superspace.

The consequences of this discovery, as well as many others that might be anticipated, as well as the many surprises that, of course, we cannot anticipate (except that history suggests that we might very well expect surprises) are likely to be very profound; profound in their implications not just for particle physics, but for many other areas of science and perhaps even for society.

For example, we must understand the laws of nature that govern the very small if we are to understand the structure of the universe as a whole—the laws that govern the very large. The very pattern of the cosmos was set by conditions that existed very early in its history, billionths and billionths of a second after the big bang. At those very early times, the processes that took place were controlled by physics that we can only recreate at the SSC. So, therefore, in Texas, in 1999, we might, in fact, unravel the mechanism that led to the pattern of the universe as a whole 15 billion years ago.

In conclusion, I regard the SSC as a great and exciting adventure. I'm enormously appreciative of the heroic efforts of my experimental colleagues to make it work and of the very generous support of our fellow citizens that makes it possible. And I have no doubt that history will look back and regard this project as one of the most memorable achievements of the end of this century. Thank you.

Schwitters: Super talk. I think it is appropriate to look at the history of this kind of activity and relate it to what's happened in the past. I would like to now turn it over to Peter Galison.

III
Peter Galison

At first, when I was asked to say something historical about the SSC, I thought I might discuss the development of accelerators from the time that Lawrence first built his cyclotrons. I would then have traced for you the various ways that the machines have been expanded through the many accelerators leading to the SSC. But then I thought that perhaps another approach might be more useful for this occasion, and that is to step back a bit from the specific problems of building accelerators and the technical and physical difficulties that went with their establishment, in order to look at the "standard model" that we now face. For as my colleagues have just mentioned, this model has been so enormously successful in compiling, predicting, and helping us to understand the particle physics world around us that it seems to leave us defeated by success.

The question that Roy Schwitters asked me to address, then, was this: why go beyond the standard model? To look at this from an historical perspective, I'd like to step back quite a bit to the start of the seventeenth century and say a little about times in the past when physicists were persuaded that they had come to the end of physics. Perhaps from the words of history we might draw some small lessons.

Descartes, one of the originators of modern science, wrote in one of his great books, modestly called *The Universe,* that he would set out the many rules that determine how much an object's motion is diverted, augmented, or diminished by its collision with other objects. Taken together, these rules would comprise all of the effects of nature from the beginning of the universe to the details of the human body. Descartes left the detailed working out of all of the effects to others who worked with or for him. But he thought he had understood the universe, and, indeed, in many ways, he made tremendous advances, not only in geometry and the application of mathematics to the world, but by also doing away with many of the old Aristotelian notions such as the existence of special properties of wetness, density, and heaviness. Descartes thought that everything could be explained solely in terms of extension and the motion of matter. There was only one stuff in the world for Descartes: you shuffled it around in different ways and it explained things. For example, gravity was the great vortical motion, spinning like a great whirlpool around the sun, and the planets were pulled around it. Magnetism was explained by little tubes that, like screws, went out from a magnet and pulled other things back toward it. Heat was explained by the motion of particles with respect to one another. Some of these ideas have survived, some have not. The ambition, though, was there and Descartes thought he had come to the end of physics.

Newton didn't. Sir Isaac devoted a large portion of his earlier work to showing how the theory of gravity that Descartes had put forward had to fail. He set out new, mathematically superior laws that could be used to predict the motion of the planets with great accuracy. Laplace, in the eighteenth century, impressed by the success of Newton's laws, thought that they were complete and that the universe could be explained simply by applying, in some sufficiently difficult way, Newton's laws.

Similarly, in the nineteenth century, many famous physicists thought that physics had come to a halt. One of them, Albert Michelson, the first American to win the Nobel prize, wrote in 1894:

> While it is never safe to affirm that the future of physical science has no marvels in store even more astonishing than those of the past, it seems probable that most of the grand unifying principles have been firmly established and that further advances are to be sought chiefly in the rigorous application of these principles to all phenomena which come under our notice. It is here that the science of measurement shows its importance—where quantitative results are more to be desired than qualitative work. An eminent physicist has remarked that the future truths of physics are to be looked for in the sixth place of decimals.[1]

His program, the one that Michelson subscribed to, was that the world was mechanical at its root, and nothing else. He believed that all of the fantastic discoveries about light and electromagnetism, all of the new electromechanical industries, including light and trolleys, could be understood by underlying motions of some mechanical substance. Mechanical reductionists thought that his all-pervading ether and its dynamics would explain everything to us.

In 1900, this mechanical reductionism was reversed by some of the leading physicists of the time who said, no, it was actually electromagnetism that provided all of the answers.

In 1925 Bertrand Russell, the famous philosopher, mathematician, and logician, reflected on doubts physicists had about the old quantum theory:

> Physical science is thus approaching the stage when it will be complete, and therefore, uninteresting. Given the laws governing the motions of electrons and protons, the rest is merely geography—a collection of particular facts filling their distribution throughout the portion of the world's history. The total number of facts of geography required to determine the world's history is probably finite; theoreti-

> cally, they all could be written down in a log book to be kept at Somerset House with a calculating machine attached which, by turning a handle, could enable the inquirer to find out the facts at other times than those recorded. It is difficult to imagine anything less interesting or more different from the passionate delight of incomplete discovery. It is like climbing a high mountain and finding nothing at the top except a restaurant where they sell ginger beer, surrounded by fog but equipped with a wireless. Perhaps in the times of Ahmes the multiplication table was exciting.[2]

So, held Bertrand Russell, from the old quantum theory of the atom, you could deduce everything else. And, again, it would be left to the lesser lights to work out, crank the machine, and produce the details. Ordinarily, you might think that this was simply the result of Russell not being himself a physicist, but that's not at all the case. Just a few years later, Leon Rosenfeld, one of the foremost theoretical physicists, commented on some of the new thinking about quantum mechanics. After reading Dirac's paper on the theory of the electron (this was part of the new quantum mechanics and Dirac had created a relativistic equation of the electron that was quantum mechanical), he said,

> After Dirac's great paper on the theory of the electron one had the impression that all the fundamental features of atomic physics had been neatly incorporated into the new conceptual structure, and with characteristic eagerness the other pioneers of the atomic world Heisenberg and Pauli, leaving to the lesser fry the polishing off of details [this gets to be a theme], turned to the major remaining task of applying the new methods of quantization to the electromagnetic field. It is difficult to those who did not witness it to imagine the enthusiasm, nay the presumptuousness, which filled our hearts in those days. I shall never forget the terse way in which a friend of mine (now a very eminent figure in the world of physics) expressed his view of our future prospects: "In a couple of years," he said, "we shall have cleared up electrodynamics; another couple of years for the nuclei, and physics will be finished. We shall then turn to biology."[3]

Max Born, who in 1926-27 had provided the statistical interpretation of quantum mechanics, wrote after 1928, "Physics as we know it will be over in six months."[4]

We must turn to more recent times, and to our colleague Sheldon Glashow, who in 1980 introduced a workshop on grand unification with the following words:

> . . . we have for the first time an apparently correct theory of elementary particle physics. It may be, in a sense, phenomenologically complete. It suggests the possibility that there are no more surprises at higher energies, at least at energies that are remotely accessible. . . .Theorists still expect novel high-energy phenomena, but only at absurdly inaccessible energies. Proton decay, if it is found, reinforced the belief in the great desert extending from 100 GeV to the unification mass of 101^4 GeV. Perhaps the desert is a blessing in disguise. Ever larger and more costly machines conflict with dwindling finances and energy reserves. All frontiers come to an end. You may like my scenario or not; it may be true or false. But it's neither impossible, implausible, nor unlikely.[5]

The last quotation I'd like to read is from Steven Hawking, who was talking about yet another set of theories having to do with gravity. He wrote even more recently, of

> the possibility that the goal of theoretical physics might be achieved in the not too distant future, say, by the end of this century. By this I mean that we might have a complete, consistent and unified theory of the physical interactions which would describe all possible observations.[6]

After cautioning that others had made this prediction before, he continues:

> Nevertheless, we have made a lot of progress in recent years and, as I shall describe, there are some grounds for cautious optimism that we may see a complete theory within the lifetime of some of those present here.[7]

Now what do we make of this provocative set of remarks by some of the leading physicists of the last 300 years, each foreseeing the prospect of the end of physics in the near future? I think that the deepest lesson is not just that people can be in error about where the boundaries of physics, will be, (for the same is true of the present time), but rather that the remarkable thing about physics is the fantastic diversity of approaches that have been applied successfully. It is not surprising that there have been a variety of speculative ideas about where a discipline should go; there are lots of examples of disciplines with a whole lot of bad ideas that didn't work out. No, the surprising thing is that each of these moments in history of physics—Cartesian mechanism, electromagnetic reductionism, quantum theory, and unified field theory—reorganized the goals of physics. And despite the widely divergent goals and the diversity of ideas that have proliferated in physics, each of these generations has in fact deeply contributed to our knowledge of the world.

So, while I think that we cannot know in advance what will come out of the SSC, what we can hope for is a continuation of this proliferation, this heterogeneity of thoughts, and this diversity of goals that has accompanied each new generation of physical thoughts. There is nothing that concentrated our collective mind better than the prospect of an imminent end of physics.

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Seybold: Thank you, Dr. Schwitters, Dr. Gross, Dr. Galison. A fascinating look at the world of physics today. We are going to take a little break, but make it a very brief one, because we have another panel of equal interest coming up on the WHERE of the SSC. I want to make one more comment before I'll allow you about a five-minute coffee break. I'm pleased to learn that physicists are no better at predicting the future of their science than surgeons have been, or doctors have been, in the past. I've read many accounts of our surgical predecessors through the centuries who have concluded that theirs was the golden era and that nothing more could be learned and nothing more could be done.

Seybold: Our second panel addresses the question of WHERE to locate the SSC. As you know, it was eagerly sought by many states and many competitors within those states. At the time the SSC was proposed, William P. Clements, Jr., was governor of Texas. He had built a large and successful oil and gas drilling company and had served in Washington as a deputy secretary of defense. His role as governor was an important one in bringing the SSC to Texas. He also helped in important ways in planning this program. He was scheduled to moderate this panel, but at the last minute was unable to do so.

Doctor Hans Mark has graciously offered to moderate and chair this panel in his absence. Most of us know Hans Mark as the former chancellor of The University of Texas System and know his credentials and his background very well. But for some of our guests and newcomers, Dr. Mark is now the Professor of the Department of Aerospace Engineering and Engineering Mechanics at The University of Texas. As I've said, he was a former chancellor of The University of Texas System, and former deputy administrator of the American Aeronautics and Space Administration, a secretary of the U.S. Air Force, a director of NASA Ames Research Center, and the co-author of more than 150 scholarly articles and numerous books, and has been very involved in the SSC. Dr. Hans Mark, thank you.

WHERE? SITE SELECTION, CRITERIA FOR SITE SELECTION, PROCESS

I

HANS MARK

THE ADDRESS THAT DR. ROY SCHWITTERS, THE DIRECTOR OF THE SUPERCONDUCTING Super Collider Laboratory, has just concluded, fascinated me. I was interested by the fact that my old physicist friends such as Roy keep talking about "the end of physics." People seem to believe this because quite often a flash of insight occurs to someone which opens up an entirely new vista of our knowledge of the natural world. After such a "brilliant insight" it takes a few years—maybe even 20 or so—to work out the consequences and after that people say indeed, that "the end of physics has arrived." It therefore takes even more time for scientists who are caught up in the new ideas to realize that there are still unanswered questions. We always know more and more about physics and I can say that because I used to be a physicist.

For the past 20 years, I have been a politician and our subject for this lecture is politics. The older I get, the less I know about politics, and therefore the statement that we know everything there is known becomes monotonically less and less accurate as time goes on for me.

Our subject has to do with where we should put the Superconducting Super Collider (SSC) and what I want to do is to give you a short history of how the SSC project was started and how it came to be located where it is today. As you all know, the SSC project was recommended by the High Energy Physics Advisory Committee of the Department of Energy in 1983. I knew about it at the time, but I did not pay too much attention to it. I arrived in Texas in September 1984 to take up my new duties as chancellor of The University of Texas System. Almost the first person who came to see me in my office in downtown Austin was Professor Peter McIntyre of the Department of Physics at the other university which has a name that I have a problem remembering. (Oh yes, it is Texas A&M University in College Station.)

Peter came to see me about the SSC and we talked about many of the technical aspects of the machine. He was working at the time on what I thought was an excellent concept for the superconducting magnets that would make up the ring around which the particles would be guided. Peter made great good sense and I listened very carefully to what he had to say. In addition to the technical aspects of our conversation, we also talked about the politics of getting the machine built, which essentially meant how to persuade the federal government to fund the project. Peter, at the time, also raised the issue of how we could get it located in Texas and had some good ideas on that subject as well. I was very impressed by Peter's arguments and decided at the time to put some of my own effort into the SSC project in any way that might be useful.

Although I did not know it, there were others who were active in developing efforts that anticipated the approval of the SSC project by the federal government at the same time. In December 1983, then President Peter Flawn of The University of Texas at Austin convened four Texas university presidents (Texas A&M University, the University of Houston at College Park, Rice University, and himself) to seek ways to support the effort to persuade the federal government to approve the SSC project and to assist the State of Texas to develop locations for the SSC. This group formed the Texas Universities Consortium which issued a report in September 1984 which developed criteria for SSC site selection in Texas. The site south of Dallas was included as one of the possible sites mentioned in that report.

I had several other conversations with Peter McIntyre at the end of 1984 and during these talks, we developed some ideas about what had to be done. At about the same time, as the new chancellor of The University of Texas System, I was arranging meetings with various political leaders of the State of Texas. One of these was with the then-lieutenant governor, Bill Hobby. During this meeting, Bill Hobby mentioned the SSC and asked me what I thought the prospects were of getting the federal government to approve the machine and also then of locating it in Texas. It was clear to me that he had already thought about the matter and was very favorably disposed toward taking some positive action. Subsequent to my conversation with Bill Hobby, I had an occasion to visit Washington. I went to see my old friend, Dr. George Keyworth, who was then the science advisor to President Reagan. Keyworth was and is a supporter of the SSC, and I received much good advice from him on what I should do.

I spent the Christmas vacation of 1984 thinking about the problem and formulating a long letter to Bill Hobby on the subject of the SSC. It is perhaps worth quoting some paragraphs from this letter in order to get a feeling for our thinking about the problem at the time.

On the second page, about halfway down, there is a paragraph which says: "There are three separate but related steps in turning the SSC accelerator into a real program. First, the federal government must be persuaded to fund the program. Second, a decision must be reached as to where the accelerator will be located, and third, if we succeed in bringing the project to Texas, we must decide where in Texas the machine should be placed. Right now, only the first two steps need concern us although we must keep the third one in mind as we proceed."

The letter then goes on to talk about a public campaign that Dr. Keyworth advised us to mount. Part of this campaign involved my old friend Steve Weinberg, who is another most important actor in this story. Steven Weinberg is a professor of physics at The University of Texas at Austin and a 1979 Nobel laureate in physics. He was deeply involved in various efforts to initiate the SSC project which I have already mentioned. I have known Steve for more than

30 years since we served together on the faculty of the University of California at Berkeley in the early 1960s. It was therefore a natural and obvious thing for me to make contact with him. We had some discussions about writing an article for the *New York Times Magazine* on the SSC which would be part of the public campaign that Keyworth was advocating. As it turned out, that article was never written, but it was probably not necessary in any event. It did give me the opportunity to renew my old friendship with Steve Weinberg and instead of an article, what we both did was to make speeches about the SSC, both in Texas and in the rest of the country.

At the top of the next page in my letter to Bill Hobby, there is a paragraph that outlines what needs to be done in Texas. If our plan was to propose the SSC accelerator for the federal budget in the fiscal year 1987, then several steps had to be taken now in order to have a credible chance of getting the machine located in Texas. Here is what the letter said: "First, a competitive position with respect to other interested states will require that we provide the land and possibly some other facilities for the project. Our best estimate is that this means several appropriate sites with the necessary easements for the 30-mile diameter ring"—we were talking about a much bigger machine at the time!—"and roughly 6,000 to 10,000 additional acres for facilities at various points along the ring. In terms of money, a guess is that a commitment of something like $20 million would cover most contingencies, but this is only a guess." (It turned out to be a very low guess.) "As I explained to you, the Governor's Council on Science and Technology will recommend that Governor White go to the Legislature during the 1985 session to secure these commitments, contingent on the approval of the project by the federal government for the fiscal year 1987. Without such a commitment, there is no chance that we can succeed, and, therefore this effort must have first priority."

So much for the letter. What I tried to do for Lieutenant Governor Hobby was to lay out a strategy which first would result in approval of the project by the federal government and then would develop an approach for locating the machine in Texas.

After a plan of action was developed as illustrated in the letter to Lieutenant Governor Hobby, we proceeded on two tracks. One was to look at the problem of siting the SSC somewhere in Texas. Since most public lands in Texas are those either assigned to the public schools or the lands that constitute the Permanent University Fund, we would have to turn to one or the other if we were going to make an offer of land to the federal government.

The University of Texas System has a campus in Odessa, Texas, The University of Texas of the Permian Basin. On my first visit to that campus early in 1985, I initiated some discussions with local leaders on the prospect for developing a proposal to locate the SSC in that area. One of the people I met on this trip was Mr. James Roberts, who is the editor of the *Andrews County*

News, which is the local newspaper. Roberts is a most persuasive individual. He is a decorated veteran of World War II, having fought on the Italian front, where he was wounded twice and finally captured by the Germans. He is both shrewd and imaginative, and he sold me on the notion that Andrews County might be the right place to locate the machine. The Midland-Odessa airport is in the neighborhood providing good access and there is a large tract of university land in Andrews County on which most of the machine could be placed. Figure 1 is a map which shows the West Texas area and the Andrews County site is noted.

As you can see from the map, not all of the SSC ring could fit on university land in Andrews County. Therefore, we felt that we should go to the Legislature during the 1985 session to secure for the Board of Regents of The University of Texas System the right of eminent domain to take over the lands that you can see would be necessary in order to build the SSC ring in Andrews County. We felt that this was essential should the federal government put the SSC in the fiscal year 1987 budget as we hoped it would. As things turned out, the effort was not necessary since there was no funding for the SSC in the fiscal year 1987 budget. However, if you look at the history of the 1985 session of the Texas Legislature, you will see that they did in fact pass an act to allow the Board of Regents to expand this piece of university land so that we could put the SSC there. Thus, had the SSC appeared in the fiscal year 1987 budget, we would have been in the position to make the offer of land to the federal government immediately.

During this same visit to the Midland-Odessa area, I also met with people who were very influential in local affairs. These included: Mr. Bill Noel of Odessa, who unfortunately has since passed away; Mr. Cy Wagner of Midland; Mrs. Joan Baskin of Midland, who was at the time the president of the Midland Chamber of Commerce; Mr. Bill Roden of Midland, who had just been appointed to the Board of Regents of The University of Texas System by Gov. Mark White; and several others. It was during the course of these conversations that the second track of our effort, which I have mentioned before, evolved. All of these people were friends of then-Vice-President George Bush from the years that he had spent in the oil industry in Midland. They suggested that we organize a visit to the Vice-President in order to persuade him to lead the effort within the Reagan Administration to put the SSC in the federal budget. Actually, the idea of visiting the Vice-President had been suggested to me earlier by Peter McIntyre. At the time, however, I did not know how I could manage to get in to see him. However, the Midland connection now made such a visit possible.

Once a decision to arrange such a visit was made, I suggested to my friends in West Texas that the best format for the meeting with the Vice-President would be to have both The University of Texas and Texas A&M University involved. There should also be some old friends of the Vice-President's from the Midland area, and, finally, I strongly urged that Peter McIntyre be asked to do the briefing. Figure 2 is a picture that was taken during the meeting. The people in the picture are, from left to right: the Vice-President; Mr. Bill Noel of Odessa; myself; Mr. Fred Khedouri, who was then the Vice-President's Deputy Chief of Staff; Dr. Frank Vandiver, who was then the President of Texas A&M University; Congressman Joe Barton, in whose district the SSC finally landed but who was then simply a Congressional advocate for the project; Mr. Cy Wagner of Midland; and with his back to the camera, Peter McIntyre of Texas A&M University. The meeting was held on July 30, 1985, and the idea was to persuade the Vice-President to become the chief advocate for the SSC project. Peter McIntyre's briefing persuaded the Vice-President and he became our most effective supporter.

At about the same time as our meeting with Vice-President Bush, we provided a full briefing on the SSC for The University of Texas System Board of Regents. We knew that the regents would have to be involved and we were, in fact, already asking them to spend some discretionary funds at their disposal to study the Andrews County site for the SSC. Such studies would have to be performed in great detail eventually, if we were to develop a successful proposal. Mr. Jess Hay of Dallas was chairman of the board at the time and it was he who encouraged us to take some risks in order to establish a commanding position. Spending the money on the architectural studies was the first of several such risks that we were to take before we finally succeeded in locating the SSC in Texas.

As I have already said, the 1985 session of the Texas Legislature took one action related to the SSC and that had to do with eminent domain. The Legislature also did something else in the 1985 session which was ultimately much more important. This was the establishment of the Texas National Laboratory Commission. The purpose of the Commission was ultimately to be the primary agent to bring the SSC to Texas once the project was approved. Since the SSC project was not funded in the FY 1985 federal budget, the Commission was inactive for some time. However, by 1987, as you will see, it was the focus of the action.

In addition to the Andrews County site, there were other promising sites in the same area near Big Spring and Garden City. The citizens of these communities spent considerable time, money, and effort in developing strong proposals since word of the SSC had spread from our early discussions of the project in Odessa and in Midland. There were also sites near Houston, there was a site south of Austin, and there were two sites in Lubbock-Amarillo area. These latter sites were particularly interesting because Admiral B. R. Inman, who is a member of this Society, suggested that we ought to look at the possibility that the Department of Energy might be interested in co-locating the high-level nuclear waste disposal site being considered at the time as the SSC. The Department of Energy had concluded that a West Texas site in Deaf Smith County had a particularly good geological formation for this purpose. We felt that they might believe it to be an attractive proposition to locate the SSC there as well. Some money might be saved in terms of staff and other operating costs. We felt that the solution of two problems at once might be of interest to the people in the Department of Energy.

The fact that so many people in Texas were willing to take some risks and to "bet on the come" by making real investment of time and money was a most important factor. The detailed site analyses that were part of the two dozen or so serious proposals coming from various communities cost both time and money. The willingness of so many people to make these investments was remarkable. Texans know that unless people are willing to take risks of this kind, nothing of value can ever be done.

In November 1986, Bill Clements was elected to a second term as governor of Texas (he had previously served as governor from 1979 to 1983). Shortly after taking office, Governor Clements announced that securing federal approval for the SSC project and then bringing it to Texas would be the highest priority item during his administration. From the very beginning, then, Governor Clements was totally committed to the SSC and our parallel effort in Washington went into high gear. Many members of the Texas Congressional delegation, people like Congressman Joe Barton and others, were already very active in promoting the SSC. Now, however, there was even more motivation and the whole delegation was appropriately mobilized. All of these efforts resulted in a paragraph on the Superconducting Super Collider in President Reagan's State of the Union message in January 1987. The President said that the project would be adopted for the fiscal year 1988 budget and that it was a most important item in maintaining the leadership of the United States in science and technology. We were therefore a year behind the schedule I had proposed in my letter to Bill Hobby two years earlier, which is not bad, considering the way such programs usually develop!

As things turned out, 1987 was "put up or shut up" time for us. In February 1987, Governor Clements activated the Texas National Laboratory Commission and gave the job of developing the proposal to put the SSC in Texas. He also asked Peter Flawn, who had left his post as president of The University of Texas at Austin in 1985, to become chairman of the Commission. At the same time, the Board of Regents of The University of Texas System would now play an extremely important role because of President Reagan's speech in January 1987. The regular session of the Texas Legislature in 1987 was just about to convene and we would have to now put up the collateral, if you will, and the incentives to persuade the federal government to locate the machine in Texas.

This would take money, and clearly we would have to engage in some legislative battles if we were to have a chance of winning. The Legislature took a step that was strongly advocated by the Board of Regents of The University of Texas System. This was to adopt a measure that established a public referendum which would authorize the state to issue up to $1 billion worth of bonds to fund various aspects of the SSC, should it be located in Texas by the federal government. This measure passed by the necessary two-thirds vote and was in due course put on the ballot for a referendum to be held in November 1987.

The bond issue legislation became what was called "Proposition 19" and Figure 3 is a replica of the campaign button for "Yes on 19" that many of us wore at the time. The University of Texas was, of course, right in the middle of the campaign for the bond issue. The chairman of the "Yes on 19" Committee that led the campaign for approval was Mr. Jack Blanton of Houston who was then also serving as chairman of the Board of Regents of The University of Texas System. Jack did his usual superb job in leading the campaign for Proposition 19. The Proposition was approved by about 80 percent of those who voted in the November 1987 special election.

In the spring of 1987, the U.S. Congress provided the first increment of funding for the SSC in the fiscal year 1988 federal budget. When that happened, the Department of Energy established a group that would develop and then issue siting criteria. These were the conditions that would have to be met in order to produce a successful proposal. The Texas National Laboratory Commission now had two important jobs to perform. The first was to select the site within Texas that would most effectively meet the requirements set forth by the Department of Energy. The second was to develop the proposal that would be submitted to the Department of Energy that would, hopefully, persuade the Department to locate the SSC in Texas.

Peter Flawn's Commission ranked the Texas sites by the criteria that the Department of Energy had issued. Proximity to population centers was an important criterion and the sites in West Texas were ruled out on that basis. Transportation was extremely important in view of the international constituency that the SSC would serve. Thus, the Dallas-Fort Worth Airport became an important factor. In view of all of these considerations, the Commission concluded that a site south of Dallas would be best from the viewpoint of geology, transportation, proximity to population centers, and the other amenities that were likely to be important. This was essentially the same site that the Texas Universities Consortium had identified back in 1984. The Amarillo site was kept as a backup in case the Department of Energy did in fact follow the idea that Bob Inman had explained to us, with respect to locating the high-level nuclear waste disposal site and the SSC in the same place.

I should say here that I think Peter Flawn did a masterful job chairing the Texas National Laboratory Commission. As I have already said, many people in Texas took considerable risks, financial as well as others, to develop site proposals. It was not easy to be rejected and there was much talk at the time of submitting proposals "independent" of the one being developed for the State of Texas by the Texas National Laboratory Commission. Such moves, of course, would have been disastrous. It is a great tribute to Peter Flawn's diplomatic skills and leadership ability that the State of Texas proposal that was finally submitted was not encumbered by other submissions from Texas that would distract the attention of the decision-makers in the Department of Energy.

Once the Dallas site was selected by the commission in February 1988, Peter Flawn resigned as Chairman. He felt, correctly I believe, that it would now be very important for someone from the Dallas area to head the Commission. Governor Clements selected Mr. Morton H. Meyerson, a longtime deputy and associate of Mr. H. Ross Perot, to do the job. (Mort is here today to tell you his part of the story as soon as I am finished with mine.) In my judgment, this was an extremely fortunate choice since Mort Meyerson had all the necessary leadership skill as well as important political connections.

We were up against serious competition at the time from other states. About 50 proposals were submitted to the federal government. I should perhaps add that this did not mean that there was one from each state; several states had more than one proposal, as things turned out. A great many people from The University of Texas at Austin were involved in helping Pete Flawn, Mort Meyerson, and the members of the Commission develop the proposal to the Department of Energy to locate the SSC in Texas. A few of these deserve special mention. One was Professor Ed Bingler, who was executive director of the Commission, and who was the "alter ego" of both Pete Flawn and Mort Meyerson during the entire process. Professor Bill Fisher, the director of the Bureau of Economic Geology, was a most important figure in our effort; Professor Austin Gleeson of the Department of Physics was extremely effective; and perhaps most important of all was Professor Priscilla Nelson of the Department of Civil Engineering.

Priscilla Nelson is one of the world's leading experts on tunneling. Providing a credible cost estimate for the tunnel that would have to be constructed for the machine in the Ellis County area south of Dallas was a major factor in the development of the proposal. Without Priscilla Nelson, I believe we would have had very serious problems. The geological formation in the area, which is called "Austin chalk," turns out to be particularly suitable for tunneling and that was, of course, one of the major advantages that Pete Flawn had pointed out earlier when the siting alternatives within Texas were considered. (Construction of the machine has now started, and I was very pleased to see the picture of the large excavation in the Austin chalk in the lobby of this building.)

Finally, Steve Weinberg was, as always, in the middle of things. In addition to the siting group within the Department of Energy, the National Academy of Sciences also established a committee to work with the Department of Energy on the SSC. The task of the Academy committee was to prepare a short list of possible sites for consideration by the Department of Energy. Steve was a member of this group and performed invaluable services during this phase of the activity as well.

Throughout all of this period, the leadership of Gov. Bill Clements was superb. I remember when the Evaluation Committee from the Department of Energy came here for a visit. The delegation was headed by my old friend, Dr. Wilmot N. Hess. Bill Hess and I knew each other at the University of California's Nuclear Weapons Laboratory at Livermore 25 years earlier, and I knew him to be a good and tough questioner. Bill Clements sat through the entire day-long presentation and he asked questions and made comments that clearly indicated that he was on top of the situation. At the end of our presentation, Bill Hess took me aside. He said to me, "You know, I have never seen this before. Usually the governor of one of the candidate states shows up for five minutes at the beginning, or perhaps five minutes at the end of such a presentation, if we are lucky. To have the governor sit through five hours of detailed hearings is absolutely astounding!" My own feeling is that Bill Clements's presence during the entire course of our presentation made more of an impression on the Department of Energy people than almost anything else we did.

During this same period, the large number of proposals were winnowed down and we began to realize that we were up against serious competition from two states: Illinois and North Carolina. In the case of Illinois, of course, the critical factor was the existence of Fermilab, which is the national laboratory that currently owns and operates the largest particle accelerator in the world. Illinois had the advantage of an existing "infrastructure" that could be profitably applied. On the other hand, they had a disadvantage in that the geology in the area surrounding Fermilab was not good for the purpose we had in mind. The question was whether the extra cost of tunneling in that area would be compensated for by the existing facilities that were already in place. Thus, Illinois continued to be a dangerous competitor until the very end.

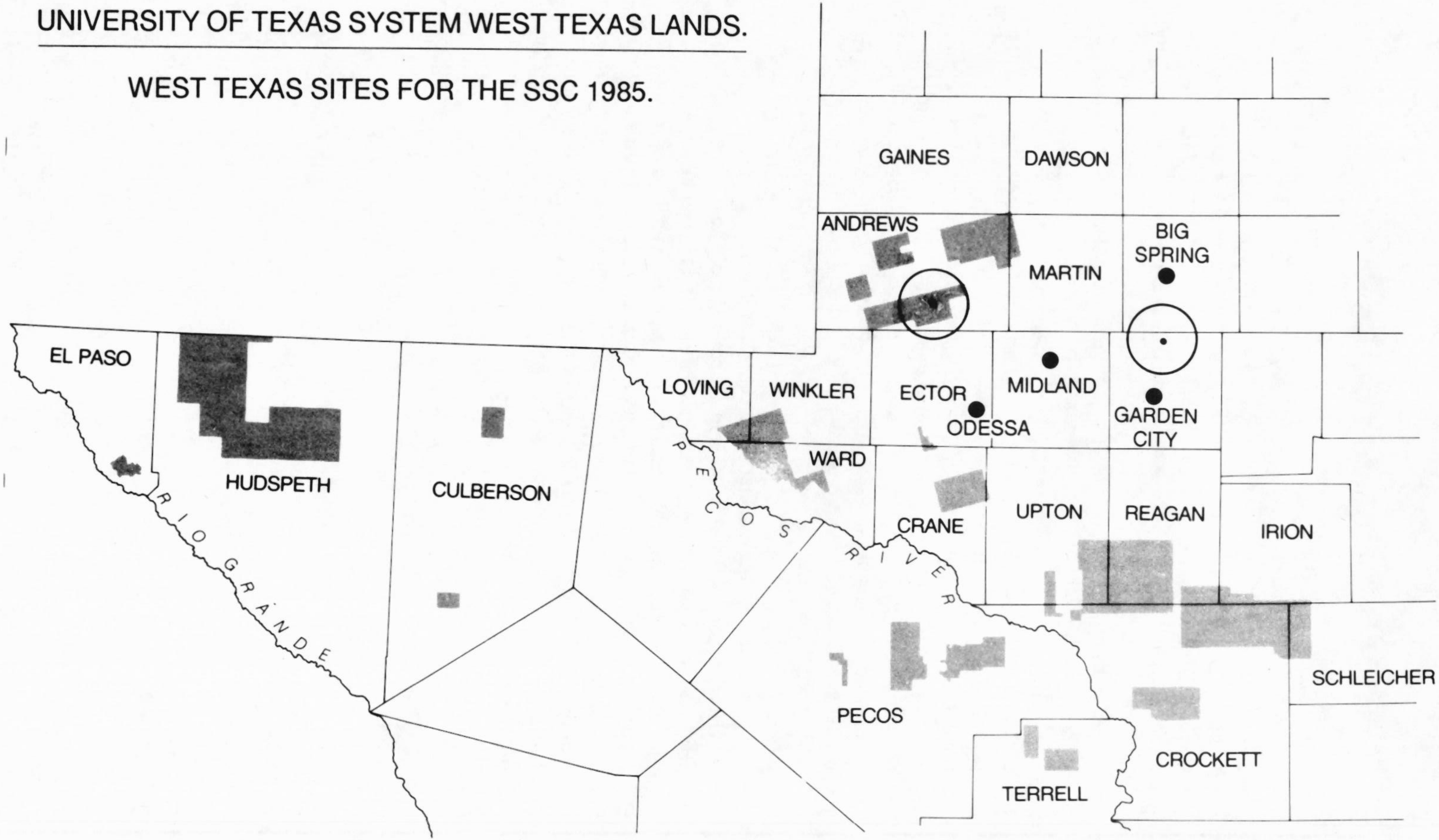
In the case of North Carolina, there was an aggressive governor, James B. Hunt, who knows high technology backwards and forwards. He more than anyone else was responsible for the development of the famous "Research Triangle" in the Raleigh-Durham area. Jim Hunt is extremely competitive. At about the same time, we were also up against him in our effort to locate Sematech in Austin, so I know whereof I speak. He was very, very effective as an advocate for his state.

As things turned out, I remember that in December 1988, I was visiting Dallas for some newspaper interviews when the decision to locate the SSC in Texas at the Dallas site was announced. I have to confess that I spent the rest of the day walking around on the proverbial cloud nine. My last illustration (Figure 4) is a picture of a couple of fellows who look just like the cat that swallowed the canary. This was taken at a meeting where we celebrated the decision to locate the SSC in Texas, and I do not need to identify the characters!

That is the story as I see it. In any situation such as this, I am always reminded of the fable of the blind men who were asked to describe an elephant. One who grabbed the tail said it was clear that the elephant was like a rope. Another who put his arms around a leg said clearly the elephant is like a tree. A third, who patted the elephant on the side said of course, the elephant looks like a wall, and the last one who touched the trunk said well, the elephant must be a firehose. There are, just as in the case of the blind men, many different views of what happened and the point of my talk is to give you one of them. I stopped being very active in the matter of the SSC after the decision was made to locate the machine in Texas. I am therefore looking forward very much to listening to the other people who are on this panel who will provide you with somewhat differing views.

As you can see, I believe that there were three heroes in the process I have described. One was Pete Flawn, who anticipated the whole process back in 1984 and who took the initiative to get things started. Then there was Mort Meyerson, who finished what Pete started. Finally, without the leadership and support of Bill Clements, the whole process would have collapsed.

It has been a pleasure for me to participate in this program and I want to thank the organizations, particularly Bill Seybold, for inviting me to come here today. I believe that history will show that the SSC will become one of the most important projects that human beings have ever conceived and executed.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WEST TEXAS SITES FOR THE SSC 1985.
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ODESSA
MIDLAND
GARDEN CITY
WARD
CRANE
UPTON
REAGAN
IRION
PECOS
TERRELL
CROCKETT
SCHLEICHER
PECOS RIVER
RIO GRANDE

FIGURE 1

MEETING WITH VICE-PRESIDENT BUSH, JULY 30, 1985

People present from left to right: The Vice-President, Mr. Bill Noel—Odessa (since deceased), Dr. Hans Mark, Mr. Fred Khedouri–Deputy Chief of Staff to the Vice-President, Dr. Frank Vandiver—President of Texas A&M University, U. S. Representative Joe Barton, Mr. Cy Wagner—Midland, Professor Peter McIntyre—Texas A&M.

FIGURE 2

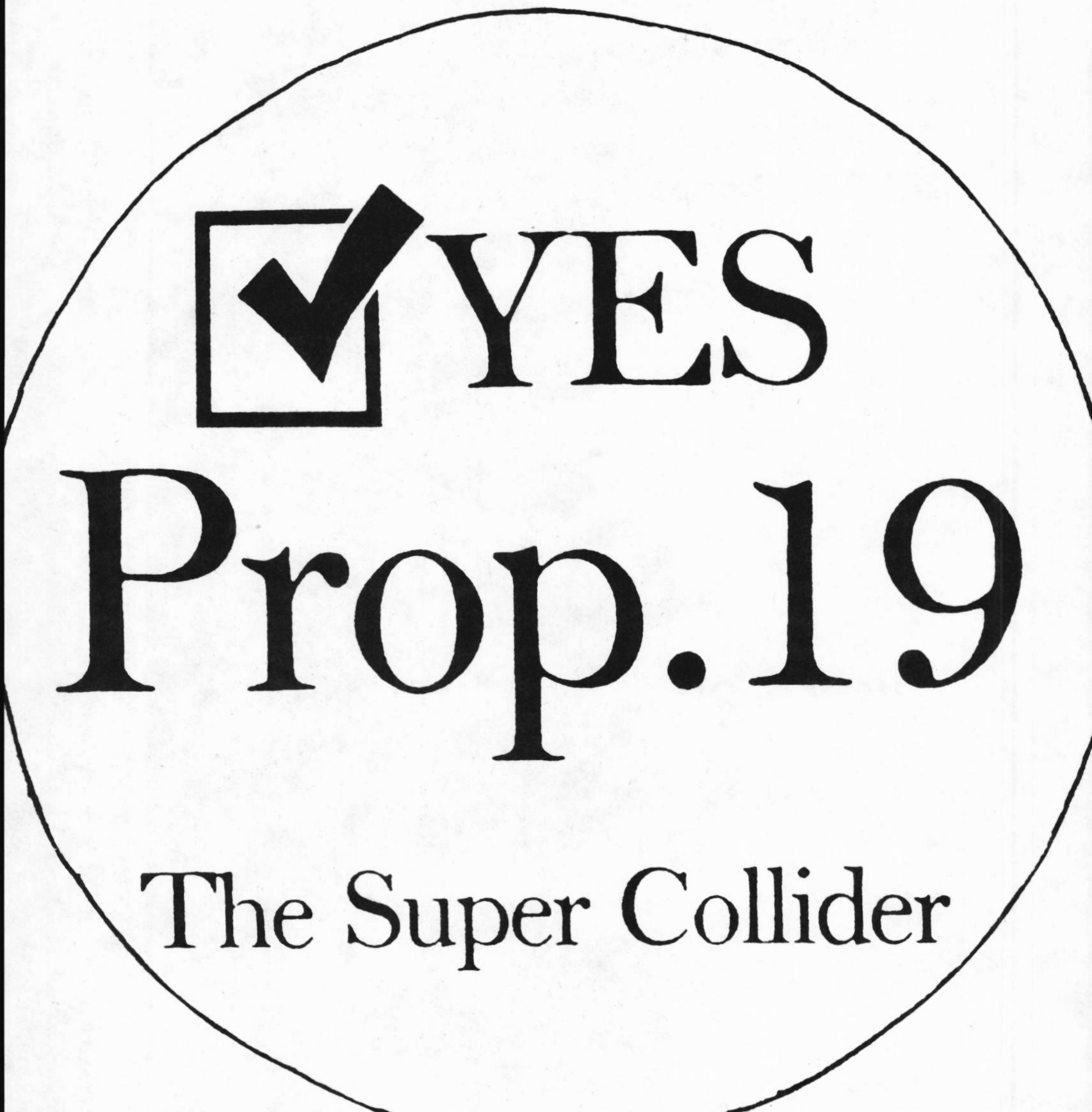
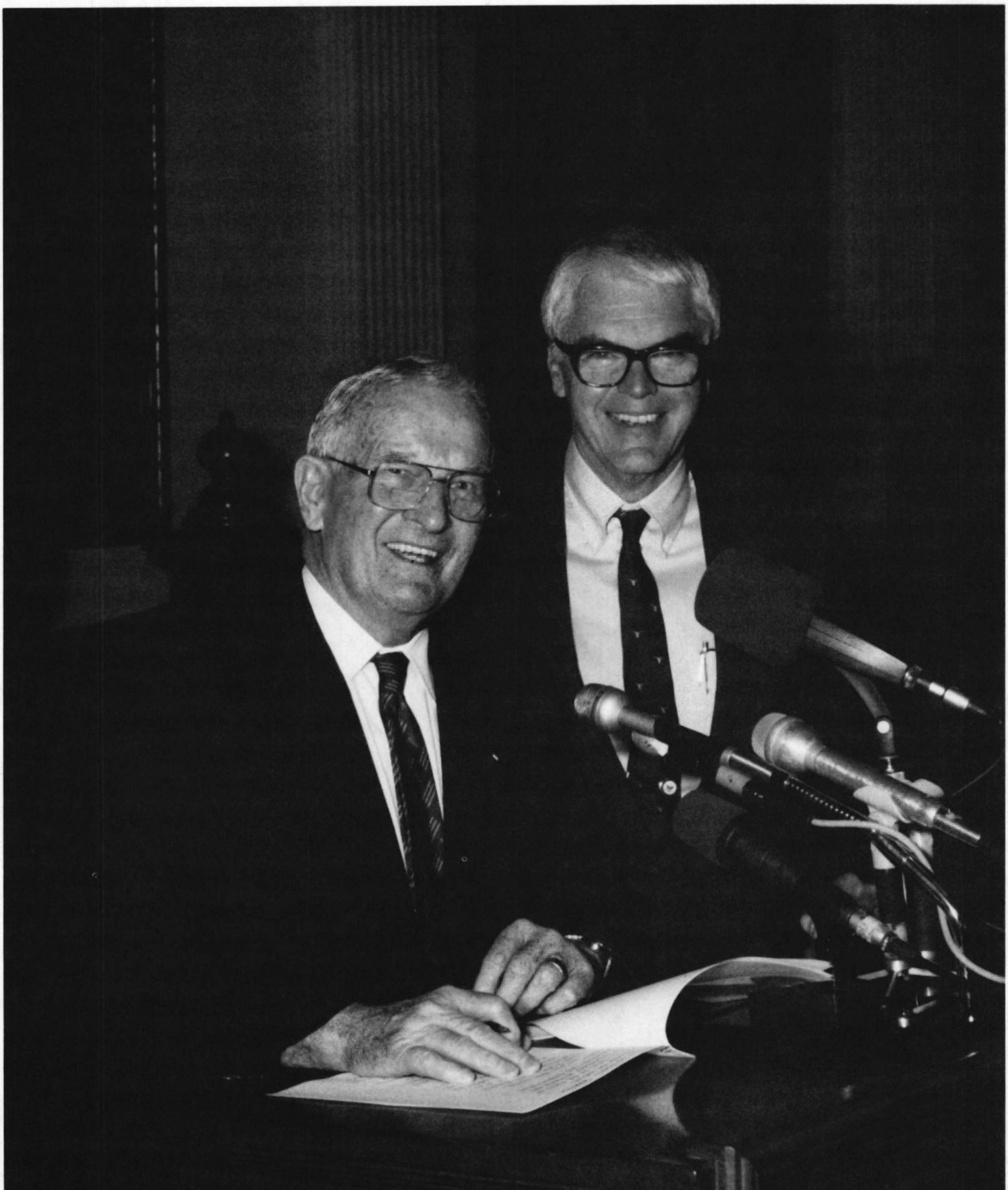


FIGURE 3



Governor William P. Clements, Jr. and Hans Mark

FIGURE 4

II
Morton Meyerson

Thank you very much, Hans. I wish that you had been present during the campaign so that you could talk to the New York *Times* and tell them that EDS really is a decent company.

I'd like to give you a slightly different twist on the story. I'm going to tell it to you from the eyes of the TNRLC—the Texas National Research Laboratory Commission, which was the statewide commission that Hans told you about. I'm also going to put a second twist on it. I'll be the first non-Ph.D. or -double-Ph.D. speaker that you've had. I'm a mere B.A. graduate from The University of Texas. My background was liberal arts. A lot of people think I'm an engineer because I have been in the computer business all my life. The facts are that I was a double major in economics and philosophy at The University of Texas and that's why we got the superconducting supercollider. I always put in a pitch for liberal arts.

I'd like to tell you about this in terms of context rather than content. I'm going to tell you stories around it so you get a feel for it. Before I ever worked in a governmental or quasi-governmental commission, I had no idea what they did.

And so, I start my story: I was on the commission when Peter Flawn was the chairman, and the principle objectives of the commission as appointed by the governor were to find the best location to compete in the national competition, putting Texas forward, and to produce the proposal that would win a competitive bid to get the site here. Governor White started the commission. There were people from all around the state, from Houston, Amarillo, West Texas, San Antonio, Austin, Dallas, Fort Worth, etc. And they were primarily Democrats.

I was retired at the time, having left EDS in 1986, and spent almost all my time building the symphony hall here in Dallas. I received a letter at home that said, "Dear Mr. Meyerson, You've been appointed to the Texas National Research Laboratory Commission. Please show up for a hearing down at the State Capitol. The Legislature wants to advise and consent on your nomination." Nobody had ever told me about it. I looked at it and said, what the heck is it? I gave it to my secretary and said, "Why don't you call these people? I don't even know what this thing is." I told them I didn't have time to go to their hearing because I was very busy building the symphony hall. I wasn't going to fool around with hearings, and then they sent back a letter and said, "We'll waive the hearing. You're on." So that's how I got on the commission.

I spent the better part of a year working with Peter Flawn. I'm going to tell you some stories today which will illustrate the saying that victory has many fathers and defeat is an orphan. This is the story of victory for the State of Texas and I think for science. And there are many fathers that will claim that they were part of it. Hans Mark deserves enormous credit for being a driving force to get

Texas motivated early in the game. Governor White deserves credit because he put good people on the commission. Peter Flawn is a particular hero of mine. I didn't really know Peter. Of course, I went to The University of Texas, but presidents of the university, when you are a student, are so far above you that you can't even think of them as human beings. But it turns out he was a human being, and he was a very decent guy, and he ran the commission in a relaxed but organized manner. I went to the meetings, I read the assignments, I voted when I was supposed to vote. We were right in the middle of the process of selecting the site, which was terribly political. We had chambers of commerce calling at night and so on. It was a zoo. Frankly, I knew we had to do it, but I wasn't too interested in it, so I paid attention and voted when I was supposed to vote. Then we got to the proposal stage and I got real interested because at EDS I had spent a fair amount of time putting proposals into the federal government to win large computer systems contracts, and I knew something about that game. Peter Flawn picked the deputy director of the Bureau of Economic Geology to help him put it together, Dr. Edward C. Bingler, and we did some good work on that.

At the end of a meeting in December, Peter Flawn said, "As my Christmas gift to everyone here, I'd like to announce that I've been elected the president of"— I really can't remember, it was the National Association of something-or-another Professors, chemistry professors. He said, "I cannot serve any longer as the chairman of this commission and so, therefore, at the next meeting, I'm going to resign. It's been great working with you people, wonderful." We gave him a standing round of applause, looked at each other and said, "What happens next?"

This next little piece, like the letter I received, is the story of my life: strange birds fly over and carry me away. Governor Clements called me. I didn't really know him then. I had met Governor Clements; he was on the EDS Board for a short while before he ran for governor. I respected him but I didn't really know him. He called me personally and asked me if I would come by his house Saturday afternoon.

So I put on my checkered sport coat, went over to his house, sat there knowingly, and said, "Yes, Governor, how may I help you?" And he said, "You can help me by winning the siting of the SSC for the State of Texas." And I said, "Well, we're all dedicated to this. The commission is fully supportive, we're ready to roll," you know, I'm giving him this team speech. And he says, "I suppose you're wondering why I've asked you over here." I said, "Yes," and he said, "I'd like you to be the chairman of the commission." I don't know how I was selected to go on the commission, and I have no idea how I was selected to become the chairman, but I'm sitting there dumbfounded looking at the governor. And I said, "Governor, this is a pretty big mission that you're talking about. We've got a very good commission group. The players that are on it are really quality people. Peter Flawn has done a wonderful job, he's a sensational person. I'm not sure I'm up to the job. I'm not very political. I can be hardheaded. I've got a lot of character flaws that you don't know about. I'm not sure that I could pass if we went to the Senate and did the confirmation hearings. I mean, who knows what would happen. I'm not sure I'm your person." He said, "You're not listening to me, Mort. We need to do this for the State of Texas, and I think you're the person to do it." And I said, "You're beginning to sound very much like another person I know." This is a true story. He said, "I didn't ask you if you're willing to serve the State of Texas. I'm more or less putting it to you, I think you have a duty to do this." And I said, "Governor, I need to think about this. This is going to be basically a full-time job. The pay is bad—zero. The exposure is enormous. The glory is nonexistent, and I'm not real sure I'm the right person because I'm not 100 percent sure I know enough about the SSC. And the way I go about doing things is I've got to understand it before I can work on it." He said, "Fine, take 24 hours, do whatever you want, and talk to me." So I went off and made a few phone calls. I called back and said, "I don't quite understand why you're doing this, but I will take the ball. How should we work together?" And he said, "Very simple. The objective is to win. Do everything that you can to be ethical and straightforward. Call me when you need me. Thank you very much."

That was a pretty good set of instructions. So I started a quick study of the history of the SSC, not from Hans Mark's viewpoint, but from what in the heck is a collider and what's an accelerator, who's done this and what is Fermilab, etc. I discovered that the builder of Fermilab, which was the largest and most powerful accelerator in this country, was still alive and at Cornell. My son was going to Cornell at the time as an undergraduate, so I flew to Cornell and met R. R. Wilson, sat down with him, and said, tell me about building accelerators, tell me what you did at Fermilab. For the next two hours, Dr. Wilson explained to me the similarities between architecture, music, symmetry, and accelerator-building. He's quite gifted, probably a genius. I was enthralled with the whole thing. I ended up by asking, "Is this worth doing and are we doing the right thing?" He said, "Yes, you are, but you ought to talk to other physicists." So I called Steve Weinberg, whom I didn't know, and I went down to The University of Texas and met with him, asked him the same question. He said, absolutely. I talked to Hans Mark on the telephone. I called Burton Richter, who's a Nobel laureate from California. I couldn't get a meeting with him because they were trying to win the competition and he wasn't about to talk to me. And I met with E. C. G. (George) Sudarshan, a theoretical physicist at The University of Texas, spent an evening with him, and I loved the conversation. I asked him if it was worth building, he said, "Yes, but there's one great danger." I asked, "What's that?" He said that we'll get so enthralled with the financial aspects of this that we'll take The University of Texas and we'll make a wheel with a square corner on it because all the money will flow over into physics. You'd better protect liberal arts, philosophy, and the soft sciences, because that's what humankind is really interested in, and they will make us better people.

I thought that was pretty stout coming from a physicist. When I got through studying the history, I was convinced it was a meaningful exercise. I went on to investigate proposal writing. I knew how you win proposals in computer systems, but I didn't know about this, so I did an investigation. I figured out who was on the selection committee and told the proposal writers, here's how we'll win. Every question they asked must be answered; do not put any blanks in there. All they're looking for is a pass/fail, there'll be 200,000 elements in it, and we'll win by doing every one of them. And that is, in fact, how the proposal came out. It was seven feet wide. We had three copies of it, and I had two Learjets fly them up, so if one went down, we'd get a copy there. You have to submit it on time. California submitted it late and it was taken out of the competition.

We submitted it, it passed muster, and then we started, I started, and the commission started working. I studied the history and I found out that Fermilab was not supposed to be built in Illinois. Fermilab had been designated to be built outside of Denver, because physicists like to ski. It's a true story. Why do you think they build an accelerator on top of a fault at Stanford? Not because it's a great location, but because you'd rather be in Palo Alto on a peninsula than in the middle of desert in Nevada or some place.

The reason it didn't go to Denver was a deal made between LBJ and Everett Dirksen, and there was another piece of legislation out there that went to Illinois. The Johnson Space Center was the other piece. So I said, the way that we'll win this thing is that we will have the best proposal and we will touch every base. We had Congressmen and Senators work with each other. We had Phil Gramm working with Bentsen night and day. We had Joe Barton working with other Democratic people (I won't name them) in the area. It was a thing of beauty. It was like watching a symphony. It was absolutely wonderful. And we had Governor Clements in the background doing what he does best. I would say, "I need to get a meeting with so-and-so." Next day, the meeting with so-and-so was done. I would say, "Would you come with me to a meeting with the deputy secretary who will explain this thing?" Bang, he was in Washington with me. You have never seen the level of support from a governor that I got as chairman of this commission. It was absolutely fantastic. Working for him was a joy. It was simple, with a single objective: win this competition and do it right.

There was lots of discussion in the commission about Proposition 19. The idea was if the state committed funds, it would separate us from the pack because other states had all kinds of environmental concerns. There were people with placards in Illinois saying, "Keep the radiation away, we don't want our milk to glow at night." There was lots of stuff going on. And we had a Congressional delegation that was absolutely together and then we got the State of Texas to commit early on that we would put these funds up, and that made it pretty powerful. All we needed to win this $8 billion project was a proposal that would pass muster. The state and federal relations lobbying group was working with us, and we were in there all the time. I'm going to end by telling you about the final meeting with the deputy secretary of the Department of Energy. The governor and I were giving a presentation and I hid under the table a foot-square cube of Austin chalk with a hole drilled through it. And at the end of my presentation I said, "The reason why the SSC should be here is that, not only have we produced a proposal that meets all the criteria, not only do we have a billion dollars that we are willing to commit to it, not only do we have a Congressional delegation that will work with us night and day, but God meant it to be here." And I pulled out the chalk with the hole drilled through it, and said, "We've got geology; this chalk is here, and we can drill a hole through it without any supports and we can put a tunnel 10 feet in diameter, or whatever you want, 53 miles long, and we can do it cheaper and better than anybody else." I handed it to the secretary. Well, Harold stopped the meeting. He looked at the secretary and said, "Hmm, look at the hole." So the meeting got to be around this piece of Austin chalk. It was fantastic. I learned from another person, I won't tell you who it is, to do things like that. But he is short, smiles a lot, has ears.

Anyway, we didn't win the competition because of the chalk cube that we put in front of them, we didn't win it because we were good people, we won it because we paid attention to 200,000 details every day and worked on it for three years. I'm really proud of what the commission did. We held meetings all over the state. It was a joy to behold. It was one of the greatest groups I've ever worked with, and if there is a true hero to this story, I would say it's Bill Clements, because without his absolute focus on this, we wouldn't have won it. Thank you.

Mark: Thank you very much, Mort. There is one thing I would like to add to what Mort said, and that is, that among a great many people who gave time to the commission and the hole in the chalk was Priscilla Nelson, you remember the young lady who was a professor of civil engineering at The University of Texas at Austin, who is the world's leading expert on tunneling. It was, I think, a critical point to have a hard cost estimate that was credible, and Priscilla Nelson was the one who did that. And, of course, I couldn't agree more with what you said about Pete. I think he's a hero, like Bill Clements.

It's now my very great pleasure to introduce our third speaker. As I've already mentioned, Joe Barton's been in on this thing from the very beginning. He's been a member of the House of Representatives, since 1985, and has now been around long enough that he has acquired seniority on the Science and Technology Committee, which is, of course, the committee that handles this project, and that, in turn, is a very, very important thing for us. Joe is in many other areas also an effective legislator, and I think we will hear a great deal more about him as time goes on. It's certainly been my pleasure to work with him, and as I mentioned before, I think we have a few more years of campaigning before we actually get done. I, for one, am pleased to know that Joe is there and is going to lead our fight. So it's a great pleasure to introduce the Honorable Joe Barton.

III
Joe Barton

Well, it really is a pleasure to be here this morning. I was sitting in my Fort Worth congressional office about a month ago, and the phone rang, and it was Bill Clements on the phone. It was the first time he'd ever called me personally. I've had official calls when he was governor, but he called up and he said, "What are you doing, Joe?" And I said, "Well I'm sitting here doing some work." And he said, "How would you like to come to Dallas and talk about the supercollider?" And I said, "Well, Governor, I'd be happy to. What have you got in mind?" And he talked about the Philosophical Society. He said, "Have you ever heard about it?" And I said, "Well, no, Governor, I really haven't." And he told me what a great bunch of people you folks are and how Sam Houston started it, and bottom line, he said, "I want you in Dallas at 10:30 on this day," and I said, "Yes, sir." Because I have asked Governor Clements to do a wad of things for me personally and politically in the supercollider. It's the first time he'd ever asked me to do anything for him, and so I was very happy to do it. Then I found out after I hung up the phone that it was the same day that I'm supposed to be down in College Station, Texas, selecting young men and women to serve at West Point, Annapolis, and the Air Force Academy, so we did a little rearrangement of the schedule. I did about half of that last night and I started at 7:00 this morning and walked out of the meeting at 9:00. I hopped on a fast plane and got to Love Field at 10:15 and got in here about 10:35 to find out that Bill Clements isn't here. But I am. So let the record show that I honored my commitment and I think I've got five minutes left before the break.

This is my briefing book for the site selection process for the years 1987 and part of 1988, because I wanted to leave no stone unturned about how we got the project here in Texas. I have to say before I go into my very brief remarks that there are a lot of people sitting out in the audience that could be a part of this panel. We've got Trammell Crow right here in the front row, who was a real trojan talking to President Reagan in the beginning of the project. We've got Peter McIntyre, the professor of physics, the head of the Texas Accelerator Center, in the back. We've got Peter O'Donnell over here, another commissioner of the TNRLC, and others, so a number of you could be a part of this particular panel.

And I would say, before I get too technical, that what Hans Mark said at the beginning, about why we got the SSC in Texas, is because Texans are willing to take risks; Texans are visionaries, Texans will be a part of the game. I think all technical merit aside (which we had), that's the reason the project came to Texas. Because when the technical merit was almost equal, time after time after time, from my vantage point in the U.S. Congress, I saw the decisionmakers, if there was a doubt, go our way. Because they knew that to build this thing was going to take a lot of grit and determination and effort and they needed a leadership group, both in the Congress and in the home state, that would go to bat and that's Texas, without question.

Having said that, let me talk about the technical aspects of it. President Reagan made a decision in January of 1987 to move forward with the supercollider. And on February 10, Secretary of Energy John Herrington testified in February 1987 before the Energy and Commerce Committee Subcommittee on Energy and Power on the fiscal budget for the Department of Energy for the coming year. Congressman Joe Barton asked him three questions, every one about the supercollider—every one. And the first question was: Is the timetable that's been established—to have the state submit proposals to the Department of Energy in August of 1987—is that firm? And he said yes, it was firm. And then we went through a whole list of detailed questions: what are the criteria going to be, who is going to be on the site selection panel, how is it going to be weighted, and most of his answers were, it wouldn't be fair to tell you because we've got to wait until we tell everybody else. But within a month, with the people at TNRLC and Governor Clements, we were already planning for August. And the first thing that Texas had to do was pick a site or sites. We don't think about that much today, but Mr. Meyerson wanted one site. Dr. Mark wanted multiple sites, the more the merrier. There was a pretty big debate. Did you want one site or multiple sites? In fact, the Texas Legislature passed a bill through the Texas Senate that said there could only be one site. Congressman Stenholm and I and about 10 or 11 other congressmen sent a letter to Governor Clements saying don't pin us down that way because there is so much animosity against Texas in the Congress that if we pin our hopes on one, they can knock it out on some superfluous grounds, but if we have two or three or four, they can't knock them all out. The end result was that Governor Clements did suggest that there be the possibility of multiple sites. Peter Flawn very adroitly got a vote in the commission that said, well, we'll probably only want one, but that's not a binding vote, we can change our mind and have others later on, and that made everybody happy. We ended up sending to Washington two sites that were official sites and about four or five that weren't official. One that was sent by the West Texas Chamber of Commerce was actually in New Mexico, believe it or not, but there were a number of sites sent. And as Mr. Meyerson has indicated, the work done on the two official sites—one in Amarillo, which was called the low-cost site, and the Dallas-Fort Worth site, which was the site that most met all of the criteria—was meticulous.

When the deadline came for all the states to submit, some of the Congressmen and Senators from the other states that had not done the homework that Texas had really wanted the site selection process to be given another six months, or even another year, perhaps, and we were able to prevent that, but they did extend it for a month. Well, when push came to shove, 35 states submitted I think 43 sites to the DOE in August or September of 1987. And the Secretary of Energy appointed a panel, a group of 21 men and women from around the country, members of the National Academy of Sciences, the National Academy of Engineers; Roy Schwitters was on that panel; Steve Weinberg was on that panel; Raph Kasper, who's now the associate director at the laboratory, was the staff director of that panel. Most of the people were from Illinois, Massachusetts, or California. There was only one Texan, Steve Weinberg, on that panel. And they had six different criteria. Tunneling or geology was the first criterion, and it was supposed to be weighted the most. Utilities was the last criterion and it was supposed to be weighted the least. Regional resources was the second criterion and that kind of concerned me because I felt like regional resources were ballet companies and symphonies and things like this, and I wasn't sure that we could compete against Chicago or New York or some of those. Of course, Mort took care of that with the Meyerson Symphony Hall here in Dallas. He'd been planning ahead, see, in true Texas tradition. While we had all this enthusiasm for the SSC in the Congress—35 states, 40-some-odd sites, this distinguished panel, the National Academy of Sciences reviewing it—we decided that we better get something through the Congress. So we established a working group of Congressmen and Congresswomen to meet for breakfast at least once a month. Some of the people that were on that working group were: Manuel Lujan, who then was the ranking Republican on the Science and Tech Committee and later became Secretary of Interior under President Bush; Lynn Martin, a Congresswoman from Illinois, who later became Secretary of Labor under President Bush; and Vic Fazio, the head of the Democratic National Campaign Committee, from California. We would meet for breakfast and kind of just strategize how to do things in the Congress, and we came up with the idea of getting an authorization bill through the House. We ended up with about 350 original cosponsors on that bill. Now this is again when all these states were implied. And so Congressman Lujan introduced the bill and it passed by unanimous consent. It never passed the Senate, but we got it through the House and that showed tremendous political support. Also during that time period, Skip Porter of the Texas Accelerator Center down near The Woodlands decided that he needed a little bit more money for doing some research on the magnets, $2.8 million, so he came to Jack Brooks, the dean of the Texas delegation, and he came to me. Congressman Brooks really did the work, I don't take the credit, but he needed a Republican to call the Republican members of the Committee and Skip couldn't sign off. So we got into the appropriation bill, a supplemental appropriation bill, $2.8 million for the Texas Accelerator Center to do advance work on magnet design. We got that through committee, we got it out on the floor, and all heck broke loose. The Illinois delegation went through and they were reading the fine print and they saw $2.8 million for the Texas Accelerator Center, and they just came unglued. It was about one o'clock in the morning and they jumped up and Bob Michel from Illinois, who was the Republican leader, was just ranting and raving against the dastardly Texans and how we'd snuck another one in and all this. To make a long story short, we lost that battle, because they called a roll-call vote on us and beat us like a drum. I mean they beat us 250 to 100 or something. But we were able to say with all honesty that it had nothing to do with the site selection process, and we later got that money. We were later able to come back in conference and get the money.

Something else that we did was to lay the groundwork for a national coalition for the SSC in that first two years, and as Mort has talked about, his people were working very closely with the staff. They did a number of field hearings where they came down and actually looked at the sites. One story that he didn't tell you, which I think impressed the site selection committee; they were supposed to have an outdoor picnic in Dallas after spending the day out looking at the site, but the weather got bad, and they were afraid they were going to have to cancel the picnic. I don't know if Bill Clements made the phone call or Mort Meyerson made the phone call, but somebody called Ross Perot, and Perot said, "No problem. We'll do the picnic in my gymnasium." And in about four hours, when it got time to go do the picnic, we went over to north Dallas and we walked into this private gymnasium and there were red-checkered tablecloths and all the food was there, and that deal was put together I know in less than a half a day, or maybe three-fourths of a day. It impressed the site selection committee when they saw that Texas could move that fast on that kind of an operation.

Of course, in November, the National Academy of Sciences picked eight of the 35 sites that passed initial muster to be on the best qualified list, the BQL list, and those were New York, Arizona, Colorado, North Carolina, Texas, Illinois, Michigan, and Tennessee. New York backed out. Governor Cuomo got cold feet and backed out within a month and, as Hans Mark said, the competition really did boil down, I think, to Texas, North Carolina, and Illinois. But it really boiled down to Texas and Illinois, because of the superb work that was done by the TNRLC and because Bill Clements was the most hands-on governor of the entire group in Washington. He literally would do anything to further the project. The Secretary of Energy did announce, on November 10, immediately after the election, that Texas had been chosen and we've been working ever since to hold it but we no longer have 350 cosponsors on bills in the House on the supercollider. It's a lot tougher this year. In fact, in the budget that's going to be submitted by the President in January, we're probably asking on the order of $800 million, up from $517 million that we're spending this year. So we're really going to have our work cut out for us, but we've spent so much and we've been so successful, and we've had such great support from the leadership group, both political parties, and the private sector in Texas, that I'm very, very confident that we're going to be successful, and that this project will make our state, and our nation, the preeminent high-technology development area in the world in the twenty-first century. There really is no project that better epitomizes, in my opinion, what's made us such a great state, than the supercollider. And if I could make one final comment, I've had goosebumps the whole time I've been on the panel listening to these men about what it takes to put something like this together. Everybody working together, many of us as small cogs, others as larger cogs, is what makes great ideas become reality, and I'm just privileged to be one of the small cogs that's had a chance to work with such good people for such a good cause. And with some luck I will be there at the end when we turn the crank and the first protons go around the beam in October of 1999. Thank you.

Mark: Thank you very much, Congressman Barton. I think that I'd like to echo what you said. People like Joe Barton and Mort Meyerson, I think, will in fact see those protons go around that beam tube.

Mark: We have a period for discussion, now, and since we didn't have a chance to ask questions of our earlier panelists, I'd like to ask Dr. Schwitters, Dr. Gross, and Dr. Galison to come up and sit with us. Any questions? Yes, there please. I'll repeat the questions so you don't have to go to the microphone. Just talk to me and I'll repeat it.

The question is, what are past and future international involvements in this machine? Let me answer from my point of view and then open it up.

If you read the letter I wrote to Bill Hobby in January 1985, you will see that one of the things I mentioned is the possibility that we buy power from Mexico to power the machine. Now at that time, we were talking about West Texas sites and I put that in because I knew that international relations would be important in getting this thing approved. The interesting part of it is that the Mexicans have a plant along the Rio Grande that is underutilitized and we, at that time, had excess capacity. Why, when that surfaced, the Texas power companies came down on me with both feet, and so that part of the international effort collapsed very quickly.

Schwitters: Yes, let me divide it in two parts. First of all, the experimental and theoretical work we talked about at the beginning was very international. The major laboratories in the world are CERN in Geneva, Switzerland, there's a laboratory in Hamburg, major laboratories in this country and Japan. In addition, the experiments are highly integrated across international boundaries. Already, we have in the program about 700 international scientists with a comparable number of Americans planning the experiments. That's the traditional aspect of high-energy physics, so it's highly international. Now, what's new is a desire on the part of our government to invite international participation in the construction of the facilities. That's a new aspect. It's been done, of course, at CERN in Geneva, which is totally international. More recently, it was done in Hamburg. That's a facility funded largely by the German government, but in order to get enough overall support, the scientists convinced their colleagues in other countries to contribute in kind some of the equipment needed to build the facility. That's been suggested for this facility. To date, we have formal agreements in place with the Russians and Chinese and actually others on the detectors to build detector components. We are engaged in discussions with the Japanese government that followed President Bush's trip last January to Japan where that country established a so-called working group that we've been working with to negotiate and plan a really major involvement by Japanese scientists and industry in some aspects of the machine. That work is not complete yet. We don't know what the outcome will be. It's in process, really waiting now for agreements between the new administration and the government of Japan. Today, if you come to our site, you'll find (we just did a census) about 25 different nationalities represented, either on the staff or from visiting scientists. So in that sense, we're already a highly international organization. But, parts and pieces are actually coming in from Russia and China and other places around the world. It's really very interesting. I received the most spectacular shipping label I've ever received when the first parts came in from Russia, and you can imagine, of course, what this means to them and to us. They have excellent people in accelerators, so they really have been a tremendous help to us intellectually, and we can really help them with the foreign exchange. But, anyway, the first parts came in with this beautiful, wooden shipping label with my name burned in with a woodburning pencil. It's really lovely; I've got it hanging on my wall.

Barton: And he used it before the Appropriation Committee last year to show them about international participation.

Mark: Are there any other panel members who'd like to comment on the international aspect? Okay, next question, yes sir.

Question: What are the particular characteristics of the Dallas site of Ellis County that made it the winner?

Mark: I think Mort, you're probably the right person to answer that question.

Meyerson: Okay, I was on the commission when all these 40 sites competed. The factors for Ellis County were as follows. The geology was virtually perfect; it wasn't exactly perfect because the Austin chalk had an underlayer of some marl, which is a little more crumbly than chalk. But we had very good geology. That's step one. Step two, we're near a metropolitan area which has an international airport that you can fly into from all over the world. So Erik Jonsson gets his kick in trying to help get the supercollider here. The DFW airport was fundamental. The third thing is the city of Dallas-Fort Worth and the Ellis County people, Arlington, Plano, everybody, all the mayors got together; we really put on a show for the visiting committee that came down here. We talk about these public hearings that Hans Mark mentioned, there were several site visitations, and the various mayors and the city councils got together, and we showed them the arts here, we showed them support in the community, etc. We actually got dinged, and there was a big brouhaha inside one of the site visitation about the civil rights action down here and open housing. Because if you don't have open housing in the state, then you couldn't get federal loans. That was the only thing that came up. I have never seen the scores that we got from the visitation, but my guess is we knocked them dead. So many details you have to work with—we had the mayors meet them, we did the airport, we did this, that, and the other. The Austin chalk is real prevalent in Austin, and we took the visitation committee down where there's a 20-foot diameter pipe under Austin, for water supply or for sewage, one or the other. And we actually took them down there and showed them pictures of drilling through it. The Austin chalk rises from Austin and it terminates between Fort Worth and Dallas. If you look at it, there's an uplift, and so we got into the edge of it, and it happens to be south of Dallas in Ellis County.

Question: It was said the purpose of the university is to make better people, and I wondered if philosophically anyone would like to tackle how this whole project is going to make better people?

Mark: Let me take a crack at it before I ask my colleagues. The answer to that has to be that if there is one lesson that you could draw from human history, it is that knowledge helps to make better people. And, that would be my answer. Gentlemen?

Schwitters: I think that's exactly the right answer. It's the overall investment of the wherewithal to continue to challenge the unknown. That's what it's all about, and that's what's so interesting to me personally, being a part of this is how that manifests itself in so many different pieces. But we've already heard your political, technical, scientific, and so on, and those are the elements of how a great society, I think, makes progress.

Meyerson: I'd like to make just a quick comment on this. This really was a fascination of mine when I went out to explore why the SSC would be meaningful. Is it worthwhile, is it worth the money, etc.? As a layman, there's no way that a person like myself, and probably most of the people in the room, with exception of Bobby Inman and people like that in the audience, could possibly understand the complexity of this machine. So at some point, you have to buy on faith that it does make sense scientifically. When you get past that point, as I did after finding all the experts and talking to them, I became convinced that the presence of the SSC would have an incredible impact on the education of the children of the state. And a kind of indirect or second tier is that it will change the nature of the universities here, it will attract world-class scientists. Those world-class scientists will change the nature of the high schools. There are 2,000 scientists working down there. Just their very presence in De Soto is going to change the high school in De Soto. The SAT scores are going to go up in this area. There's going to be a fiber-optic network someday tying the universities together. Hans Mark and I talked about this, and when they do that, we'll have live presentations at the SSC in the classrooms at Texas A&M, Rice, University of Texas, Dallas, etc. The physics departments are going to change. The high school curriculum is going to change. There's going to be a science museum. It's going to change. And for those of us, hopefully, who will be here in 2010, we'll look back and say, "We have made a radical change in the education of our children." We've changed the nature of the state of Texas, and we are in transition between agrarian and educational interests and high-tech interest and other interest. And I think it will really make an impact. I made one telephone call to Colonel Leventhol and asked him if he would set up some people to meet with Roy Schwitters, because I knew that there was medical help available buying by-products of the supercollider. As a result, we attracted a potential Nobel Prize-winning doctor down here, on the cutting edge of research in radiology and treatment of cancer, who probably wouldn't have been attracted to our medical school had we not had the SSC here and had we not had cooperation from Roy Schwitters. And you watch, we'll be a mecca. Our medical school will be better for it. This was not my idea, this is something that Wildenthal and Schwitters came up with. And I think it's wonderful.

Question: I think we all agree this is a very exciting time for challenges, for expansion of knowledge. I would like to hear some of the panelists give their view on priorities in relation to some of our other large projects that are also challenging such as space, the lunar station, the human gene, housing, nutrition, rural population. Is the answer, with our resources, to give some money to each, or do you have priorities?

Mark: Let me repeat the question. The essence of the question is how do you prioritize large projects. How do you prioritize among scientific projects, and then how do you prioritize large scientific projects like this one against other things that we ought to be doing. And if I may, let me take a crack at that and then again ask my colleagues to respond.

First, with respect to prioritizing space stations, SSCs, and human gene projects against funding health care, secondary and primary education, and inner cities, what you have to keep in mind is that the scientific and technical projects are all very small compared to anything else that we do. Joe Barton mentioned $800 million. That is less than one-third of one percent of the budget that Joe and his colleagues will pass next year. And so, when you add everything up, space stations, geno projects, you are still talking about a small amount, far less than one percent of the federal budget. And that percentage, I would submit, is necessary. I think in my letter to Bill Hobby, I quoted George Will, who said that a great nation has the obligation to explore. And that's what we're talking about here. It is not something we like to do or want to do. It is an obligation. And to put one percent or something less of your public funds into that, I think, is reasonable.

Now, what about the priorities between space stations, SSCs, human genos, and so on? I had a lot to do with getting the space station started as well and so I have always been torn between those two. In my estimation, I don't have any problem prioritizing between the space station and the SSC since I moved to Texas. The answer is we've got to do them both. The space station is being done at the Johnson Space Center in Houston and the SSC is being done here, so it's fair.

Seriously, I think that we mentioned the committees at the National Academy, we mentioned the procedures that the scientific community goes through to prioritize these things. In the case of the space station, we had a committee a few years earlier similar to the one that I mentioned in the case of the SSC. In the case of the human geno, the same thing happened, only a little bit later, because that's a project that was started a little bit later. I think the answer, again, has to be that a nation such as ours, must carry on three, four, or five large science projects like this. This is embedded in our history. This is not something that's new. I remind you of things like the Erie Canal or the Panama Canal, for that matter, which were large technical projects. We do this and we do it very well. And I think George Will is right, we have an obligation to do that.

Barton: Could I give you a slightly different answer? In Congress, it's not normally a fight between research projects like the ones you mentioned, it's a fight between basic research and consumer-oriented spending, and the federal budget is about 1.6 trillion dollars, that's $1600 billion. Of that, basic science, military and non-defense, is about $64 billion, and of that, high-energy physics, all together, is about $4 billion to $5 billion, and of that, the SSC this year is $517 million. So when you break it down, in order of magnitude in comparison, we're not spending a lot. The debate we have is do we put money into basic research or do we put it into housing or in our roads or Medicare or things like that. And I think in the coming Congress you're going to see more and more pressure put on discretionary non-entitlement spending that doesn't have an immediate payoff. Because more and more people are going to say, patch the potholes in my road, and I'll worry about the next century when that gets here. And so it's vital that we have people like Roy Schwitters and Steve Weinberg and Hans Mark and others that can create the political support, the popular support, among the country to keep these things going. Because if you look at our population growth, not necessarily in this country, but in the world, we have got to have increased productivity to maintain the standards of living and increase the standards of living in the countries around the world, and that's where the SSC comes in. I can't tell what Roy Schwitters and his scientists are going to discover, but I can go back and look at other high-energy physics accelerator projects that came on line in the forties, the fifties, the sixties, and the seventies and see what they discovered that has commercial application today. So it's really not a debate between the space station and the SSC or the human geno or even AIDS research. It's a debate of do we put money into the future or do we spend it right now on needs that get votes in the next election.

Question: First I want to compliment Mort Meyerson for his salute to the liberal arts. If it hadn't been for his background in liberal arts, we couldn't have created one of the greatest concert halls in the world. I want to ask Dr. Schwitters a question. How do you think that most theoretical physicists view first call? I ask that question because I've always been fascinated about the definitive nature of the mass versus the big bang?

Schwitters: Let me repeat the question. This is a technical question. The question is really how do we talk about these concepts, especially the origin of time and the big bang? How do we visualize, and how is it even appropriate for us to talk about these concepts that seem to be so far removed from ordinary day-to-day reality; is that the essence of the question?

Question: How did you have the big bang if you didn't have mass? Where did that mass come from?

Gross: Let me qualify my statement that high-energy accelerators, such as the SSC, explore the processes that governed the universe at the time of the big bang and before. Actually, the big bang is a rather late occurrence in the history of the universe. It occurred a few hundred thousand years after what we now think was the beginning. And the physics that created that explosion, whose remnants we see in the microwave radiation permeating the universe, is very well understood and beautifully described by Steve Weinberg in his book, *The First Three Minutes.* But we have learned a lot more physics which would be operative at times before the big bang. Although it's very difficult to directly observe events before the big bang we can, using our knowledge, play the movie backward until we get to the first nanosecond of the universe. But even that, in a sense, is infinitely removed from the first nanonanosecond or from the very first instant. What happened to the universe as it went through this evolution as we play the movie back, we don't know beyond a certain point. Perhaps we are going to learn it, as I intimated, at the SSC. I mean, given the results that we will learn from the SSC, we'll be able to push the movie back another order of magnitude. Can we arrive at the beginning and what was there before the beginning? Those are questions which, I think, are on the verge of moving from philosophy to physics. It's my faith, and that of many of my colleagues, that once philosophical questions become physics questions, eventually they will be answered. So I can't give you the answer, but I can assure you that that question will someday be answered.

Mark: This discussion reminds me a little of the speeches I used to make five or six years ago around the state promoting the SSC. I remember I was in a little town in East Texas once and there was a Baptist minister there who asked me somewhat the same question. And I finally said, "Look, the real reason for building the SSC is that we'll understand Genesis." And I think, David, that is what you're telling me.

Question: Why does the tunnel have to be underground?

Schwitters: The beams that circulate in the rings of magnets are potentially dangerous, should they lose control and exit the magnets; therefore, the underground requirement is to provide shielding against such an accident. There's no runaway radiation issue like there is in a nuclear reactor, but the beam itself carries a tremendous amount of energy, about 100 kilograms worth of TNT equivalent, and the uncontrolled release of that, when it's underground, would simply go into the rocks and nothing would happen. If it were above ground, it would be quite serious, and potentially hazardous.

Barton: I think we're about to end this, and I want to follow up on something that Mort mentioned, and also that Dr. Mark mentioned. It's the Proposition 19 button that he has. Nobody's really talked about that, and I think we should mention that a little bit. Texas was the only state that took to the people this proposition: are you willing to fund with state tax dollars a commitment to the national government to help build this project? And hundreds of leaders, from the governor through the chancellors of The University of Texas and Texas A&M, the University of Houston and Rice, barnstormed the state in the middle of the greatest recession the state had had since the Great Depression and said, will you put up $1 billion, or allow the legislature under the auspices of the TNRLC to put up $1 billion, and we passed that two to one. And as soon as we passed it and word got out in Congress, Senator Domenici added an amendment in the Senate that said you cannot consider that. He said, you can't consider any kind of state cash contribution, and we said, that's fine. We just sent press clippings to DOE and let history take its course. And the other thing is something that Mort talked about—how meticulous attention to detail matters. We're going to have a tough fight for the SSC every year in the Congress until it's built, because it's not an entitlement program. And last spring, when we were having a real rough go of it, at our little weekly luncheon with Senator Gramm, I was complaining. I said, "I'm spending half my time working on the SSC and we just seem to be having a real tough time." And Phil Gramm said, "Well, there's a problem." And I said, "Well, what do you mean, Senator?" And he said, "You're only spending half your time working on the SSC." So if the Philosophical Society of Texas is what it's supposed to be, you are influence-makers and decision-makers in this state, and I challenge you to use some of your influence outside the state if you run into people from the other parts of the country that don't know as much about the SSC as you're going to know when this panel and the rest of the program is over, to help us keep up the fight to make this thing a reality.

Question: I want to make a comment on the question . . . I think the answer that I quote came from Father [Theodore Martin] Hesburgh. He said that God created the first few nanoseconds and then the laws of physics took over.

Answer: The concept that David Gross talks about is that ultimately the origin is not knowable, but what you can do is push back that frontier between what's knowable and what's not, and you then learn things that not only are important philosophically in themselves, but that also have enormous practical applications. That's the process we're talking about, and, of course, this is why all of us are so anxious to bring the project to Texas, because that puts our state on the forefront of this whole effort.

Question: The concept that we're going to know it all is rather arrogant, in my opinion. The pursuit of it is beckoning us, and we know we don't know it all, but isn't it marvelous to try and find out?

Answer: I don't think anybody can top that.

Seybold: This has been a marvelous morning, exceeding our expectations. And I want to thank all the members of our panel and make one other comment before we go to luncheon in the Peacock Room. Isn't it remarkable how well things work out? Governor Clements couldn't be here for this last panel. Hans Mark stepped in and Bill Clements got a lot of compliments that he wouldn't have gotten had he been here! Thank you all.

WHO? USERS, EDUCATION, MEDICAL

ROBERT KRUEGER

As one individual who never had either high school or college physics, I enjoyed finding people of such eminence who could explain with such clarity and simplicity everything from the political complexities to the beautiful symmetries of physics. I was struck not only by Amy Freeman Lee's question about matter and the big bang and the implicit question about what was there before the matter, but I was also struck today by all of the references to symmetry, and the only thing that came back to me was William Blake, who wrote, "Tiger, tiger, burning bright in the forest of the night, what immortal hand or eye hath framed thy fearful symmetry." And those who have seen Blake's drawings may feel that Blake, perhaps if he didn't see the physics, may have seen into metaphysics and beyond physics, in his own visions. Perhaps he would have some interesting ideas on what preceded the big bang.

But symmetry aside, we're now going to have the chance to talk about who will be the users, both in education and medical matters, of this wonderful project, the Superconducting Super Collider, and the person who will be your moderator today is Dr. Norman Hackerman, former president of two of our state's most distinguished universities, The University of Texas at Austin and Rice University, and a very eminent scientist on his own. And, among his other many distinctions, a member of the Philosophical Society of Texas. Dr. Hackerman.

I

NORMAN HACKERMAN

THANK YOU. YOU MIGHT ASK WHY THIS SOMEWHAT IRRATIONAL ORDER OF WHY, where, who and what, which should be what and who. That is not the Society's fault. I have to be someplace else this evening and I asked them to change it. So you are going to get the users before you get the hardware.

A couple of points that are worth noting, not derogatory to some of the slightly emotional cheerleading this morning. This is a national project, and it's my concern that it not be identified as a Texas project. If all those who work on getting the funds for this are to be successful, we have to be sure to make it very clear that it happens to be sited in Texas, but it is for the nation as a whole, in fact, for the world as a whole. Also, it ought to be noted that the guiding force is ignorance, not what it will do for us tomorrow or next year or even early next century.

I am a scientist, but not a physicist. I do not use big costly instruments such as this one. In fact, I may be impinged upon by the fact that money is used for this to which I might otherwise have had access. Nonetheless, we are thinking animals, and it seems to me imperative that we probe our ignorance of nature's forces and its elementary particles. That is the reason for this machine which my colleagues in physics will use. Whether they learn lots or little, it is necessary to probe the system just by virtue of the kind of beings that we are.

Just as I want to be sure to try to leave an imprint that this is a national and international instrument, I also want to try to leave clearly with you the impression that it is being built for that very small cadre of able physicists who can make use of it for their experiments and, from that, for their theory. The other things are peripheral. It's nice to be able to use it for other purposes, but the central purpose is for the few physicists in the world who can understand what's going on, who have the potential for understanding what's going on, and who will make some sense out of the intricate information they get.

But there are peripheral activities. Now, to kick this off we have Raphael Kasper, who has been involved with the unit for a long time. He was the staff director of a committee that recommended on the site, so he has some five or six years experience with it. He has been down here for about four years. He is going to tell us something about users in general. Then Dr. Glatstein is going to talk about users medical and if there is any time left, I'll talk about users educational.

We will leave some time for questions. In particular, the kind of questions that wonder about what was present in the first nanosecond or less. The pivotal question for you to think about tonight at dinner is "nothing." Suppose there was nothing there in the first nanosecond. Can you conceive of nothing? It's a very difficult thing for me to do. At any rate, Raph Kasper is going to tell us about users, how they're going to be dealt with once the instrument is in operation, and what kind of problems he anticipates.

II
Raphael Kasper

We've reached a point in a number of fields of science where making progress now depends on the construction and operation of very large and very complicated facilities—facilities that demand the resources far beyond those available to single scientists, small groups of scientists, or even existing institutions. The use of such large facilities is often called, sometimes pejoratively, "big science." But I think it's more accurate to talk about them as "shared facilities." The SSC, like most high-energy physics laboratories around the world, is such a shared facility. What the SSC Laboratory will do is provide collisions of protons and associated laboratory facilities, and those collisions and facilities will then be used by a world community of scientists as that community sees fit to use them. In this sense, the SSC is not very different from other large scientific facilities, like oceanographic research vessels, or spacecraft, or large telescopes. In those instances, too, the facility itself is beyond the means of individual scientists, so they get together and share the costs and the benefits. Now, who shares the facility and who uses it? The answer to that question raises a lot of important issues about the SSC and, in fact, about the conduct of modern science in many fields. I intend to touch on, but not resolve, a set of those issues in the next few minutes. It's only partly because I have only a few minutes that I won't resolve those issues: it's also because I'll pose them as a set of questions to which I don't know the answers. And to which I think no one else does quite yet know the answers.

The users of the SSC are determined, and will continue to be determined, through the initiative of high-energy physicists around the world. Three years ago, the SSC Laboratory announced to those physicists that in 1999 the laboratory would make available 100 million collisions per second of 20 trillion electron volt protons banging into other 20 trillion electron volt protons. We asked that community of physicists, "What do you want to do with the collisions? How do you want to look at them? How do you want to do experiments?"

We received more than 20 proposals from scientists all over the world, including five proposals for what could be called very large detectors. Now, in this context, what does very large mean? Roy Schwitters mentioned a few statistics, and it's always fun to talk about what large means at the SSC. The large detectors of the SSC will weigh on the order of 30,000 tons. They will have the groundloading of a 200-story building, of which there are none. And they'll be located in underground halls the size of football stadiums. They'll be designed and built and then operated by enormous teams of scientists. One of the large detectors proposed for the SSC, already under design and soon to be under construction, involves more than 900 scientists from 117 different universities and laboratories in 17 countries around the world. So it's proper to think of the large detectors—the experiments of the SSC—as being very much like scientific laboratories in and of themselves, and not small laboratories at that.

The management and operation of a laboratory that is being built and operated by 900 or more people present a set of issues that I think are unprecedented, at least in scale, in the history of science. Let me enumerate just a few of the issues we and the world scientific community are going to have to wrestle with over the coming year.

How are scientific and technical decisions made in groups of many hundreds of scientists? What constitutes a democracy, for instance? Are not detector collaborations something closer to autocracies? How can the inherent scientific conservatism of large groups be overcome to encourage initiative and assure that the experiments of the SSC are innovative? What's the responsible and appropriate role for the SSC laboratory as opposed to the role of the builders and operators of the detectors? After all, we're going to spend $8 billion to construct this accelerator and its detectors, and with the expenditure of a huge sum of money like that comes a responsibility to produce results. So what's the role of the Laboratory with respect to these large, worldwide groups of scientists? How does one apportion credit to individuals or to small groups within the collaboration? How do you tell who's doing the real work and who's just signing on to the list of contributors to the accelerator? How can the interest and initiative of young scientists be encouraged and nurtured in such large groups? The senior management of such groups tend to be older, established scientists, yet most of the really good new ideas in the field come from young scientists. How do you encourage and nurture the young scientists working in the milieu of such large groups? And, as a last issue, who should have access to the data accumulated by the large detectors? An awful lot of information is going to come out of the collisions at the SSC. Who should get to see the data? Who should get to use it? Who should get to publish it?

Beginning several years before the completion of the SSC—and that means very soon now—not only will the staff of the SSC proper be about 2,300 people, but the laboratory population will include several hundred other long-term visitors who will be building, assembling, and operating the detectors. By long-term, I mean periods of months or years. These people will arrive in Ellis County with their families and with all the needs and demands of full-time residents of the county. Here too issues abound for the laboratory. How and where will the long-term visitors be housed? What amenities must the laboratory provide? How will a quiet, semi-rural area like Ellis County adapt to the influx of several hundred families of scientists, many of whom will come from other countries with other customs and other ways of life? And vice versa. How will the hundreds of scientists and their families adapt to the way of life in Ellis County? What will the effect of these new families be on the schools and other social institutions of the county?

We have some time to deliberate and discuss and argue and fight about the resolution of these and myriad other issues, but not much time. As you've gathered from Dr. Schwitters's talk and from pictures on the wall, the SSC has now passed from what was a conceptual paper project to a real one with people and equipment and buildings and tunnels. Things are happening very fast now at the SSC, and either we plan well for the effective use of the Laboratory, or modes of operation will spring up helter-skelter, probably in ways we can't anticipate, and maybe in ways that will cause us problems later on.

Let me shift my attention for a moment to another group of users, and another use, of the SSC. We have, as Dr. Schwitters said, a goal of creating a world-class scientific laboratory, but we're also in the process of creating what we hope will be an important and dynamic resource for science education. We've all heard stories about the crisis in science and mathematics education in this country, and I won't recount them for you. I also don't want to dwell on the intuitively satisfying argument that, in an increasingly technological world, a degree of scientific and technical literacy is necessary for people who want to live productive and fulfilling lives. I think most of you here today would accept that argument. In this regard—and maybe Norm Hackerman will talk a little about this later—it's worth distinguishing between educational programs whose purpose is to develop and maintain a flow of new scientists and engineers and those whose aim is to assure and inform citizenry. The two types of program have aspects in common, but many that are different as well.

In designing the educational program for the SSC, the laboratory has tended to view education broadly as encompassing the formal school system (at all levels, from pre-kindergarten through post-graduate study) as well as other mechanisms for disseminating information (like exhibits and the use of television and other media).

Ties between a laboratory like the SSC and universities are naturally quite good. The way of life at a high-energy physics laboratory involves participation of professors and graduate students. I should note here—violating for just a moment Norm's admonition not to talk too much about Texas—that the involvement of universities in the SSC has been greatly enhanced by a fellowship program for post-doctoral researchers and junior faculty members that was established by the State of Texas, sponsored by the State of Texas, and paid for by the State of Texas. It is now in its third year of operation, and it is rapidly becoming a highly prestigious fellowship. The evidence for that is the enormous competition that has developed each year for the awards. The State of Texas funds 24 fellowships each year. In the first year we announced the program, there were 39 applicants. They were all first-rate, but it was a fairly small number. Last year, there were more than 100 applicants, again for only 24 positions, and this year we expect still more. The applications are pouring into the laboratory as we speak.

But the interaction with universities is natural in a high-energy physics laboratory. The laboratory's real challenge lies in the area of elementary and secondary school programs and those programs directed toward the general public. It's been demonstrated in the past—with the space program, for example—that large, visible scientific projects create an excitement that attracts the interest of people of all ages. We hope to use that attraction at the SSC as a first step in building our educational program. But it's only a first step; a necessary one, but certainly not sufficient. The challenge is to use the vibrancy of the SSC Laboratory to gain the attention and interest of students and to build on this to create or enhance science and mathematics education programs. There's a tendency to confuse getting excited by things like the SSC or the space station with achieving some educational progress. In fact, the excitement is only the first step. Of course, you have to get people interested and involved, but then you have to turn that interest and involvement into real education.

The laboratory provides some things that can be useful in this regard. In addition to its excitement and visibility, the laboratory can contribute facilities, equipment and, probably most important, interested and interesting scientists. We're already working quite closely with teachers and students in a number of projects that have had success—projects in curriculum development, teacher training, student internships, and the like.

This morning Mort Meyerson mentioned the possibility that the influx of people to the SSC might have a direct effect on the schools of Ellis County and the various areas where people who've moved to the SSC are living. In fact, that's already been seen. Peter O'Donnell has compiled statistics demonstrating that, in the last two or three years, SAT scores in the high schools located just south of Dallas and in Ellis County have risen tremendously. I'm sorry I didn't bring a graph because it's a striking change. It starts a couple of years ago, and now schools in that area south of Dallas that have traditionally been, in a sense, laggers in development of quality education in the Dallas Metroplex area have leaped ahead of even the well-regarded schools in Plano and Richardson and other parts of the north Dallas area.

Let me just note two general issues among the many that we'll face in our education program. Again, I have time only to mention them, not to resolve them. I couldn't resolve them even if I had more time. They're issues faced by all attempts at improving science education, not just ours at the SSC. One is the matter of figuring out what works and what doesn't work in science education. A related question is how to evaluate success. We know, for instance, that a great number of students have been taking part in our programs; and we can tell by the smiles on their faces, sometimes, that they're enjoying those programs. But how do we know whether we're really making a difference, whether we have an educational program that is educating? We also recognize that we're not the only ones interested in improving science and math education. There are many programs all over the country, and we have to find ways to identify and incorporate into our efforts the best components of already existing programs.

A second general issue has its roots in the enormous scope and scale of the problem of science education in this country. If with all of our workshops, internships, teacher training sessions, tours, and exhibits, we can have a positive effect on only a handful of teachers and students, we'll have done a little to affect the overall problem. Our challenge is to find ways to somehow extend the reach of our activities and to multiply their effects. So we're trying out ideas like training master teachers who, in turn, would train others. We're working on the use of new interactive computer technologies to reach more people than we can actually touch through the laboratory. It's a challenge, but we'll be working on it over the years ahead while we're also building the accelerator.

Hackerman: Thank you, Raph. Another type of user is peripheral, but potentially very important, and that is the potential medical user off some of the beam lines. Dr. Glatstein, who is on the faculty at The University of Texas Southwestern Medical School, formerly the National Cancer Institute, has both experience and interest in this area. And we're going to ask him to tell us how it will be used for medical purposes, how it might be used for medical purposes.

III
Eli Glatstein

Well, thank you very much. What I'd like to do is give you sort of a brief overview of why we're so interested in the protons for cancer treatment. There's a lot of information that's coming forth, and I'd like to give you some indication of why we're so enthusiastic about the facility which we hope to be constructed in Waxahachie.

I'd like to begin by simply saying that about 20 to 25 years ago when Bill Cosby got his first TV comedy show of his own, his theme song was by a now-defunct group called the Crusaders, and it was called "Put It Where You Want It." Now, without making any social commentary, that is actually the essence of the problem in radiation oncology, how to put the radiation where you want it so that it coincides with the location of the tumor.

Well, with x-rays, we have some very good effects on tumor, but we have some problems. And the problems reflect the nature of x-rays. X-rays penetrate through and through. They're continuously attenuating as they traverse through the body, and they give up their energy rather slowly along the whole course. Thus many organs and tissues are irradiated coincidentally because they are in the pathway of the x-ray beam.

Protons are much different. Protons, depending upon the energy and the momentum that the particles have, travel in a straight line and you can select them so that they'll stop on a dime. They'll stop very abruptly. And in that same instant, as they're stopping, they give up virtually all their energy in the same location. So if we pick the right energies and have enough of them, we can make the deposition of the energy from those protons correspond precisely to the location of a tumor. Now that assumes we know exactly where that tumor is, and exactly what its limits are.

But that is what's been going on in two centers in the country for some time. There are two proton facilities in the country, one in Boston, an old physics cyclatron about 50 years old that's been tweaked for medical usage over the last 10 to 15 years, and a new facility in Loma Linda in California. Now the Boston experience over the last 10 to 15 years is very interesting. Most of their efforts focused on ocular melanomas, tumors of the eye. They chose this very specifically for a couple of reasons. First of all, the output of their machine was not good. They wanted something relatively superficial, and they didn't want anything too huge to deal with at the beginning. And the other reason they chose ocular melanoma was that it's notorious for being refractory to ordinary x-rays.

I'll not go through this in great detail, but the point of their experience is the following. They're able to control 90 percent of these tumors, arrest them, stop them, sterilize them, cure them locally. A small percentage of them have disseminated, but 80 percent of the patients they treated with ocular melanoma are *alive and have useful vision.* Not bad, considering the alternative is enucleation of the eye. Now that sort of experience, along with some interesting experience in other areas I won't go into, makes us very enthusiastic about protons for cancer treatment.

The Loma Linda machine has only been in existence for a couple of years now. It's a Cadillac by comparison to Boston. They have a wide variety of rooms and a wide variety of energies. They're building up experience very rapidly and their preliminary results look very good. One of the things that's always of concern in these sorts of facilities is that there might be some sort of competition between basic science and clinical medicine. At Southwestern, we don't anticipate that that will be any kind of problem for two reasons. First of all, it's our honest belief that when we put world-class physicists together with a group of competent scientifically-oriented physicians, that you'll get something very good out of that interaction, not something very hostile. The second thing is that this particular unit, this facility, has so much capability of generating protons, there's really no reason to believe that there'd be any competition for the production of particles.

Let me just finish by saying that x-rays have only been in existence less than 100 years. The centennial will be celebrated in December of 1995. If Roentgen were around today to see what he hath wrought, he would be stunned, he would be overwhelmed, at the technology and the science and the multiple uses that his discovery has led to, and we are very optimistic that the development of the facility at Waxahachie, the supercollider, at least with the respect to medical usage, will begin the second century of radiology in a most impressive way. Thank you very much.

Hackerman: Well, you've heard of one peripheral use and it's obvious that type of use would be very pertinent to all of us. We have a greater empathy for medical properties than we do for quarks, and the fact is that the presence of this instrument may be of some value to the medical profession.

Let me get back to education for just a moment. And then we'll open up for questions and comments. Raph has already said the important thing to you: an installation such as the SSC has within itself the kind of gravitational pull that provides the interest, not only for school kids, but for adults as well. The fact that that installation is available should make use of that interesting attraction.

If there is one thing it can do aside from learning more about nature's forces, it is to try to make the general citizenry more comfortable with nature. If the SSC can do that, it will have paid for itself even if it never discovers another elementary particle. Such problems as we have in this country with an anti-intellectual, anti-science movement come from the fact that the general citizenry is simply not comfortable with science and the technology that it spawns.

The value of science in general, and recognition of the central position of understanding as much as possible about nature's forces and material specifically, should have an extremely valuable influence on the citizens of this country. In terms of education I am talking about non-science majors. There are enough science majors constantly available to take care of our needs in this area. They are "natural" in the sense that it is not necessary to entice them into field. We have to make sure that the non-science majors do not feel left out by the system. Further, we must convince them that we are concerned about their futures, even if they don't understand the gadgets with which they have to deal. In fact, this holds even if they don't understand the small elite group of individuals who do understand. We have conditions which are not that much different than Louis XVI of France faced, i.e., separation and isolation of a small group of people from the large mass of people. In that case, it was an aristocracy built on births. In this case, it is an aristocracy built on understanding of certain naturally occurring phenomena.

So whatever this SSC can do, aside from elucidating still further the way matter holds together or flies apart, if it can also contribute to the easing of concern by the rest of the people in the world, it will have done a great thing. Is it unique in that respect? I'm not sure, but I could make an argument that is unique. For example, the space station will not do it since it is so remote, even though there is a lot of hype that will come to us through the media. But here, where you can touch and feel and see what is going on, I think there is a real chance that some kind of contribution to this issue is possible.

We have about fifteen minutes left, and there is probably fifteen minutes of argument amongst you, so I'm going to stop and ask you for your questions and comments.

Question: Dr. Hackerman, I'd like to thank you for reminding us that this is a national and international project. And Dr. Kasper, I can answer your question about how will the semi-rural inhabitants of Ellis County respond, since we've lived in Dripping Springs for fifteen years: not well, not well at all.

I was curious about the medical aspect, if it is for research or for treatment?

Answer: I'm talking basic treatment. We would try to treat patients with the idea of establishing something of a permanent value. In a sense it's clinical research, but the aim is treatment.

Question: Is the Loma Linda facility generally available to universal scientists or particular people?

Answer: No, sir, it's a closed shop, and from the patient's point of view, you'd better be well insured. In fact, most insurance companies won't pay for it.

Question: This will be a closed shop, will it not?

Answer: This will be a closed shop in the sense that the physicians responsible for this will be part of The University of Texas, and if they're not part of the University of Texas, they would have to be visitors of The University of Texas staff. It will not be open to private practitioners.

Question: In connection with the educational application, if you have a team with a thousand people working on these big research projects, how do you envision weaving graduate students into this? How many years does a graduate student on a team have to spend before he receives his Ph.D.? How do you subdivide the tasks to define these projects?

Answer: These are very good questions and questions that physicists have been addressing for some time. As I mentioned, the trend toward larger and larger groups has been going on for some time. It's a matter of scale that changes at the SSC. Now, in fact, the way that these groups of thousands work is that they do much of their work in small groups at their home institutions. You'll recall that I mentioned that there are 900-and-some scientists from 117 institutions working on the one large detector. That means that the average group is eight or nine people; some are smaller than that, there are a few that are larger than that. In fact, those groups are made up of faculty and graduate students, and they're working on parts of the detector. They're either designing components of the detector or developing ways to analyze the data that comes out of the collisions. So a graduate student working in a group of that sort is doing what a graduate student normally would do. There is a problem here, and that is that we won't have actual collisions at the SSC until 1999, so that most graduate students who are working now would hope to have their Ph.D.s finished by the time the collider is working. But there's enough important science that has to be done in the design of the components and in figuring out ways to analyze the results; there's plenty of work for them. They're working essentially the way graduate students work in all other areas of physics.

Question: I just wondered how a graduate student with a new idea would be able to surface the new idea, you know, reach the top of consideration, and maybe actually get tried. I'm still worried about a thousand, even though you may break up into teams of eight or nine to work. Those of us who read the scientific journals have seen these papers or publications where the list of authors is longer than the report or the results. You worry, then, if one of those buried authors is in fact a graduate student who just completed a Ph.D. Did he really get to contribute original ideas or was he working on the team with limited opportunity?

Answer: The ideas really do matter, and they can percolate up to the top in the old-fashioned ways. In fact, the internal dynamics of these big groups is very effective and very exciting. That's just not been the problem. However, you hit the problem, at least in my view, that the author list is the problem. For various reasons, the tradition in the field is to put all of those names on the paper, and therefore, in my view, it's the outside recognition problem that's not being handled properly. Inside the collaboration, there's typically a very lively internal set of notes or literature going on, effectively peer reviewed, and, believe me, the bright young graduate students are the guys who actually run the show when experiments are going on or these things are being built. The professors are busy flying to Washington all the time. So that works pretty well. I think the author list is a very serious issue and that's something that I'm very tentatively trying to discuss with the elders of the tribe around here, but, boy, it's a tough one.

Question: I was somewhat chilled to hear your analogy with Louis XVI, knowing what happened to that isolated group. Can you be a bit more specific about how you think scientists should act to keep their heads in the coming decades by using this supercollider to kindle more excitement in the general population about science?

Answer: Well, my response will be more general than just the SSC itself. Those of us who are scientists ought to recognize that we're not a class apart. I'm not too sure if that's the case right now. That's a very severe indictment, by the way, and my colleagues are going to jump all over me. I believe we have too much of a tendency to say, "Look, we know what we're doing, just provide the support and we'll do it." And there's nothing wrong with that argument except it shuts other people out. My belief is that those of us in the field, however far advanced, ought to be much more concerned with the 99 percent of the population who are not research scientists. Actually, it's 99.9 percent, to be precise, since a best estimate is that there are 250,000 research scientists and engineers in the country. So it behooves us, if we're interested in the continuation of our field of interest, to make sure that those who support us are as well-advised as possible about what we do. The argument is that that is hard to do, that the rest of the people don't really care. In other words, their attitude is, just give us new technology, we don't care how you do it. I don't believe that. I believe that although it's hard to interest those who are not dedicated to the sciences in nature, it's possible, and if we're as creative and original as we think, we ought to find a way. I believe that all we need to be interested in is to make you aware that nature is made up of relatively few components: time, space, force, and material. Instead, we approach it as specialists from our disciplines, and if you listen to us and don't know our language and lose interest, we say the devil with you. We'll go to somebody who does understand and who does want to hear us. And I think that's a wrong way to go. So the reference to Louis XVI is not a bad one.

Seybold: Dr. Hackerman, I want to speak in support of your concept about the public interest in this project. Cancer is a very emotional issue. I don't think the possibility of using this proton beam for more successful treatment of human cancer should be relegated to a very small peripheral position as far as its presentation to the public. Dr. Glatstein and I just talked about how Roentgen, discoverer of x-rays less than 100 years ago, would be astounded at what's become of his simple instrument today. And we see the possibility of these proton beams and this initial instrument as an advance in the potential of treating human cancer. I think it will be helpful to the projects you're talking about and to sell it to the public, and to make the public understand what basic research, basic science, physical science can do.

Hackerman: You heard a good deal this morning which bordered on that. My early proposition to you was that ignorance drives this activity. I think that's the real motive. I'm going to close this session by telling you the stockpile of knowledge and understanding is certainly growing at a very rapid rate, but the stockpile of ignorance is still infinite.

WHAT? DESIGN, ENGINEERING, CONSTRUCTION

ROBERT KRUEGER

THE QUESTION OF WHAT? DESIGN ENGINEERING AND CONSTRUCTION IS GOING TO be moderated by Dr. Peter McIntyre of Texas A&M University, who was mentioned this morning as one of the key players in designing, among other things, the political grouping, and the other approaches that were important in bringing the superconductor supercollider to our state. So, without further ado, I can see from the three tangerines that he is holding that Dr. McIntyre, among other things, is probably a juggler. But we can look forward, I know, to a very engaging discussion from our three panelists. Thank you.

I

PETER MCINTYRE

(Remarks are not available because of technical difficulties with the sound system.)

I'D LIKE TO INTRODUCE TO YOU MY FELLOW PANELISTS. DR. GERALD DUGAN IS THE Associate Director of the SSC laboratory. Before joining the SSC, he was the director of the accelerator division of Fermilab's Tevatron. He was responsible for its running and improvement and supporting what is today the cutting edge of this field of high-energy physics.

Dr. Tom Bush is the director of the magnet division at the SSC laboratory. He is responsible for the development and the manufacture of these thousands, tens of thousands of superconducting magnets in industry, and before joining SSC, he was the head of a number of programs, both for missiles and nuclear weapons systems within the U.S. Navy.

So at this point I'd like to turn over to Dr. Dugan.

II

GERALD DUGAN

THANKS, PETER. THE FIRST COUPLE OF FIGURES THAT I'LL SHOW YOU ARE AN attempt to summarize the history of accelerators in two transparencies. The attempt at showing you this is to put the SSC in context with the previous history of accelerators. The first figure shows you over on the left the beam energy of an accelerator. This is a logarithmic scale that varies from 100 kilovolts up to 1,000 teravolts; on the bottom axis we have time. The first accelerators were developed back in the 1930s and in fact all the accelerators on this graph were really developed to satisfy the demand for high-energy physics, basically, for ever-increasing beam energies to study ever-smaller parts of matter. This dotted line represents an exponential growth of energy with time, and that dotted line is essentially the demand curve that these accelerators were supposed to satisfy. The general theme here, which I'll go through in more detail in a minute, is that as time goes on, efforts to satisfy this demand curve led to the development of acclerators with different kinds of technologies. And, as each technology came to saturation and petered out, the next technology was developed in order to satisfy this curve and keep on delivering ever-higher energies.

The first accelerators were basically rectifier generators and then electrostatic generators. Electrostatic generators are the kinds of devices you probably associate with mad scientists. They're large spheres of metal with large columns to insulate them from ground. Very high voltages are developed upon the spheres and particles are just dropped through that potential to create energies in the range of a megavolt or so.

In the early 1930s cyclotrons were developed, which are circular particle accelerators. In fact, Peter showed you a number of pictures of various peoples' impressions of cyclotrons. In the early 1940s before World War II, a kind of accelerator called the betatron was developed and that curve is shown here. The green circles are intended to represent accelerators that accelerate electrons. The red circles are proton accelerators. The betatron petered out at about a hundred Mev and after World War II, there were a number of new developments. The first of those were the proton linacs and the electron linac which ultimately led to energies, in the case of the electron linac, as high as 50 Gev—that's the linac out at Stanford—and in the case of the proton linac, energies as high as approximately 1 Gev. The highest energy proton linac is at Los Alamos.

The cyclotron, which petered out as a circular accelerator around 20 or 30 Mev, basically because of the relativistic mass increase of the proton, was replaced much later on in time by something called the sector-focused cyclotron, which allowed somewhat higher energies to be developed, but still didn't come anywhere near this curve. There was also a development called the synchrocyclotron which made some small improvements, but really didn't do very much. The real descendant of the cyclotron was the synchrotron.

The synchrotron was further improved by something called the alternating gradient principle in the middle 1950s. But, as you can see, none of these curves, even the proton synchrotron, really can keep up with this demand. That was appreciated in the mid 1960s and it took a simple but nevertheless somewhat revolutionary idea, to go the next step.

This step is basically the concept of the collider. In all these machines the beam energy was dissipated by taking the beam and using it to hit a stationary target that provides a certain amount of energy in the center of mass. But if you take two beams and collide them with each other, you can get an energy in the center of mass which is the sum of the beam energies. And that idea was capitalized on in a series of machines called colliders whose development started in the early 1960s. This is shown in the second figure. Again, the green points here are electrons and the red points are protons. These machines were able to satisfy the exponentially rising demand curve. And you can see on here the position of the SSC, which when it comes on will of course provide the highest energy in the world, and will be essentially on this curve. The predecessor of the SSC was the Fermilab Tevatron and another similar machine is the machine in Germany called HERA. These brown squares represent superconducting accelerators. The red ones are proton accelerators, but they're not superconducting, they're normal-conducting, and these two accelerators, in fact, accelerate and collide protons with anti-protons, whereas the SSC and the first proton collider, the ISR in Geneva, are proton-proton colliders.

The SSC itself is, as Roy told you, really a series of machines. This shows you the layout of it and compares the collider itself with three of the existing high-energy machines who are on those previous curves: CERN's large electron-positron collider, the Fermilab Tevatron, and the Stanford linear collider. The SSC's main ring is fed protons by a series of injectors, and those injectors, if we blow that picture up, are essentially a 600-Mev linac, a 12-Gev low-energy booster, a 200-Gev medium-energy booster, and a 2000-Gev or 2-Tev high-energy booster.

The work that you heard described for proton therapy will utilize the beam at just about this point, just a short distance after it starts getting accelerated in the linac. To show you this in the context of the Livingston plot (figure 2) that I showed at the very beginning, I've tried to indicate over here on the side the location of the SSC injectors on this plot. This device, which I'll show you a picture of, is the first part of the linac. It's called the radio frequency quadrupole, and is essentially a modern version of the electrostatic generator, which is no longer used. The SSC linac, producing about 600 Mev of energy, lies about here. You can see this is essentially a successor to the proton linacs which stopped their development around the mid-1970s. The low-energy booster, the medium-energy booster, the high-energy booster, and the SSC are all examples of proton synchrotrons, so they all belong to this class and you can see the SSC itself is essentially the next step in the extrapolation of this line. But it needs to be fed by machines of successively higher energy in order to be able to function.

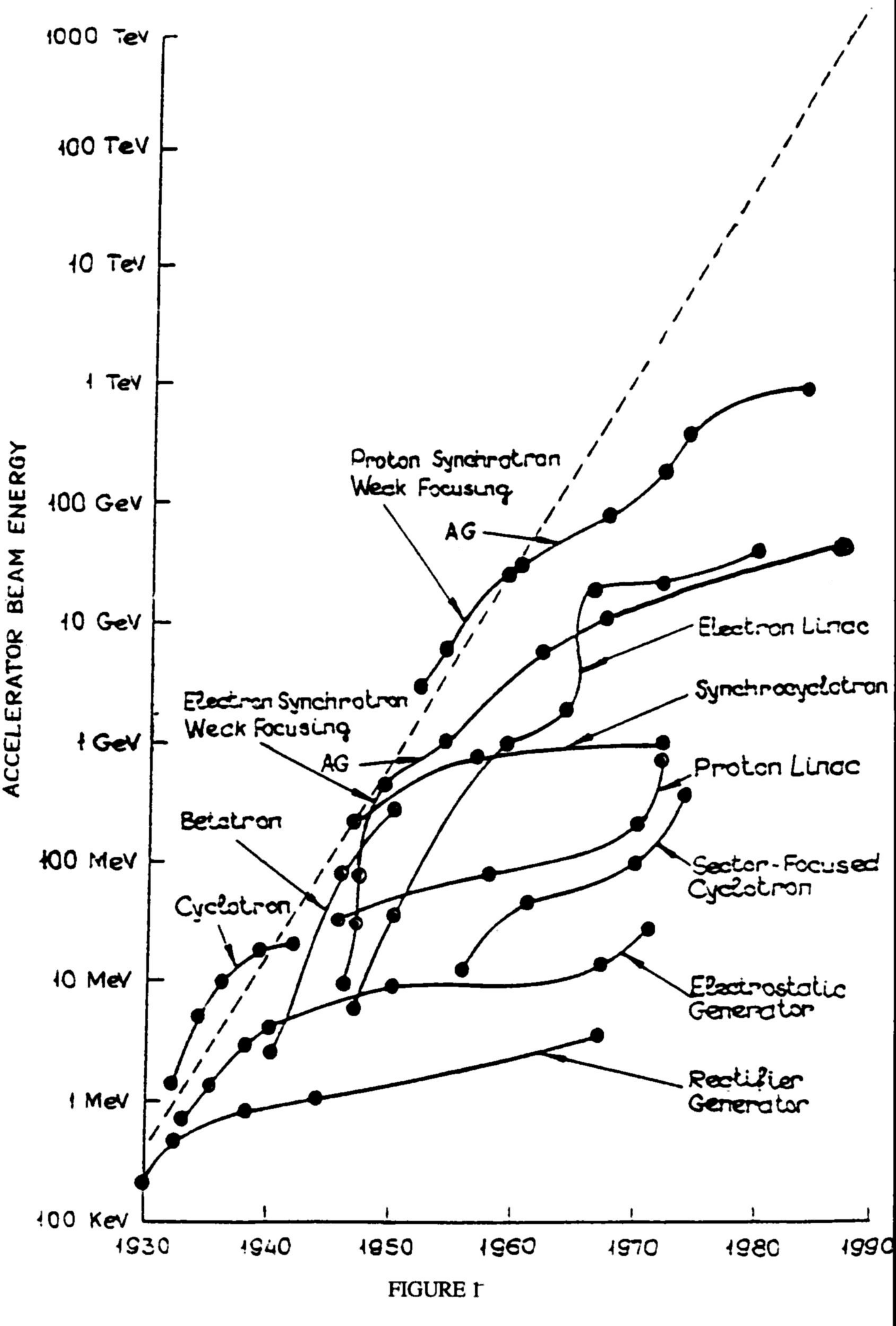
This part of the machine is the only part that I can show you any pictures of at the moment. The radio frequency quadrupole that's shown here is a device which will accelerate the beam to about $2^1/_2$ Mev. It was built for the SSC laboratory by Los Alamos. The ion source over here will sometime in the next couple of months be coupled into this machine. The machine, driven by a klystron located behind this wall, will feed RF power into this, providing acceleration of the beam from this point to this point, about $2^1/_2$ Mev.

That's the first real part of the accelerator machine that we will have functional, and when we complete the linac, that little piece of the linac will be located in an area here, which I'm sure you won't be able to see on this scale. But right down here at the very beginning of the linac, this picture shows the civil construction which is now underway for the linac. The ion source will be housed in this square box at the end, and by the time the beam reaches about 140 meters down the end of this tunnel, it will be at 600 Mev and will then be passed on to the next accelerator in the chain.

Eventually, after going through all those successive accelerators, the low-energy booster, the medium-energy booster, and the high-energy booster, the beam will enter the SSC itself. The SSC, as you know, is located underground, with a tilt as shown here, relative to the surface of the earth, and is serviced by a number of shafts which are located around the ring as shown in this isometric drawing. We're right now in the process of digging many of these shafts and in fact the activity that's pictured over there, which is the N-15 site, located in this picture right here, is the first place where people have started digging these shafts. This is a picture of the N-15 site. It's essentially the same picture that you see over there, but I want to point out this shaft, which is the magnet delivery shaft, that's a 60-foot by 40-foot oval about 250 feet deep, which will be used to deliver the first magnets down to the tunnel. There's a couple of other shafts here which you probably can't see, located here and over here. This shaft will deliver utilities to the tunnel, refrigeration, and electric power developed in these buildings.

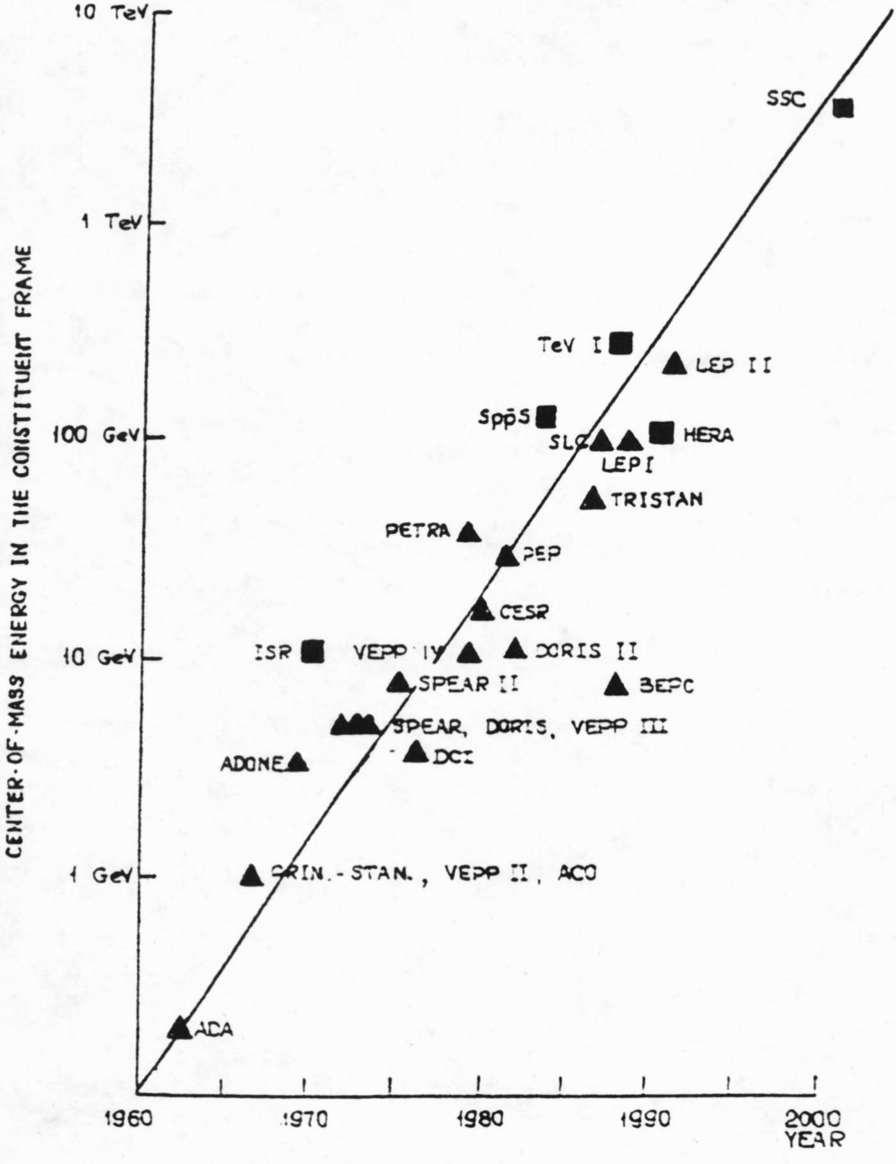
You also see on this picture a long skinny building here. That long skinny building is where we conducted the string test which was the first demonstration test of a basic subsystem of the machine. Inside that accelerator string test building, had you been over there in the preparatory stages, you would have seen a picture like this. These are the two rings of the SSC. When we actually ran the test, we only tested one cell in the lower ring. But this is approximately what you would see, if you were in the SSC tunnel, once the machine gets completed. This enclosure is somewhat larger than the tunnel, but not a lot larger.

Okay, finally, I wanted to make one comment about what happens to these accelerators that I showed you on the Livingston plot when they are no longer competitive in terms of reaching this demand curve for high-energy physics. It turns out that people have found many, many different uses for them, and the uses depend in detail upon exactly what kind of accelerator and what its energy is. I tried to list here some of those uses. Linacs are used for radiation therapy, as you've heard already. They've also been used as drivers for light and heavy ion fusion, which is essentially inertially confined fusion. They also are used



1000 TeV
100 TeV
10 TeV
1 TeV
100 GeV
10 GeV
1 GeV
100 MeV
10 MeV
1 MeV
100 KeV
ACCELERATOR BEAM ENERGY
1930
1940
1950
1960
1970
1980
1990
Proton Synchrotron
Weak Focusing
AG
Electron Linac
Synchrocyclotron
Electron Synchrotron
Weak Focusing
AG
Proton Linac
Betatron
Sector-Focused
Cyclotron
Cyclotron
Electrostatic
Generator
Rectifier
Generator

FIGURE 1



GROWTH OF PARTICLE COLLIDERS

▲ Electron-positron or electron-electron colliders.
■ Proton-proton or proton-antiproton colliders.
■ Electron-proton colliders.

The energy in the constituent frame is derated for protons relative to electrons to take account of the composite structure of hadrons. A factor of 6 derating is used below 2 TeV center-of-mass constituent frame and a factor of 10 derating factor above.

FIGURE 2

to drive objects called free-electron lasers which are used for defense applications and also for chemical processing. Linacs themselves have been used for radiation processing and also have been proposed for treatment of radioactive waste. Cyclotrons are used for radiation therapy and also for production of radioisotopes. And synchrotrons (the SSC and most of its injector machines are synchrotrons) have been used for atomic physics research, for radiation therapy, and have found a very large application, in the case of electron synchrotrons, as synchrotron radiation facilities where the synchrotron radiation from the beam is used for material science, for biomedical applications, and also for microelectronics, even nanotechnological applications.

Thus, high-energy accelerators, driven to be developed by this demand curve for research in high-energy physics, have been utilized afterwards in all sorts of different ways in different parts of society once that development is completed.

III
Tom Bush

Well, since this is the Philosophical Society, at least we ought to address one philosophical point before we end this part of the afternoon. First of all, let me reintroduce Gerry and me. You have heard from all these august speakers this afternoon and this morning, and they made all kinds of significant contributions to the supercollider. The fact of the matter is Gerry and I are the two who have to build it, and so we have a little different perspective, I think, on what's going on than some of the others did.

Several people mentioned that it was important to make sure that this was a national project. And, personally, I have taken that on as a goal of mine. My parents, grandparents, and great-grandparents are Texans by choice, coming here in the 1850s and 1860s, as pioneers of Denison, Texas. I was lucky enough to be born in Oklahoma City and I have insured that there are a significant number of University of Oklahoma graduates as part of the design team here to make sure it is not a Texas project.

"My magnets," which I am responsible for (and I do have a personal feeling toward them), were painted red for a rather obvious reason. There was absolutely no way in the world they were going to be burnt orange, I can guarantee that. But the fact of the matter is Roy and I sat down one day and decided they should be red, white, and blue for the United States, and that's what they will be.

Let me tell you a little bit about something that's different between the supercollider, I think, and all of the other laboratories, and probably the reason that a person with a rather strange background like me has anything to do with it; there are several of us in the program. First, I am not a high-energy physicist, and even though I have a Ph.D. in physics, I don't really consider myself a physicist, for it was a long time ago when I did that kind of work.

Because of the size, the magnitude, the complexity, not necessarily in the kinds of parts, but the number of things that had to come together on a very short period of time (and frankly, nine years is a very short period of time for something this large), and also because of the fact that we have set ourselves a ceiling price, we felt we needed to engage industry in a most significant way, probably much different than had been done in the past. I think that a lot of this has to do with the foresight of Roy and some of the other people when they were first putting the program together. But we had to include industry in a most significant way. To characterize this, a word we use which probably doesn't really describe it, but at least it keeps the thought in our mind, is a partnership. We have brought in industry in ways that are, I believe, unique. We had them involved in research. We had them involved in development, sometimes doing it independent of us through some kind of contractual mechanism; sometimes doing it in-house alongside us; sometimes the other way around, where we will actually have people in their facilities doing what I call some rather fundamental research or research and development for some of the parts we'll need in the program.

I will use examples primarily out of the magnets because, since I spend my waking and sleeping hours worrying about them. The superconducting wire, which I think Roy mentioned, is one example. The task there was to take an industry that was producing a little bit of wire, enough for the markets they had, and to encourage them to increase its capability by a factor of two or three, and to make sure that the characteristics of the wire were controlled to levels that were essentially 100 times better than they had ever done before. The variability within the characteristics of the wire had to be tightly controlled if we were to build 8,000 or 9,000 magnets just alike. Instead of trying to do this in the laboratory and then giving a finished product to industry, we turned the process around. We went to them and we explained to them what we needed. We got them to accept those challenges and then we got them to figure out how to meet them. In fact, they are doing it very well today. The result in this particular case is that the price of superconducting wire will come down something on the order of tenfold from where it was a few years ago. The amount of wire that we will manufacture, believe it or not, is 100 times more than had ever been produced in the history of the world. That's the kind of industrial capability we had to create out there to do this.

That's one example where industry has taken the lead. They are the ones that are doing the research. They are the ones who are building the machinery, the concepts, and the ability to provide this product. And without good wire, we have no machine.

Another example, a little more subtle, is the steel that we use to surround the superconducting coils. Although the ability of the steel industry to produce the kind of steel we want was pretty good, we wanted a set of characteristics that were tightly controlled. And again, we went to them and explained what we thought we needed, and through an interactive process, the same as with the wire, we settled on what we believed were characteristics that could be achieved in our timeframe and something we could afford. And, frankly, industry is a lot smarter than we are about what can be bought for a certain price, and we settled on those characteristics and let them go work on that problem for us. And they have done that very well also.

There are other examples throughout the laboratory where, because of the size and importance of this project, we have called on other techniques and experience and expertise out of industry to help us. One of the companies that has teamed with us and is a part of us on a day-to-day basis is EG&G. Many of their employees work side by side with us. They come out of a background that already had this knowledge and experience and they're in those positions and roles within the organizations to perform the kinds of functions for which they have more experience than we do.

We're not building a few hundred magnets, we're not building a few hundred of hardly anything, we're building a few thousand. And so we needed to have the experience of companies that know how to build many things exactly the same at the lowest price. So again we called on industry; in the case of the magnets, General Dynamics, Westinghouse, and Babcock and Wilcox are the ones that we used. Other companies, Martin-Marietta and others, will build other parts that we'll need lots of, and they'll have to build exactly the same one every time, which is a difficult process unless you've done it, unless you know what you're doing. So we use industry to do that, and we've moved an enormous amount of not only our manufacturing but also our engineering design and our production design out into industry to let them do that for us.

Such things as installing all of the hardware, the logistics that is involved in bringing all these pieces together in one place at one time, the problem of delivering something on the order of 16 magnets every day to the tunnel shafts at the right place for four years, through a 24-hour-a-day, seven-day-a-week cycle, is something that some large industries like Bechtel and others that have been involved in building large projects know how to do, and we invite them in to help us do that.

There are other examples but the point is that we have made industry a part of us and the interesting thing about that is that they will carry away some things from us. For example, by the time we're through in the superconducting wire business there will be a significant industrial capacity out there. It's not within the laboratory. They know more about it than we do. In the case of the superconducting magnets, there will be three companies in the world, perhaps four or five, that can build, design, and tailor these things to other potential projects.

There is even another level, and it's a fascinating one to end on. There are inventions that have and will come out of the Superconducting Super Collider. There are some advances already in plastics that can absorb radiation damage, which is something that can be used in many applications. The superconducting wire I've mentioned. But there are also some very subtle things that probably we never think about coming out of a place like a national laboratory. Let me give you just a couple of them. Believe it or not, we have a patent for a general secretary menu program. Somebody has worked out a technique for handling paper better. We have somebody that's put together a document-control system that they're patenting. Suspension systems for cryogenic lines and high-speed counters are techniques that are being patented. But the point I wanted to make is, it's not just what we think of as the first-order things, but the many subtle things that get developed because of the fact that you have a lot of very bright people involved. You have a lot of things going on that you don't sense as being part of a large project also contribute to the good of our society.

I want to emphasize and leave you with the fact that this laboratory is different with respect to its industrial-laboratory partnership. That's the way we'll progress and be successful. And it then leaves behind an enormous residue of good things out in industry. Many are already there now. Thank you.

McIntyre: As one who has associated with several of the laboratories over the years, I'd like to underline Tom's point and congratulate him and his colleagues on the job they're doing there. When Stanford built SLAC, it required a large number of kyrtrons, but it didn't go to industry; it developed them in-house. When Fermilab developed its superconducting magnets for the first superconducting accelerator in the country, it didn't go to industry, it built them in-house. There were legitimate trains of reasoning that led to those decisions. The technology wasn't ready to hand over to an industry and there was concern over how one would bring industry up as a partner quickly enough. But in the long term, I believe that we as a country have paid a price, and a fairly heavy price, for not having brought industry in as a partner in developing those labs.

As one example, until the SSC's activity in putting superconducting magnets into U.S. industry, U.S. industry had never built successful superconducting magnets. European industry has built them routinely for years. So has Japanese industry. That was a major embarrassment to us, and I think a major hindrance to the transfer of that technology into other kinds of applications, be it electric motors or power distribution or energy storage or anything else, that we were progressively falling further and further behind on even though we were leading in some of the front-end development. So I want to really congratulate SSC on the job that it's doing in that connection. It's cutting new ground for this country. That is, I think, very good.

I'd like to open for questions and comments and discussion.

Question: You talked about the superconducting wire, but as a chemist, I don't think you ever mentioned what it was made out of. And, secondly, I wondered if you'd like to comment on what's gotten a lot more hype in the press, that is, the higher-temperature superconductors which would seem to minimize another problem which you haven't mentioned, that is, the need for liquid helium in this magnet system, whereas you might only need liquid nitrogen if you have a higher-temperature superconductor.

Answer: Well, the materials are, for the superconductor itself, niobium titanium alloy, which is stuff you can find fairly routinely in a couple of places in the world. There's a nice niobium mine down in Brazil and in the old Soviet Union, in parts of Russia, there are a couple of places to get titanium. Both of these metals are fairly common, and they're not particularly expensive. They are formed into rods with copper, which is used to give them the softness you need to wind it into wire.

The other issue was the famous liquid-helium question. I can answer a couple of ways, I guess, and certainly I'm not the expert. But one of the things I understand is that you need that temperature in order to do the cryopumping of the beam pipe, to keep the background gases from colliding with the protons—I guess that's the right way to say it. And the other thing is, as I mentioned, we really are enhancing enormously an existing industry and the existing technology in order to get the wire we need at the price we can afford on the schedule we need. And that technology started evolving over 15 years ago. So to try to pick up something now, where I'm 18 months away from delivering the first magnet, giving it to my colleague Gerry here, would be very, very difficult. Essentially the magnet design is done, it's tested, and we're in the business of turning it into a production piece of hardware.

Answer: I might just mention there are components called power leads in a spool piece, which is a subset of the machine, where we are looking at the use of high-temperature superconductors. There are small items, but they might be a place where it would pay off for us to use that material.

Question: What is the useful life before it becomes obsolete like the car I just bought?

Answer: We're aiming for a 25-year useful life. In other words, we're specifying all the components, etc., to be tested in such a way that we believe the machine will survive and function for 25 years. If you look at typical accelerators, that has been more or less the kind of time scale over which they've been useful for high-energy research. We've got some history that backs that up and we believe that technically we can achieve that. So it's longer than your car.

Answer: One comment I would make further to Gerry's point is that after the Fermilab accelerator had operated successfully for research for over a decade, it came to a point where one could see that the productive research program was petering out. At that point Fermilab installed the Tevatron superconducting ring to more than double the energy of their accelerator, from the 400 million volts that it originally had as a ring of magnets with copper conductors to a trillion volts of energy. The same thing could happen, hypothetically, with the supercollider. Over the years as we use an accelerator, we continue to improve it, to find better ways to do things, and I think the field has a pretty good track record for incorporating that progression of improvements to extend the performance within the footprint that we build at a given time for a pretty long period. So what I would hope and expect to see happen is that the SSC will run for a while as it's built, and then over a period of years, it'll upgrade its capabilities and extend them, capitalizing on that investment. I'd like to talk to you some more about MRI after the meeting.

Question: In this admirable diffusion of development to many small businesses, do you run into a terrible tangle of patterns? What do you do about that besides diffuse business for lawyers?

Answer: Well, I guess I agree with Shakespeare about lawyers. I don't have any problem with that statement, in spite of anybody in the audience. No, it's really not as complex a problem as it perhaps would seem on the surface. Obviously, the task is to make sure that each industry or each part of industry that you're using has an agreed-upon structure for what it is going to do. And if you can get through that process pretty fast and in a pretty straightforward fashion—and you usually can—then your job really is coordinating among those industries and letting them do what they're best at. And most of the time it works well. You'll always have a few problems, but so far, frankly, we have been quite successful, or lucky. But either one's all right.

Answer: I'd like to make one comment on that as an inventor. I hold several patents, some of which I've done through research with the supercollider and others elsewhere. There is, I think, a policy sort of problem that we have in the U.S. that costs us somewhat in our competitiveness, and it goes as follows. We, the United States government, sponsor a whole lot of basic and applied research, some of it at laboratories, some of it at universities. In that pattern of research, a lot of technology emerges—patented technology, technology that has potential application to things that are quite, quite distinct from the development that was the origin of it. With the way that our government runs that research funding, quite understandably they take the point of view that the funding they provide needs to be very tightly targeted on the mission for which they are contracting to have that technology developed. If a parallel application of the technology emerges that seems to have promise, the inventor, or the head of the agency that's come up with it, has quite a free hand in government policy on proceeding with developing that, as long as it doesn't cost the government any money. The policy perspective that the government takes is that the further development of any such technology towards a practical application is not an appropriate use of federal funds. The federal funds are there to drive a targeted development that has evolved out of the mission of an agency. So the government says, please keep us abreast of what you're doing because we want to be proud of it and we wish you well and we'll get out of your way and we won't complicate your life, but we won't fund you to go develop that trail. They take the perspective that you go to the private sector for that. Well, I've been down that trail too. Some people confuse the term venture capital with risk capital. There's this "R" word which folks don't like to deal with. Between where a technology emerged for, let's say, developing something for the SSC or for some other purpose, and where it can make contact for an application in a real-world profitable thing, a new product or gadget, there's a gap. Sometimes that gap is big, sometimes it's relatively small, but there's always a gap there, and that gap has a whole lot of risk associated with it, and it has cost associated with bridging it. The problem is that in our economically stressed times, the private sector is understandably loath to reach out into that gap very far. Nobody wants to pay the bill, nobody wants to take the risk. That's an understandable point of view from all sides. It's also a point of view that hinders and in many cases annihilates any practical transfer of that technology being developed in a laboratory to making new products. Ironically, we taught the Japanese how to do that back after World War II. We sent over some of our best and brightest economists and businessmen to advise them on how they should get on their feet. And one of the things that emerged from that was a thing called MITI. It was a government agency which had as its mission to forge teamings between universities and laboratories on the one side and industry on the other, and amongst industries to try to develop technologies into real products, to go from the lab into the marketplace. They put a whole lot of money into that for a whole lot of time, and it was generally credited with being pretty effective. I think we need as a country to ponder how we might do it better, because I don't think we're doing it well at all today. One man's opinion.

Question: I'm heartened by the evidence that we have increased both quantitatively and qualitatively industry's capacity to produce wire and magnets. My question is simply: what alternate markets are there, say, for magnets? You say that Europe has been well ahead of it. I assume, therefore, that there is a market, but could you clarify what the market is, particularly for magnets.

Answer: Well, there are a couple of things, actually, that are lying around right now that perhaps we will stimulate because of the advances we're going to make in price and quantity.

The two things that come to mind are things that need some work. One is something the Japanese just did, which is a magneto-hydrodynamic ship which is a long word. It essentially turns out that, using a magnet very close to and very similar in some of its shape and characteristics to our dipole magnets, you actually can propel the water down the inside length of that magnet and use that to propel a ship through the water. The Japanese just launched one six months ago. It's a concept the United States has been working on. U.S. industry teamed with the U.S. Navy and other people have working on it for 15 or 20 years, but they never could get around to it. It has enormous economic advantages in the number of moving parts that you have to maintain on board a ship, which is a terrible problem. That's one.

The other one that comes to mind may be one of the reasons you'll have a company like a Westinghouse involved or even a Siemens. This is something called magnetic storage devices. I'm not sure what the acronym is, but it's not important. When you have a bundle of superconducting wire you're storing energy in the magnetic field that that wire allows to exist. The idea is that during the off-peak periods from your use of power generators, you can pump energy into superconducting storage devices in the ground or something quite safely. They can be very large, and again have no moving parts, which is a nice advantage. And then during the day, when you need the power, or during the warmer part of the day, or in the afternoon when you need lights, you can use the power out of that in addition to your generating capacity. The advantage is, obviously, you don't need to create as many power plants, so you can reduce your capital, in that sense.

McIntyre: My laboratory, the Texas Accelerator Center, is in fact a member of one of the teams Tom was referring to on energy storage. We're teamed with Bechtel and General Dynamics to develop such a system which would store power for electric utilities. And at our lab, we have, in fact, done the testing of the conductor for that, where you use a superconducting cable that's about the size of your arm rather than the rather thin one for the magnets of SSC and it stores the extra energy from a gigawatt power plant in a coil the size of a football field and gives any given power plant about a 30 percent extra reach in terms of the peak demand that it can provide. Right in our lab, we're actually now developing a very modest version of that thing. It has, I believe, the potential of a very lively business market, and that is for an uninterruptible power source for office buildings, hospitals, schools, just about anything that uses a computer or any form of load that suffers from momentary interruption. In your office buildings, you probably will have occasions once every few weeks, depending on whether your utility is more reliable than ours, where the lights will kind of flicker. What happens at that point is that someone somewhere on your piece of the grid has dropped a big load, or taken one on, and it drops the A/C voltage on your line down to near zip for a fraction of a second. In fact, 99 percent of all such interruptions are less than a second in duration. That doesn't cause you much inconvenience if all you're doing is reading a book or something, but it can if you're trying to work on a workstation or do anything that involves computing or anything that involves sensitive machinery. Questions? Comments?

Seybold: Before we adjourn, I want to say that I have enjoyed the program, and I hope you have, too. We are pleased that you're all here, and pleased to have our new members.

There are several people to whom I owe special thanks for their help in planning this program. Seeking help, I started with Governor Bill Clements and Peter O'Donnell. From them, I learned who was important to the SSC and to whom I should go for suggestions.

You've all heard of the large role that Governor Clements played in getting the SSC in Texas. You've also learned of the roles of Mort Meyerson, Congressman Joe Barton, and others, and how the campaign was planned and executed. But you have heard little about the role of Peter O'Donnell. He was primarily involved behind the scenes and with the work of getting a Texas bond issue authorized to bring the SSC to Texas. From Governor Clements and Peter O'Donnell, I learned of the early involvement in the project of Peter Flawn, Steven Weinberg, and Hans Mark. Each of them encouraged and helped me and pointed me to Dr. Roy F. Schwitters, the director of the SSC Laboratory. When I called on him, he went all-out to help me. He had many suggestions, worked to recruit some of our speakers, and spent much time on our plans during the course of the year. I went back to him for help repeatedly, as late as day before yesterday when one of our speakers dropped out at that late hour for reasons beyond his control. Roy, we couldn't have had a program without you.

I want to add a final thanks, not only to all the program participants, but also to Ron Tyler, our secretary; to Colleen Kain, his executive assistant, a genius at planning details; and to her assistant, Evelyn Stehling. The support of the staff was outstanding.

I say, again, thanks to our local arrangements committee and their better halves who made these local arrangements as nice as they are.

Finally, I want to say it's been a great honor to be president of the Philosophical Society of Texas in 1992. For this I thank you all indeed. I don't have a gavel but if I did, I'd turn it over to Bob Krueger, our president for 1993. Congratulations to you, Bob.

Krueger: I've already spoken of my pleasure and my gratitude to you for entrusting this responsibility to me, and I will only repeat now that it is genuine and heartfelt, but I think before we leave and gather together for this evening's meeting, I would like us all unanimously to give another round of applause to our outgoing president who's done just a splendid job today and throughout the year. Dr. Seybold.

Is there any further business? Without objection, we're adjourned.

SUNDAY DISCUSSION

ROY SCHWITTERS, MODERATOR

A QUESTION THAT CAME UP THAT I DIDN'T ADDRESS IN ANY COMPLETENESS IS THE competition. What is the competition worldwide? It has been stated many times this weekend that the highest energy accelerator in the world today is the Fermilab Tevatron outside of Chicago. It's a laboratory that was built in the late sixties and has been gradually improved and upgraded. That's not the largest accelerator, though.

The largest accelerator is in a tunnel underneath France and Switzerland just outside of Geneva. It's called the CERN laboratory. CERN is a marvelous laboratory. It was founded after World War II as the expression of European unity and it's grown into the finest laboratory in the world in our field. It's a wonderful place.

In the late seventies, they embarked on building what's called the large electron-positron collider. So they built a tunnel one-third the size of ours, 27 kilometers in circumference, that goes, if you know the area, from the Geneva airport to the Jura and back around again, crossing the French-Swiss border several times. That machine, for technical reasons, uses electrons and positrons. You cannot accelerate them to the same energy that we can protons, but, nevertheless, it's a very clean and simple and beautiful system to study in your experiments.

They are proposing to put into that same tunnel the kind of superconducting magnets we used, to provide proton-proton colliding capacity. Because the size is roughly one-third of ours, the energy will be roughly one-third. They will try to make up for that deficiency by running at a higher intensity and that's probably the major competition. Now, that's a great laboratory. However, in order to be competitive, they need to push this magnet technology, and they're actually a couple of years behind us in the magnet technology.

So it's a real horse race. They have a smaller machine to build. At the moment, I think it's fair to say that you can't distinguish between the schedules. Ultimately, we'll have more capability because we have three times the energy. We'll push the frontier back further but, that's not to say that there aren't some very exciting scientific discoveries in between where the first guys there will get it. So it's an interesting scientific competition. It's a very great laboratory and a very serious, and yet friendly, competition that's underway there.

Question: When you turn the accelerator on, how long will the entire experiment take?

Schwitters: That's a very good question. To fill up, to put all these little needles of protons in and get them colliding, will take about a couple of hours. You build them up in energy, you bring some more, it's like running things up a ladder. Finally, you fill up the whole machine, accelerate it, and the whole process takes a couple of hours. They then will sit there and circulate and collide for the rest of the day, for 24 hours or so. By that time, many of these billions of protons will have scattered out, and so then the intensity has been diminished and it's time to start it up again. So you get into a cycle of about a day, fill it up, collide for most of the day, fill it up, and so on. You do that seven days a week, as long as you can run and still pay the power bill. We expect to be "on" with the collisions occurring about one-third of the time. Which means, you're clearly running probably two-thirds of the year. The rest of the time you're doing maintenance and fixing things.

Now, when that's happening the particles are colliding at the rate of a hundred million collisions a second. They're relatively big objects in our world, and so a lot of them hit at the rate of a hundred million a second. We describe the debris that comes out. Of course, you do that in a computer with bits of information, and to describe one event, it takes roughly a diskette worth of data—roughly a megabyte. So you can imagine a hundred million diskettes of data being produced a second. We don't do that because it would pile up a lot of diskettes and that would be a problem, so we have to design what we call triggers to select just those few nuggets that are interesting. The effects we expect to see are such that we might see a dozen or a hundred interesting collision events that would tell us about the symmetry breaking in a whole year. A hundred million things are happening a second, and out of that huge haystack, we need to find a few dozen nuggets in a year of running. So that's why we run for periods of years until the time it takes to double your data is so long that you better improve something or increase the intensity or something like that. But the experiments are measured in years, and you analyze them. On the other hand, you can be sitting at the computer console and a gold-plated event comes in, and it's absolutely spectacular, and you know right then that you've discovered something interesting. And it's fantastically exciting when that happens.

Question: You said that the expected useful life of this facility is approximately 25 years. What happens at the end of 25 years? What do you do with the facility?

Schwitters: It's been suggested we grow mushrooms down in the tunnel. We don't have much experience with these large laboratories. In this country, and around the world, up until the 1960s we were talking cyclotrons like Eli talked about at Harvard. In that case, the universities either decided to shut them down or they went into other areas like medicine. It's only since the 1960s that we have these huge laboratories on a national or even international scale. It's a deep question. There are political imperatives because of the size of these objects. Up until now, we've been able to make evolutionary changes to the equipment and stretch out their useful life. What shocked a lot of Europeans, and a lot of foreign scientists in general, was the fact that the U.S., when embarking on this program, would do a national site selection, would not just append it to Fermilab. At their laboratory in Geneva, they have just built from that base and continued to use each machine as input to the next, bigger device. In our country, we haven't done that. When a major new facility comes along, we hold an independent competition on a national basis. I personally think it's the right thing to do because it brings new blood into the system in a way you could never do with an existing laboratory. But it also creates obvious difficulties, as we've seen here, of starting up a new operation in the face of severe budgetary problems at existing institutions.

Question: But you won't start building another bigger machine 10 years from now to take the place of this one?

Schwitters: Well, let me be careful. I can't imagine that myself, but physicists talk about these things. There are two complementary methods for getting at these questions. The people who are electron-positron gurus are trying to think of new technologies and are beginning to think about what it would take to go beyond the supercollider now. It's very conceptual. It's viewed by most people as requiring full international participation from the beginning. It just cannot be done on a regional basis. What they're talking about would be a set of linear accelerators aimed at each other, each 20 miles long, and tremendously expensive. At the moment the technology is just not available that makes it the least bit practical. But it doesn't mean we're not thinking about it.

Question: I understand you suggest the experiments are not duplicable?

Schwitters: Oh, they are. The world is changing, and we're using old words to describe new ways of doing business. These experiments, so called, are in detectors, as Raph Kasper told you; they're like new laboratories. What we try to do is design a balanced program where we have more than one detector, where they can overlap each other in many capabilities, but not exclusively. It would be silly just to build two identical detectors. So, in that sense, they're complementary features, and what you hope is that there's internal competition within a big group and then external competition between the two groups so that you can confirm a result. But you can be sure that with something as important as the mass-generation idea is discovered, or some new quark or supersymmetry, the scientific community's not going to believe it unless this is confirmed.

Question: What is the magnitude of the snafu projection? We're bound to make as many mistakes as you made putting up the great telescope.

Schwitters: I was explaining to some people yesterday that a little before the telescope issue came out, we were faced with the same problems. The aberration of the focusing magnetic fields in these magnets could have caused the protons to drift out of the machine prematurely. And that's not good, that's bad. It's kind of funny, you run computer simulations and, of course, you have to make guesses at what kind of errors you have in there. So you put in a set of random numbers and describe the errors in the machine. And then you run different samples of random numbers to see what's important and what's not. But we came up with a concept of the unlucky machine. Namely, you could imagine one machine in twenty where the beam doesn't go around. And it was considered rather unacceptable that you build a hundred miles of accelerator and the thing doesn't work. The beam tube started out at four centimeters in diameter, and by increasing it to five centimeters, we could gain a tremendous amount of confidence in this particular area of error. Now the problem was that caused everything to grow in size. Going from four to five centimeters was a $500 million decision, and we had to go back to the government. The new secretary of energy was not amused to hear about that. In my field, people were saying stay within your original budget, cut down the scope. But Clements; Meyerson; Harold Shapiro, the president of Princeton; Bob Stempel, the former head of GM—these people on our board were saying, you've got to keep your scientific priorities. If you don't believe in that, then why should we believe you at your next level? And so that was the debate that took place and we kept the scientific parameters fixed in that process. It was an interesting experience.

Question: Would you comment upon what you believe to be the scientific benefit from the competition that I presume exists between the Swiss-French collider and what you're doing here and what the ultimate benefits will be from that competition?

Schwitters: The benefits are, I would say, the traditional benefits of a good, healthy competition. Exchange of new ideas, of forcing you to do things in a timely and therefore better way all the way around. It just makes you sharper. That's obvious. You can say, why does the world need two of these things? And I think the approaches are sufficiently different that we will learn in the long run, in some rather technical areas, how you might extend these facilities to the higher intensities or the higher energies, and so on. So the approaches are somewhat different, and in that way we'll learn new directions to go with this facility in the future. For example, as I said, in order to compete with us, the

Europeans will have to push to have ten times more intensity. That means, instead of a hundred million of these collisions, they get a thousand million collisions a second. Fifteen years from now, we may want to go that route with our detector. So it'll teach us about that. It teaches us a lot of new technical innovations to exploit the facilities we've got. Finally, the physics and the results are so subtle that if a new result is claimed in one place, you can be sure it's going to be checked by the other, and that's going to be an important quality control mechanism on the actual scientific results. We're at a stage where I think it's appropriate to question whether it's diverting resources that are too thin or whether it has the traditional values of a good, healthy competition. I think we're approaching the edge, but on balance I would say that this is still on the side of maintaining competition. But one has to consider a different approach in the future because of the large sum.

Question: Is this free interchange?

Schwitters: Oh, completely free interchange. For example, the CERN laboratory tried a different path on the development of the superconducting wire I showed you. Well, it turns out they failed. The director-general of that was a former colleague of ours at Harvard, a well-known bon vivant—Carlo Rubbia—and he didn't exactly enjoy admitting defeat on this one, but a few weeks ago I was in Geneva and he said, "Gee, we really have to collaborate on this wire. Why don't you give me some of yours?"

Question: What happens in 25 years when you shut it off? Where does the medical community get its source of protons at an affordable cost?

Schwitters: Well, I think Kern Wildenthal's very effective at coming up with support. I'm not worried about that.

Glatstein: I can't answer that one directly, but all I can honestly say is that, as I said yesterday, there is the Boston unit, there is a unit out in California that's cyclotron-based, rather than linac-based, but there are ways of generating protons. We just simply change the cost, that's all.

McIntyre: I'd like to dissent slightly from you on the view of the competition between LHC and SSC. To me, it's a real frustration to see that playing out. SSC was conceived and put forward as a laboratory well before LHC was ever thought of. It has performance that exceeds by a factor of three to four what is even in principle possible, in my view, with LHC. LHC is I believe, an attempt at short-term gains, launched by our former colleague Carlo, which is, again in my view, ill-conceived and is going to cause the Europeans to lose momentum in the fullness of time rather than to seize it from us. It particularly frustrates me that, as far back as the early '80s, in our international congresses on particle physics and accelerator physics, etc., one after another of our senior statesmen of the field would stand up and say, never again can we afford to duplicate facilities. We have to now do a great proton collider in one place and a great electron-positron collider in another place and maybe a neutron collider, but not duplicate facilities because the cost has gone beyond where that can be justified. The frustration to me is that nowadays in our international congresses, we don't even hear the rhetoric that we must avoid that duplication. There's a sort of embarrassed silence that the Europeans have forgotten that. Could you comment on that, please?

Schwitters: Peter is saying that he feels that it's arguable now: are you gaining the benefits of competition with two facilities or is it too expensive and are you dividing precious resources to the detriment of one or the other or both? Is that a fair way to put it? And I'm not going to disagree with much of what Peter said. I think that is an issue and I think it's very close to the edge here. Peter is right. In our community in the late 1970s, when it became clear that this kind of work was a scientific imperative, we began discussing the question of a world machine. And there was a lot of nice rhetoric, and the elders of the field would have workshops and meetings. There was a meeting in Japan in 1984, and it became clear then that the regional prerogatives would, for the next generation, outweigh this attempt at true internationalism. And I share many of Peter's scientific concerns. The simple fact is the Europeans don't want to hear that argument, and they're more than welcome here at this facility. I think we would have a better program if we had more of them here. There's no question about that in my mind, but there is a strong sense of unity and support for the CERN laboratory, and they see their very future threatened in this debate. And we simply don't have the wisdom to deal with this at the moment.

Question: Isn't it true that the intellectual life of the scientist is short relative to the grandeur of the problem? Many times we're going to get what we can get while the getting's good, like your friend in CERN. But it is pretentious to talk in terms of eons. . . .

Schwitters: That's part of the debate. It's part of the mix that makes it so interesting. However, we've seen in this country that you can exceed it. A single ego can, and does, push some of these things. But you're now looking at major institutions under some threat. The important thing is to come back to the science and make sure that it's really robust, and that can be questioned in some of these. Peter was right to raise the question. I personally believe that we can still have both of these, but I agree. This is outside of high-energy physics, but a very important subject for world science and technology is the question of fusion power—the famous power from the sun, from the ocean. It's felt now among many bodies that the next major facility in that field should be fully international. The plasmaphysicists have now formed regional centers in this country, Japan, Europe, and Russia to plan this machine. Now, right at the moment, I don't see how they ever are going to address the question of siting. So at the moment, they're relatively happy to sit and do design studies, you know, 'til the cows come home. But how you actually get on and build one of these things the next time around, I don't think anybody has any idea.

Krueger: On the one hand, we are talking with some surprise and a bit of tension about international competition, but on the other hand, we competed very hard to get it to Texas. We would like to have it in Texas, we got it in Texas, we're happy about that, we would like to have a facility in the U.S.A., and we shouldn't be surprised if others behave the same way that we have behaved, which is to say that they would like to be leaders too. It seems to me that international cooperation is probably going to be more difficult than national cooperation. And as Dr. Schwitters just said, the question of siting, it's undoubtedly going to be an even bigger and more difficult one internationally.

Schwitters: With the SSC, despite all the political reminiscences that we heard yesterday, there was a shared vision. There really was, I think, remarkable cooperation after the siting decision was made; people pulled together and supported the site here. I think the notion that everybody else backed away was a little extreme. On the contrary, I think it's amazing how much that shared vision was able to heal those obvious wounds and center the new facility here. We don't have the mechanisms yet on the international front. That's the point. That's Peter's frustration. We have good friends, excellent people in Europe, but the Europeans just don't seem to share the same kind of willingness to move around that we have in this country. I mean, Peter, many people have done work at CERN from this country and so there's not the same sense of shared values and mission on this and willingness to spread it around. And that's a problem.

As we tunnel around, what we are committed to do by the terms of our environmental impact studies, and what we're planning to do is to deposit it locally at the various service areas. If you go around the map, you see our land is largely confined to main campus areas on either side of this racetrack, and then a number of fifty-acre sites where we put some service buildings. And we will deposit those soils on our land, trying to contour it in a natural way, and then replant over the surface. My hope and goal is that we restore a lot of the natural plants, trees, wildflowers, and so on to those areas. We have not yet worked out the details of that. There's not much dirt down there, it's just a very thin layer of soil over the rock, and how we actually do it and make sure that we don't wash away and fill up all the streams with dust and whatnot, we still have to work that out. But that's our commitment.

Question: We may have answered this yesterday before you arrived, but 1992 has been a politically risky year for the SSC. Have you cased the incoming Congress to see whether you have more friends, fewer friends, or the same number?

Schwitters: The question is what's it going to be like next year. The politics were complex last year, as you point out. There were a number of peripheral issues having to do with balanced-budget amendments, leadership races within the Republican party, and so on. We are beginning to meet the new Congress now to see how they will come out. I think there's some good news and some bad news there. In the case of the Senate, we've probably lost a few friends, but we had a very strong vote in the Senate, and, of course, very strong leadership from our delegation here. In the House, we lost a few of the outrageous critics, so that probably helps. It's too soon to call. I can't give you a good count. I personally think that the most critical thing will be the response of the new administration. There'll be a new secretary of energy, a new science advisor, and in the newspapers during the campaign Clinton definitely, specifically supported the SSC, and also in our various professional magazines, when asked questions about science policy, certainly gave answers that were fully consistent with this program. We're optimistic, but I think it's just simply too soon to say what his position and the vice-president's position will be on this matter.

Krueger: I'd like to offer a suggestion. In the past we often got funds for education by connecting it with national defense. We no longer need to connect it directly with national defense, but I think, as Congressman Barton indicated yesterday, we might not have 350 votes for it now that it has been sited in Texas. We don't necessarily want to connect it with national defense. It should be viewed not as a Texas site, but as a U.S. physics initiative.

Schwitters: We have to be very careful with the arguments. One of the most difficult things in running the laboratory is the morale question when it came to these votes. A lot of very talented people drawn from all over the world who want to build this. Probably the most shocking and depressing thing to most of our staff, especially the foreigners who have joined us, was the quality of the debate on both sides of the questions. The arguments, pro and con, were not very good. So we have to frame those arguments extremely well. I happen to agree with you. I think that the Congress is very sensitive to these issues of education and the larger value to society, but we found in the end that we had to be scrupulously honest on the basic scientific mission; if we tried to sell this, say, as a cure for cancer, but weren't absolutely clear, then the arguments can come back and bite us some way. And that's one of the difficulties in this.

Question: The word philosophy in the eighteenth century meant science, quite simply. The scientific clubs that were formed, the American Philosophical Society and before that the Royal Society and the French Academy, was that they combined pure science, invention, and innovation. The Royal Society was filled with businessmen and innovators and men pursuing science. I understand exactly what you meant when you said there was a morale problem in making the argument in any other terms than pure science. But, in a sense, I think that's impossible. I think the object has got to be to put it in much larger terms, in more solid terms, than emerge in the political debate, which probably offended and disconcerted some of your colleagues, especially those from abroad. When you say $8 billion, which I gather is the figure for this—I've been working on a problem where $8 billion would put all the kids who ought to be in Head Start in Head Start. We now have only 23 percent of them in this country, and the payoff there is four to six dollars for every dollar you invest in reduced dropouts and incarcerations. How does a democratic society make that calculus? Ultimately, I think, that's got to be faced. If we had an optimum discussion, we ought to have all the elements here that would require a societal decision on this matter. I think I know what the answer would be: that we have imposed on ourselves an artificial restraint, by running the economy at 7 or 8 percent unemployment instead of 4 or 5 percent unemployment as we did in the 1950s and 1960s, and barely a 2 percent rate of growth upon average versus what it should be, at 4 or 5 percent. A society moving that way would have the resources both for Head Start and the pursuit of science. We ought to be looking at the total societal decision and not the hardware or what the votes will be next year.

Schwitters: You're right. I gave the wrong impression there. What I meant to say is I think we have to put forward the basic scientific rationale very clearly; that is what draws the scientist to it. Now, having said that, I completely agree with your point. We have to justify to society the total paybacks, so to speak, to culture, to education, to science. All of those arguments must be made. I think we just have to frame them very clearly and very honestly. For example, in my personal view, the most important return to society is this kind of project and all that that means. There is a pull for us to accomplish the scientific goals and in that process we must make concessions, both technical and managerial, in order to pull it off. We present tremendous educational possibilities in that process, and the totality of that effort, in terms of the cadre of people that are going off and doing things, is the real return to the society. We have to make that argument, which is really what you're saying. I completely agree with that. I didn't mean that we shouldn't; in fact, it would be arrogant not to. But what was so depressing to many people in that debate was the unreasonable expectations being raised on the technical spinoffs of what might come from this. I think the educational spinoffs and those benefits are clear and tremendous.

Question: Have you discussed the operating temperature in the process? Do you have an operating grade of temperatures for the supercollider?

Schwitters: Basically, the tunnel itself is just in a room temperature environment. But inside those magnets, their nominal operating point is slightly more than four degrees above absolute zero Celsius Kelvin. And we could later improve the performance by reducing that temperature down to two degrees. We would have to add more refrigeration if we did that. In that case, you can actually put more current in the magnets and, therefore, raise the energy and have other benefits. I should have mentioned this in answering the question of longevity of the facility, but we planned in at least the possibility of enhancing performance later.

Question: Is this new wire so efficient that we're going to solve the problem of the superconductors in all applications, like trains? That's a big thing in Japan.

McIntyre: You're talking about magnetic levitation for trains? There are two magnetic levitation technologies that have been mature, neither of them in the U.S.: one in Germany and one in Japan. The Japanese technology uses superconducting magnets to provide the levitation. It's called repulsive levitation, pushing the train up off the reaction to the metal plate in the guideway. The German technology uses room-temperature magnets that are operated in a pulse mode and that's called the tractive levitation because it pulls the train up to a reaction rail that's along the side of the train. Neither of those two technologies, I believe, is yet ready for actual implementation on high-speed, long-distance routes. That's my opinion. My laboratory has participated with Ebasco and several other firms to develop the beginnings of a possible U.S. technology. We have a real problem, though, I believe, in seeing this going anywhere in the U.S.

The Germans and the Japanese have each invested public dollars to the tune of about a billion dollars each, and they had gotten to a point where they had demonstration trains running. They have probably another half-generation to go in each of those technologies before they become mature and the basis of something you could do over long distances. But they're on the road, as it were.

We haven't begun that process. Whether we could catch up or whether we're going to be a client-state to one or the other of them if we want to use those trains is yet to be seen, but there's a fundamental mindset here that goes back to the turn of the century where, within public policy in the U.S., trains in particular were identified as a mode of transportation that really shouldn't receive any further public subsidy, and we're paying a price for that. We don't have a train intrastructure worthy of the name in this country today. In Europe, if you travel from one city to another, you don't get on a plane. Only a very silly person would get on a plane, because they have a wonderful train system that connects every place to every place.

Question: I agree absolutely with everything you said, but I'm curious about the type of wire. When he started talking about refrigeration, I said, "Does this wire have to be refrigerated?"

Schwitters: It's got to be refrigerated. It's four degrees. But as explained, just building this quantity of wire and refrigeration drives the cost down. The wire will go down in price by a factor of 100 during this process. The companies involved here are, national companies. I talked to some of the senior people at Westinghouse. Why do they want to get in? Why does Westinghouse want to build accelerator magnets? They'll never build another accelerator magnet, but they want to have a hands-on experience with that technology and they want to see those prices go down. It's their long-term strategy to pick off some of those technologies. Now, maybe it's not trains, maybe it's power transmission or power storage like we talked about, or building ships that don't need propellers. What they do in a program like this is put many of their top engineers on it at very low profit because the competition is tough and there's just not going to be a lot of money to be made in accelerator magnets. And they're banking on the sort of excitement and training and enthusiasm that will come to their engineers and technical staff as part of this, and banking that ideas will spin off from that within their own company. As Peter said, this has been done a lot in Japan, where high-tech projects like the levitation project have already been built.

Question: You have explained the duplication. Is that the main reason that some physicists feel that the SSC is a boondoggle?

Schwitters: I think the main reason is that many physicists in many other fields of science, or areas of physics, feel that they're not getting enough money to do their research. They think, therefore, this is a threat to their work. What was interesting this summer, after the House of Representatives vote, is that many of them rethought that position and saw quite clearly that when money is taken out of one project like this, it doesn't necessarily come back into science. Many of these people saw that we're all in this together and that a wiser strategy was to try to support good science where it's taking place. The threat of reduced funding is hurting everybody throughout many areas of science, and when any scientist looks at his or her priorities, obviously their own work, by definition, is the highest priority. There are also some people who honestly believe that this is too far removed from ordinary experience to be worthwhile and therefore we should stop pushing the frontier. There are eminent scientists who believe that, but as we've seen, there have been eminent scientists throughout history who have believed that.

Question: Is there a threshold in energy between what now is available with the accelerator and what the SSC will have as a capability? Are you crossing a threshold in energy? If CERN builds a smaller machine that raises the intensity, where do they sit with respect to that threshold?

Schwitters: To our knowledge, there are no sharp thresholds here. We know that the questions that underlie the standard model will be resolved by a certain scale of energy, and we chose the SSC energy to go beyond that so we'd have, as described here by David Gross, a no-lose situation in terms of learning something. Either you'll find new things, or you'll find something else going wrong in the models or theories. So that's why it was chosen. But the thresholds are fuzzy. The LHC, being smaller in energy but higher in intensity, may or may not be competitive in some areas. We don't know enough to know. My guess is that we will have a decided advantage for technical reasons, because the increase of intensity clouds the pictures we take, so to speak. These collisions and their debris are very complicated and the CERN strategy to get more advantage will mean that they will overlay each picture with 10 or 15 others and it just makes it much more difficult to interpret the results, but there are no sharp thresholds. In contrast, with the other style of experimentation, the electrons and positrons in many cases do have sharp thresholds, and, therefore, you could build a machine, as happened in the early '70s in Italy, that fell just a smidge short of the discovery of this generation. And just because of the number of digits you've got on your hands, you count in powers of ten. Well, they went up to 2.8, 2.93, and then stopped. At 3.1, all hell broke loose and Nobel Prizes were won, and as soon as this was discovered the guys cranked it up to 3.1 and were terribly embarrassed. In that case you can have sharp thresholds. Probably not in this case.

Krueger: Maybe I could pose a question for most of us who are not physicists, but who are very interested in what you're doing and in what we believe it could add for our knowledge in other areas. I think back to when Walt Rostow was commenting on how the word science used to refer to knowledge and those who were scientists were just people interested in knowledge. I think back to John Donne's line in one poem around 1600 when he said, "The new philosophy calls all in doubt, the element of fire is quite put out." Galileo found that the element of fire was put out because there were new worlds, and so what we've seen is that there was a time in which people who are concerned with metaphysics and transcendental questions, or questions that involve things beyond our senses, were part of the world of what was then called science. Now I'm wondering if energy and matter are coming together and if the discoveries of physics are now leading back again, whether the wheel is coming full circle. Maybe that's not as precisely put as I might like, but I think that you understand that my interest is whether what you are doing is likely to lead to different conclusions, postulations, or even discoveries in areas of philosophy and, who knows, maybe even theology.

Schwitters: People really are tremendously excited by these ideas. They care about these ideas of quarks and relativity and symmetry and things we're talking about. So I think they do play a role, if you will, in the background of knowledge that an educated person has at his or her disposal. I think the general theme that we're seeing in our science, and that we hope to carry on, that of unification of ideas, of structures and matter and forces with unified, simplifying principles, is terribly profound. The physical world that we live in doesn't appear to be just arbitrary and capricious. It's built out of pieces that have definite relationships, and the further that we go into our field we're hoping to find a simpler unity, a simpler set of building blocks. The standard model that we've talked about here has to describe 19 parameters, 19 knobs that were set for the universe a fraction of a nanosecond after the big bang. What David Gross told us yesterday is that now science is starting to ask why those knobs were set to the values they were set at. That becomes a scientific question, whereas I think before, at least in polite company, most physicists would have been embarrassed to talk about such things. I believe that we're going to find deeper relationships, so to speak, between those knobs. The idea is that somehow our whole universe, everything we see when we look out at the stars and look inside these accelerators, has this profound unity.

Seybold: We are the Philosophical Society of Texas, founded "for the collection and diffusion of knowledge" and the promotion of science. We continue in that spirit. Louis Pasteur, the great French scientist, was asked, what good was his discovery of microorganisms? "Well," he responded, "what good is a newborn babe?" Now we ask what good is new knowledge and new truths about the structure of the nucleus of the atom. Is it not to extend human understanding and to extend the limits of human performance? The potential, like that of the newborn babe, is tremendous.

Question: An argument that I haven't heard that I think is significant is that high-energy physicists saved our bacon in World War II, and kept me from having to go all the way to Japan, and I, for one, am willing to pay my share, which I figure is about $50, of this project to be sure that we maintain world leadership in this field. Because I'd hate to think that some other country would get more information about high-energy physics than we have and be able to use it against us. Do you think that's a significant argument?

Schwitters: The information, of course, is published in the open literature, and so everybody has access to the information. Physics is not an armchair activity, however; it's the doing, it's the inventing, it's the pushing, it's the actual accomplishment of all of these tasks that matters, and in that sense, there's no question in my mind that the country, is investing in its future. The ability of this country to carry on major technical activities is a fragile resource that could be lost. I completely agree with you.

McIntyre: Related to your question about the boundary between this field and our view of philosophy today and a philosophical view of nature, one of the features that I find most intriguing is the several boundaries that we have between chaos and order and what we're learning about that in the world of the atom and of the nucleus. The fundamental scale for all of the things that we think of as the ordered systems in our universe, whether it's our body or the room or the earth, is the scale of the atom, and atoms are spaced next to one another in a very well-defined distance scale that's coming from the electromagnetic interaction that holds electrons around the nucleus in a solar system, whose size is absolutely immutably set by the quantum principle, which was the underpinning of this century's physics. That quantum principle tells you that atoms can't come in all sorts of different sizes, they come in a very particular size that's governed entirely by the fact that there is a conserved quantum number that is the I.D. card, as it were, of an electron and a proton. And then, of course, the magnitude of the charge and the strength of the field between. Once those things are set, you have the potential for the large-scale order of interesting things in our world. For that to work, however, there has to be a dense, solid core down at the heart of that solar system for the electron to go around. That core has to contain within it one of these two charges, or otherwise the electron wouldn't be attracted to it and wouldn't form the atom. So that gives rise to the inescapable need that there be a second interaction of nature, and that interaction of nature has to occur with a much stronger pole strength and on a much shorter distance scale than electromagnetism, and that's what we call the strong force that locks the quarks together to make protons. The remarkable feature of this strong force is that within the proton, these three particles that Roy has talked about, the quarks that are bound together to make a proton, are immutably locked together. Hard as we have tried, up to a trillion volts of collision energy, we find it completely impossible to "bang out" one of these quarks, leaving the other two behind. You try to bang them together to knock one out and a weird thing happens: as soon as it gets a little bit away, a quark/anti-quark pair spring out of the vacuum. The quark of that pair stays behind so you still got three. The anti-quark goes off with the fellow that you hit forming what we call a meson. It's another elementary particle. It's a very strange process.

Schwitters: You break a string, so to speak. You break the string and two more are created.

McIntyre: And perhaps the most peculiar feature of this is that when we say somewhat correctly that a proton consists of three quarks, there's also the glue that's holding them together, which are the virtual particles of the strong force. You might think that these three quarks weigh pretty close to a third of the weight of a proton, which in turn is essentially the entire mass of an atom, but that isn't true. As far as we can tell from the scattering experiments that we've been doing for the last 20 years, these quarks seem to weigh almost nothing at all. They weigh not much more than an electron, so nature is playing a very peculiar shell game upon us within this proton. You start weighing the quarks experimentally, and you find they don't weigh anything. The answer to that conundrum is that the quarks are at any given moment whizzing around relativistically at essentially the speed of light, and it's their kinetic energy of motion together with the potential energy, with springs, of the strong forces holding them together, that accounts for all the mass that is us, that is everything in this room. If you could hypothetically snip the bonds of that strong force that is binding the quarks, something that we now believe is probably impossible, but if you were to hypothetically do that, you would find that you are releasing essentially that entire field of energy that is mass. This very peculiar interplay between order and chaos on succeeding scales of nature leads one into almost a religious experience. Suppose that you were a smart God and you wanted to create an interesting universe. If you were really smart, you'd do it in the most economical way possible, with the least complexity of rules. The most economical way you could do it would be to organize matter in such a way that you had interesting things that could be put together. That would require you to have electromagnetism, so you could put atoms together to make organized pieces of matter that were stable over lifetimes and generations and geological times. Then you'd have to have a strong force, as I said, to put together the nucleus so this atom could have an immutable identity. You can't change an atom by hitting it with a hammer or by any other process we can do to it. To have that immutable identity so you can have organized matter that doesn't just change from day-to-day, you must have a second force that's holding the core that gives its identity on a very, very small scale compared to the atom. So you've got to have a strong force. And in order to make this thing run, you've got to have energy. To release energy, you're going to have to have something in your universe that releases immense quantities of energy. Rather obviously, you can't locate your interesting things that are going to go on at the spot where you have that energy being released, or you're going to burn them up. So you have to have another very long-range force that's felt by all forms of matter rather than locally, as in the atom, and that's gravity. And in gravity you pull together gaseous matter and light it up with nuclear fusion using the strong force and generate the abundant energy that is the sun and that gives the possibility of interesting things happening here. And last, but not least, if you're going to have a whole variety of chemical elements starting out of the big bang, you've got to have a further, rather subtle interaction of nature that makes it possible, over a long time, for one chemical element to transmute into another, and that's the weak force. So those are the four forces of nature we know of. And the interesting case that emerges is that no matter how smart you are as a hypothetical prime mover of the universe, that's what you've got to have if you're going to have an interesting place.

Schwitters: Let me jump in. This line of argument goes on that we're in the universe we're in so that we can be here to learn about the universe, and there might be many others. In fact, it's a serious point. But that's one line of the argument that does definitely get into the philosophical. There's a new book people might be interested in called *Genius,* by James Gleick, on the life of Richard Feynman. Feynman was probably the most respected and certainly one of the most original theoretical physicists of this century. He died a couple of years ago. Many of you may have seen him; in the last months of his life, he was on the commission that studied the Challenger space shuttle accident, and he did this marvelous experiment where he showed with a glass of ice water the essence of what went wrong with the famous O-ring. He was a wonderful man and the book touches on many of these kinds of questions that you raise, just because of the way Feynman was. He was such an incredibly original creative thinker along these lines. He had written on his blackboard when he was gone a statement that "the world is made out of atoms." That was what he thought was the most important thing to know, and it touches on what Peter said. The world as we know it is made out of a whole bunch of absolutely identical objects. We call them atoms, and that's the way it is, the full complexity in everything we see. Feynman's legacy was that statement: the world is made out of atoms. There's another wonderful quote from a chemist, I've forgotten which one now, who said pity a universe without physicists, because there could be many atoms around in that universe, and a physicist was an atom's way of finding out about atoms.

Question: These advertisements are much easier to read. Little books are great fun and deal with all these questions beautifully.

Schwitters: The best one of those is called *Surely You're Joking, Mr. Feynman,* and I also happen to agree. I like it and I like the message. Other people don't. Victor Weisskopf, who was one of the former directors-general of CERN and an eminent professor at MIT, made a nice statement. He said reading that book about Feynman is like reading and hearing about Mozart and never hearing the music. Victor's point is that the depth of his contributions to his science were truly on the scale of Mozart.

Question: Will there be at the SSC a station for cancer patients, or at least where research on cancer can be conducted?

Schwitters: The spirit in which we are entering this collaboration with the medical school is that it be a center for research, teaching, and clinical work.

Glatstein: We hope to build a facility down there for medical use. There would be teaching, treatment, and research. The cost of that would probably be in the neighborhood of $25 million. It's a major commitment.

Question: Are there other medical uses?

Glatstein: Potentially, there are a number of other things that might be done with it in terms of isotope production and things of that sort. I don't think we've thought very extensively about that just yet, but there are some other potential uses.

Seybold: I promised everyone that we'd be through by 10:30 so those who are staying in the hotel could check out. We have thoroughly enjoyed our panel this morning. We appreciate this loyal and interested crowd. We've heard some fascinating questions and some fascinating answers to questions that can't be answered, but searching for the truth is an exciting process. And as I expressed yesterday, mankind always comes out ahead when a new truth is found.

I want to say thank you to all of you for the privilege of having been your president this year. I want to say thanks to all of you who came. I want to say thanks to all of you participants who made the program possible. I want to say particular thanks to this man [Roy Schwitters] without whom I could not have put the program together. He was not alone, but he was a key player. He came to the rescue and helped fill up our panels. I want to say best wishes to my successor, Bob Krueger, for the coming year. And I declare the panel closed and the meeting over. Thank you all.

NECROLOGY

Mark Edwin Andrews
1904–1992

If the Philosophical Society was founded on the nineteenth-century precepts which embraced "moral philosophy" and "natural philosophy," more commonly called the "arts and sciences" today, Mark Edwin Andrews was an ideal member of the Society. His career as a lawyer and a businessman is well known. He was also a distinguished Naval person, first as an officer rising rapidly from lieutenant to captain, and after World War II as a civilian assistant secretary of the Navy in charge of procurement of all the needs of that organization under the command of its secretary, James V. Forrestal, his friend and Princeton classmate.

Less well-known were his talents in such diverse fields as collecting, writing, and teaching. The latter were accomplished during his stint as an attorney, when he taught at South Texas School of Law and wrote two books. Earlier, at Princeton, he began collecting antique furniture and continued to do so for a lifetime, particularly while furnishing the Irish castle, Knappogue, which he and his wife Lavon acquired in the 1950s. The Irish and English furniture in Knappogue match in quality similar pieces found in London and Dublin museums. His service as a chairman of the Bayou Bend Advisory Committee of the Museum of Fine Arts—Houston attests to his expertise in the field of fine antique furniture.

He was a Princetonian of wit, grace, charm, and culture. Our Society lost one of its most valuable members when he died in Houston on August 22, 1992, at age 88.

T. A.

George A. Butler
1899–1987

George A. Butler, Houston lawyer, banker, businessman, and rancher, was born on December 20, 1899, in Estherville, Iowa. He liked to say he was a farm boy. Those who admired his urbane personality and many accomplishments were somewhat skeptical of the country boy legend. After his death on May 19, 1987, those attending his funeral at the Episcopal Church of St. John the Divine in Houston were reassured that George Butler approved of that legend when the church's great organ boomed out "Home on the Range."

George Butler attended the University of Iowa, where he was a member of Delta Tau Delta fraternity. He received his LL.B. in 1925 from George Washington University. While in law school and serving as a Congressional aide, he met and married Anne Garrett, daughter of Congressman Daniel Garrett, of Houston. Later that same year, George and Anne Butler moved to Houston. Mrs. Butler predeceased Mr. Butler in 1977.

George Butler started the practice of law with a firm which represented Jesse Jones, a leader of Houston's financial community. In the 1930s, he became a director of all of Mr. Jones's numerous companies (including National Bank of Commerce, predecessor of Texas Commerce Bank) and kept the Jones interests intact while Mr. Jones was busy during the Depression heading the Reconstruction Finance Corporation and serving as secretary of commerce. On April 27, 1941, George Butler and Jack Binion formed their own firm, which they called Butler & Binion (and which is again known by that name after shortening its name from Butler, Binion, Rice, Cook & Knapp). He claimed his greatest satisfaction was the prestige of this law firm.

George Butler acquired control of several business and industrial concerns over the years and enjoyed seeing them prosper under his leadership. In 1955, he founded Bank of Texas, predecessor of First Interstate Bank of Texas, and in 1965 he founded Post Oak Bank. He turned his talents to ranching and was proud of the prize cattle on his Rocking A and Mayfair ranches in Washington and Burleson counties, Texas. (He thought "Mayfair" sounded more attractive then "Wagon Wheel" or the like.) He maintained homes there and at Roaring Gap, North Carolina.

Among the many business and charitable organizations of which George Butler was a director or trustee were the National War Fund (during World War II), United War Chest of Texas (president), Houston Community Chest, Hedgecroft Clinic (a treatment center for polio of which he was a cofounder and chairman), Bank of Texas, Post Oak Bank, Houston First Financial Group (chairman), Merchants Park Bank, Gulf Resources and Chemical Company, American General Insurance Company, Houston Post Company, Lincoln Consolidated, Inc., Texas Eastern Transmission Company, Braniff Airways, Inc., Midhurst Corporation (subsidiary of Pearson plc), Houston Endowment, Southwestern Legal Foundation, Houston Law Foundation, George Washington University, Grand Central Art Galleries in New York, Texas Department of Welfare (chairman), and Texas Democratic Party (chairman). He was a member of the American Judicature Society, American Bar Association, State Bar of Texas, St. John the Divine Episcopal Church (senior warden), Houston

Country Club, Houston Club, Bayou Club, Ramada Club, and River Oaks Country Club. He was a 32nd Degree Mason and a Knight of San Jacinto of the Sons of the Republic of Texas.

George Butler was chairman of the George and Anne Butler Foundation, from which the University of Houston has benefitted, and his memory is preserved in the George A. Butler Research Fund and the Butler & Binion Lectureship, both at the University of Houston.

While at the ranch, George Butler became interested in the nearby Washington-on-the-Brazos State Park and became chairman of the board of the association of that park, where he channeled much of his energy into construction of the museum and reconstruction of historic buildings. In 1975, he was quoted as being proud of the fact that attendance had risen to 250,000 visitors annually. One of the local farmers, not too pleased with all that, said he was grateful the visitors were not quite so numerous. He said he knew, because he had seen Mr. Butler out at the gate stomping on the vehicle counter.

George A. Butler is survived by a son, George A. Butler, Jr., and two daughters, Ida Jo Butler Moran and Anne Butler Leonard, and numerous grandchildren and great-grandchildren.

O. C. D./W. P. H.

Edward A. Clark
1906–1992

Edward A. Clark was born in San Augustine on July 15, 1906, and died in Austin on September 16, 1992, at the age of eighty-six years. Services were held at Good Shepherd Episcopal Church, Austin, and at historic Christ Church Episcopal, San Augustine.

He was for many years an active and prominent member of the Philosophical Society of Texas and served as its president in 1975. He is favorably remembered as an enthusiastic philosopher and one of the Society's most distinguished members.

Ed lived most of his life in Austin but claimed his Medallion Straddlefork Farm in San Augustine as his home. It brought him much pleasure to reminisce about the old days and people of his native county. Among his favorite subjects were his land and timber holdings in East Texas and being qualified and recognized as a tree farmer.

His father and mother, Mr. and Mrs. John D. Clark, moved from Newton County to San Augustine where Mr. Clark operated a general mercantile store and served as a director of the First National Bank. His mother, Leila Downs

Clark, was a lady of nobility who lived to be ninety-six years of age. His grandfather, Col. Edward D. Downs, was sheriff and tax collector of Newton County and a banker in San Augustine. He was also an early member of the Texas House of Representatives and an outstanding leader of Texas.

A great fondness existed between Ed and his grandfather Downs, and during his youth, Ed acquired much of his wisdom, wit, and knowledge of people while driving his grandfather around the county in a Model T Ford visiting friends.

He attended Southwestern University in Georgetown for two years and received an undergraduate degree from Tulane University in 1926 and a law degree from The University of Texas in 1928.

In 1927, he married Anne Metcalfe of Greenville, Mississippi, whom he met while both were students in New Orleans. Anne preceded him in death in 1989.

Ed was elected and served as county attorney of San Augustine County, and in 1932 he moved to Austin to become an assistant attorney general under James V. Allred. When his mentor, Allred, became governor of Texas, Ed was appointed as Governor Allred's assistant, in which position he acquired much political acumen that benefitted him in assisting others to obtain public office. Ed became secretary of state in 1937, and at the age of 30, he was looked upon as an exceptionally talented and promising young leader of Texas.

He and Everett Looney, who served as first assistant attorney general under Allred, formed a law partnership in Austin which later became the prestigious firm of Clark, Thomas, Winters & Newton. Ed also served as a captain in the United States Army in World War II.

Ed and President Lyndon B. Johnson were close friends, dating back to 1937, when Johnson was elected Congressman for the Tenth District. Ed and his political capabilities weighed heavily for Lyndon B. Johnson in all of his races.

In 1965, President Johnson appointed his friend Ed Clark ambassador to Australia, entreating him to make friends for the United States. As an ambassador to Australia, Clark was very successful and became extremely popular. It is said that he was the most widely known and beloved American in Australia. Named in his honor in 1989 was the Edward A. Clark Center for Australian Studies at The University of Texas.

Clark was responsible for bringing the Harold E. Mertz Collection of Australian Art to the Harry Ransom Humanities Research Center, University of Texas. Anne brought distinction to herself by writing the very interesting book entitled *Australian Adventure,* which has received wide distribution, particularly in Texas and Australia.

On his return from Australia, Ed was appointed federal commissioner to the 1968 HemisFair in San Antonio.

He became executive director of the Inter-American Development Bank in Washington, D.C., was on the arms control and disarmament agency committees, and was for six years a regent of The University of Texas System.

He and Anne donated their 24,000-volume collection of Texana to Southwestern University. At the time, Ed said, "The collection expresses both a reverence for the past and a regard for the future. . . . The spirit of Texas is the greatest and most enduring of all the many elements which might compose a Texas heritage. But the spirit of Texas cannot be transferred by deed, or bequeathed by will. It can be acquired only through knowledge gained by the individual's own efforts. . . . Books are the essential and fundamental source of that knowledge, and a collection of them, brought together with loving care and maintained with pride, may well inspire others to the effort necessary for them to realize to the fullest extent the benefits of their Texas heritage."

Ed and Anne shared a strong commitment to higher education, and together they received the Mirabeau B. Lamar Award for Distinguished Contribution to Higher Education. Ed received the Ima Hogg Historical Achievement Award, the Distinguished Alumnus Award from The University of Texas Ex-Students Association, and the Outstanding Alumnus Award from The University of Texas Law Alumni Association. He served on various boards, committees, foundations, and councils of The University of Texas. He was a trustee for many years of Southwestern University, The University of Texas Law School Foundation, and St. Stephens Episcopal School. He held honorary degrees from Southwestern University, Georgetown, Texas, and Cleary College in Ypsilanti, Michigan. The Edward Clark Centennial Professorship in Law was established in his honor at The University of Texas.

He was an early life member of the Ex-Students Association of The University of Texas and past chairman of the Institute of Texan Cultures, San Antonio, and also past president and honorary lifetime member of the Texas State Historical Association.

Other organizations of which he was a member were the American Bar Association, Judicature Society, Texas State Bar Association, Southwestern Legal Foundation, Littlefield Society of The University of Texas, Sons of the Republic of Texas, Knights of San Jacinto, Sons of the American Revolution, Phi Delta Phi legal fraternity, and Kappa Sigma social fraternity.

Ed Clark maintained extensive interest in the banking industry, serving as president and chairman of the First National Bank, San Augustine, and as senior chairman of the Board of Texas Commerce Bank, Austin. He was on the governing board of many financial institutions, among them the San Benito Bank and Trust Company, San Benito, Texas Commerce BankShares, Houston, Employers' National Life Insurance, and Employers Casualty Insurance Company, Dallas.

Ed Clark's ability was unequaled in financial campaigns for worthy causes. He was instrumental in raising millions of dollars for his beloved Southwestern University and University of Texas. He chaired the committee which raised multi-millions to restore the Ashbel Smith Building for The University of Texas Medical School in Galveston, co-chaired a campaign to raise money for the Lady Bird Johnson Fund to benefit the LBJ Library, organized the effort to finance construction of the State Bar of Texas headquarters, and raised funds to purchase the telescope at the McDonald Observatory in Fort Davis. He also was chairman of the committee to raise funds for the revision of *The Handbook of Texas* for the Texas State Historical Association.

Ed was a man of unusual ability, boundless energy, and great foresight. He had expressions that condensed many lengthy conversations into a few words. He probably knew as many people as anyone in Texas, and he probably was as well-known as any person in Texas. He outlived most of his contemporaries, and his longevity no doubt was due to his continued interest in people and local, state, and world affairs. Ed accomplished much in his lifetime, and he touched many lives. He had the reputation of being able to accomplish anything and everything he undertook. He had a winning personality and the ability to make and keep friends. He enjoyed immensely the opportunity to visit with people, and his conversation was always spiced with East Texas expressions. His great sense of humor kept him in a good mood most of the time. He received glowing tributes in editorials of the Texas newspapers, and he will be long remembered as a loyal and true son of Texas who exercised tremendous influence in the affairs of his state for more than half a century. He is greatly missed.

Edward A. Clark is survived by a daughter, Leila Clark Wynn; granddaughter, Anne, and husband, Charles Wiessinger, Jr., of Rolling Fork, Mississippi; granddaughter, Martha, and husband, Matt Wiessinger, of Greenville, Mississippi; granddaughter, Margaret Wynn, and grandson, William T. Wynn, of Jackson, Mississippi; and five great-grandchildren: Leila, Charlie and Guy, children of Anne and Charles Wiessinger; and Douglas and Molly, children of Martha and Matt Wiessinger. He is also survived by a sister, Kathleen Clark Fisher, and brother-in-law, Joe J. Fisher, of Beaumont.

J. J. F.

PRICE DANIEL
1910–1988

PRICE DANIEL (MARION PRICE DANIEL), PRESIDENT OF THIS SOCIETY IN 1979, served the State of Texas in more capacities than any other Texas statesman, living or dead. More than likely that distinction will never be equalled. He had a rare combination of talents and principles that guided him throughout his life.

Born in Dayton, Texas, on October 10, 1910, he received his LL.B. from Baylor in 1932. He was elected a to the House of Representatives in 1939, and became speaker in 1943. He was attorney general from 1946 to 1953; a member of the U.S. Senate from 1953 to 1957; governor of Texas from 1957 to 1963; and justice of the Supreme Court of Texas from 1971 through 1978. Because we measure our leaders not by their tenure but by quality of their service, history will record that Price Daniel was an exceptional public official.

As attorney general, he ran an excellent law office. Since I served as his first assistant, I saw it firsthand. His instructions were to "get the law right, and let me worry about the politics." That is the way it was. One of his early cases involved upholding the validity of an order of the Railroad Commission that all natural gas, produced with oil, be returned to the reservoir or be put into pipelines. Otherwise, the oil well was to be shut down. Before that, huge amounts of natural gas were flared and burned. These were "the flare gas cases." Major interests of oil companies were arrayed in opposition. It took political courage, and the cases were won in the Texas Supreme Court.

Daniel, as attorney general, was also recognized for his major effort in an original action in the United States Supreme Court in defense of the tidelands of Texas. Most coastal states own only three miles into the sea. Texas entered the United States with the title it acquired from Mexico; i.e., three marine leagues, or about ten and one-half miles. The oil and gas beneath the Gulf of Mexico out to three marine leagues are enormously valuable; and there was also a matter of principle. The case was magnificently briefed and argued in the U.S. Supreme Court, but it was lost by a vote of four to three. Justice Tom Clark of Texas and Justice Jackson recused themselves. The case was later won, under Daniel's leadership, in the Congress, which relinquished the title to the tidelands of Texas.

As governor, he proposed 151 measures, of which 131 were enacted. He recommended taxes for needed services, but his views on taxation were basically populist and anti-sales tax. He had problems with the Legislature about that. It prevailed on the sales tax measures.

The State Library and Archives Building was the jewel of the building program during his administration. History, heritage, and tradition were important to him.

I was privileged to serve with Price Daniel for approximately eight years on the Texas Supreme Court. He was a careful and studious judge. While he had law clerks, he wrote his own opinions, and he carefully studied the opinions of his colleagues. His views were impressive and influential on the improvement of groundwater law and the law dealing with minerals, including oil, gas, uranium, and lignite. He was a champion of fairness and simplicity in the rules of civil procedure promulgated by the court. It is fitting that the new building in the State's court complex is named The Price Daniel, Sr. Building.

Price Daniel held many other offices during his lengthy career, including assistant to the President of the United States for federal and state relations and director of the Office of Emergency Preparedness (1967-1969). He was a leader of the Men's Bible Class of the First Baptist Church in Austin and was president of the International Christian Leadership (1956-1957). He was a trustee of Baylor University and Baylor College of Medicine in Houston and was honored by his alma mater with the LL.D. degree in 1951.

Price Daniel died on August 25, 1988, and was buried in a family cemetery in Liberty, Texas. His wife, Jean Baldwin, a direct descendant of Sam Houston, is loved and respected by all of the members of the Society who have the privilege of knowing her.

J. R. G.

Ballinger Mills, Jr.
1914–1992

Ballinger Mills, Jr., 78, of Galveston, died of heart failure on September 29, 1992. Born in Galveston, he received his B.A. cum laude from Yale University, and LL.B. from The University of Texas School of Law. Mills was admitted to the Texas bar in 1939. He was a partner in the firm of Mills, Shirley, Eckel & Basset. Mills served as president and director of the Sealy & Smith Foundation for the John Sealy Hospital. He was a member of various boards including: American Indemnity Co., Texas General Indemnity Co., Galveston Corporation, Gulf & Interstate Railroad Co., UT Chancellor's Council, University of Texas Medical Branch Development Board, UT Law School Foundation, and UT Institute of Texan Cultures Development Board. He was a member of the American Judicature Society, Association of the ICC Practitioners, Texas Association of Defense Council, and the American and Galveston County Bar Associations. Mills is survived by two sons, Ballinger Mills III of Austin and Charles Leonard Mills of Oklahoma City, and three grandchildren, Ashley Lynn Mills, Ryan Leonard Mills, and Brandi Ballinger Mills.

B. M./W. L.

AYLMER GREEN MCNEESE, JR.
1911–1990

AYLMER GREEN MCNEESE, JR., WHOSE LOVE FOR TEXAS, PRIDE IN BEING ONE of its native sons, and dedication to the institution he loved most, The University of Texas, were the hallmarks of his life, died in Houston on Sunday, November 18, 1990.

He was born in the little town of Hubbard, in Hill County, whose claim to fame and recognition comes from being the birthplace of Tris Speaker, the legendary baseball player. McNeese yearned to be a college athlete. So when he entered The University of Texas in 1929, he went out for football and became a close friend of Harrison Stafford, who later became an All-American back for the Texas Longhorns. When Stafford received an athletic scholarship from the U.S. Military Academy at West Point, McNeese succeeded in getting an appointment to the academy to be with his friend. But the military life was not to his liking and he re-entered The University of Texas, where he received a B.A. degree in 1933 and his LLB. degree in 1937.

During his post-graduate tenure at the University, McNeese taught a class in public speaking. One of his students was Catherine Elsbury, who became his wife and lifetime partner, and who passed on shortly after his death.

After graduation, he joined the prestigious law firm of Fulbright, Crooker, Freeman, Bates & Jaworski in Houston, specializing in petroleum law. Later he became vice-president and general counsel for the Glenn H. McCarthy Interests. In 1953 he was asked by the board of directors of the Second National Bank to be assistant to its president, L. R. Bryant, Jr. In 1956 McNeese was named president of the bank and its name was changed to Bank of the Southwest as it moved into a new building that became one of the showplaces of downtown Houston. He was elected chairman of the board of Bank of the Southwest in 1967 and served in that capacity until his retirement in 1982.

Of all his accomplishments during a career that spanned a broad spectrum of interests and public service, none matched the gratification that came when he was named to The University of Texas Board of Regents in 1959, where he served until 1965. He was reappointed to the Board of Regents in 1971 and served as its chairman from 1973 to 1975.

McNeese served on a number of corporate boards: National Airlines, Fort Worth and Denver Railroad, and Temple-Eastex Incorporated. He was an active layman of Christ Church Cathedral, the historic Episcopal church in downtown Houston. He was a lifetime trustee of the M. D. Anderson Foundation and the Baylor College of Medicine, a director of the Texas Medical

Center, the Houston Symphony Society, and Mary Baldwin College, and a member of the Sons of the American Revolution and the Sons of the Republic of Texas.

He never lost his love of the land, which was nurtured as a youngster living in Hubbard. He raised Simmental cattle and American saddle horses and enjoyed his time in the country, far removed from the bustle of the big city.

His survivors are a daughter, Margaret Carter McNeese, M. D.; a son, Thomas Dwyer McNeese; two granddaughters, Catherine Carter McNeese and Bridget Theresa McNeese Schuessler; and a grandson, Thomas Aylmer Dwyer McNeese, II.

The legacy McNeese has left with those who knew him and the institutions and interests he served is an uncompromising standard of ethics and principles and an unquenchable affection for Texas and all that its heritage represents.

R. J.

TOM SEALY
1909–1992

TOM SEALY, 83, OF MIDLAND DIED ON APRIL 27, 1992.

Born in Santa Anna, Texas, Sealy received his LL.B. from The University of Texas Law School in 1931. He served as a lieutenant colonel in the U.S. Air Force during World War II. Since 1936 he had been a member of the law firm now known as Stubbeman, McRae, Sealy, Laughlin & Browder, Inc., and was its managing partner until his resignation from that position in 1980. He retired from the active practice of law in February 1989.

Mr. Sealy donated much of his time to civic endeavors on both the local and state levels. He was an honorary director (formerly director) of First City Bank, Midland, and had served as a director of a number of other corporations.

Sealy not only devoted his time and energy to The University of Texas at Austin and to The University of Texas Law School but he also served the entire University of Texas System and higher education in general. He was a former president and life member trustee of The University of Texas Law School Foundation. He served as chairman of The University of Texas System Board of Regents and the UT System Development Board. He was a member of the Governor's Committee of 25 on Education Beyond High School and was the second chairman of the Coordinating Board, Texas College and University System.

In 1966 he was chosen as distinguished alumnus by The University of Texas Ex-Students' Association and in 1970 was named an outstanding alumnus of The University of Texas Law School.

He was a member of the American Bar Association as well as the State Bar of Texas and Midland County Bar Associations and was a fellow of both the Texas Bar and American Bar Foundations. Sealy was also a former member of the International Association of Defense Counsel, and was a member and former president of the Texas Association of Defense Counsel. He was an honorary trustee (former trustee) of the Southwestern Legal Foundation and a former member of the advisory committee to the Texas Supreme Court.

Among the honors received by Sealy are the establishment by a client in 1972 at The University of Texas Law School of the Tom Sealy Law and Free Society Lectureship; establishment in 1982 at The University of Texas Law School of the Tom Sealy Research Professorship in Energy Law by Atlantic Richfield Company; selection as "Boss of the Year" by the Midland Legal Secretaries Association in 1967; "West Texas Friend of The University of Texas" by The University of Texas Ex-Students' Association of Midland in 1982; National Jewish Hospital/Asthma Center's Humanitarian Award in 1985; and the 50-year Award from Texas Bar Foundation Fellows in 1985.

In addition, Sealy was a former Midland City councilman, past president of the Midland Chamber of Commerce, director of the Texas Association of Taxpayers, former member of the board of governors of Midland Memorial Hospital Foundation, and a member of and former chairman of the Texas Research League.

In addition to his extensive work in the fields of education and law, Sealy was active in church work. He was a member and former elder of the First Presbyterian Church of Midland, as well as a former trustee of the Texas Presbyterian Foundation and Austin Presbyterian Theological Seminary.

Sealy was a member of the Midland Country Club and Petroleum and Plaza Clubs.

He was preceded in death in June 1990 by his wife of 54 years, Mary Velma McCord Sealy. He is survived by a daughter and son-in-law, Nancy and Andy Thompson of Fort Worth; two grandsons, Andrew and Christopher Thompson; a brother, Dr. W. Burgess Sealy of Fort Worth; a sister, Mrs. Kenneth Knowles of Bowie, Maryland; and several nieces and nephews.

W. B. S./W. D. S.

Logan Wilson
1907–1990

Dr. Logan Wilson, a former president and chancellor of The University of Texas System, died on November 7, 1990, in Austin after a lengthy illness. He was 83 years old. A longtime member of the Philosophical Society of Texas, he served as its president in 1974.

During his administrative tenure at the University, Wilson provided the leadership to bring UT Austin into the top rank of universities in faculty salaries and academic recognition. He advocated "peaks of excellence" throughout the university, building vigorously upon the strengths that were already present. He also played a crucial role in the passage of the state constitutional amendment expanding the Permanent and Available University Funds. The Texas Commission on Higher Education, the first statewide board empowered to coordinate higher education in Texas, was created largely through his vigorous efforts.

After ten years as the chief executive officer at The University of Texas, he moved to Washington, D.C,. in 1961 to serve as president of the American Council on Education. As chief spokesman for higher education in America during the turbulent 1960s, he provided national leadership at a critical period characterized by explosive growth and alarming campus unrest. In 1971, he retired to Texas where he continued as an active volunteer in state and national affairs.

Wilson graduated from Sam Houston College in 1926, received a master's degree in English from The University of Texas in 1927, and accepted his first teaching assignment as an assistant professor of English at East Texas State Teacher's College. After a second master's degree and Ph.D. degree in sociology in 1939 from Harvard University, he served in quick succession over the next five years as associate professor of sociology at the University of Maryland, professor and head of the sociology department at Tulane, and head of sociology at Kentucky. His skill as an academic administrator led to his appointment as dean of Newcomb College at Tulane University in 1944, as vice-president and provost at the University of North Carolina in 1951, and as president of The University of Texas in 1953.

Special honors and recognition that he received during his long and distinguished career are numerous. Among the 19 colleges and universities that have awarded him honorary degrees, are Harvard, Chicago, Tulane, and Texas Christian universities. In 1966, the Association of Texas Colleges and Universities awarded him a distinguished service medallion. The University of Akron recognized his accomplishments with its Centennial Award in 1970, and he was appointed senator-at-large by Phi Beta Kappa Honorary Society in 1964.

Among Wilson's many books, his first, *The Academic Man,* published in 1942, has been most widely acclaimed. In many respects, this classic publication has served as a blueprint for his own career as a distinguished administrator and academician.

Probably his most difficult administrative decisions were those concerning desegregation of The University of Texas in the 1950s. Under his leadership, the university in 1956 was the first major southern university to open all academic programs to black students. But housing and public facilities remained segregated well into the 1960s.

Logan Wilson is survived by his wife, the former Myra Marshall, whom he married on December 27, 1932; sons and daughters-in-law Marshall Wilson and Laura of Houston and Dr. Reed Calhoun Wilson and Tina of Portland, Oregon; grandchildren Logan Marshall, Catherine Louise, and Isabell of Houston and Jenifer of Portland; and brother Calhoun Wilson of Huntsville and Houston.

W. H. H.

OFFICERS OF THE SOCIETY

For the Year 1993

President
ROBERT KRUEGER

First Vice-President
STEVEN WEINBERG

Second Vice-President
WILLIAM H. CROOK

Secretary
RON TYLER

Treasurer
JAMES DICK

Directors

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STEVEN WEINBERG
WILLIAM H. CROOK
WILLIAM D. SEYBOLD
WILLIAM C. LEVIN
FRANK MCREYNOLDS WOZENCRAFT
J. CHRYS DOUGHERTY
JOHN CLIFTON CALDWELL
ELSPETH ROSTOW
WILLIAM PETTUS HOBBY
JOE R. GREENHILL

PAST PRESIDENTS

*Mirabeau Buonaparte Lamar 1837-59
*Ira Kendrick Stephens 1936
*Charles Shirley Potts 1937
*Edgar Odell Lovett 1938
*George Bannerman Dealey 1939
*George Waverley Briggs 1940
*William James 1941
*George Alfred Hill, Jr. 1942
*Edward Henry Cary 1943
*Edward Randall 1944
*Umphrey Lee 1944
*Eugene Perry Locke 1945
*Louis Herman Hubbard 1946
*Pat Ireland Nixon 1947
*Ima Hogg 1948
*Albert Perley Brogan 1949
*William Lockhart Clayton 1950
*A. Frank Smith 1951
*Ernest Lynn Kurth 1952
*Dudley Kezer Woodward, Jr. 1953
*Burke Baker 1954
*Jesse Andrews 1955
*James Pinckney Hart 1956
*Robert Gerald Storey 1957
*Lewis Randolph Bryan, Jr. 1958
*W. St. John Garwood 1959
George Crews McGhee 1960
*Harry Hunt Ransom 1961
*Eugene Benjamin Germany 1962
*Rupert Norval Richardson 1963
*Mrs. George Alfred Hill, Jr. 1964
*Edward Randall, Jr. 1965
*McGruder Ellis Sadler 1966
*William Alexander Kirkland 1967
*Richard Tudor Fleming 1968
*Herbert Pickens Gambrell 1969
*Harris Leon Kempner 1970
*Carey Croneis 1971
*Willis McDonald Tate 1972
*Dillon Anderson 1973
*Logan Wilson 1974
*Edward Clark 1975
Thomas Hart Law 1976
*Truman G. Blocker, Jr. 1977
Frank E. Vandiver 1978
*Price Daniel 1979
Durwood Fleming 1980
Charles A. LeMaistre 1981
Abner V. McCall 1982
*Leon Jaworski 1983
Wayne H. Holtzman 1983
Jenkins Garrett 1984
Joe R. Greenhill 1985
William Pettus Hobby 1986
Elspeth Rostow 1987
John Clifton Caldwell 1988
J. Chrys Dougherty 1989
Frank McReynolds Wozencraft 1990
William C. Levin 1991
William D. Seybold 1992

*Deceased

MEETINGS OF THE PHILOSOPHICAL SOCIETY OF TEXAS

December 5, 1837	-	Founded at Houston
January 29, 1839	-	Austin
January 18, 1936	-	Chartered
December 5, 1936	-	Reorganizational meeting - Dallas
January 29, 1937	-	Meeting and inaugural banquet - Dallas
December 4, 1937	-	Liendo and Houston
1938	-	Dallas
1939	-	Dallas
1940	-	San Antonio
1941	-	Austin
1942	-	Dallas
1943	-	Dallas
1944	-	Dallas
1945	-	Dallas
1946	-	Dallas
1947	-	San Antonio
1948	-	Houston
1949	-	Austin
1950	-	Houston
1951	-	Lufkin
1952	-	College Station
1953	-	Dallas
1954	-	Austin
1955	-	Nacogdoches
1956	-	Austin
1957	-	Dallas
1958	-	Austin
1959	-	San Antonio
1960	-	Fort Clark
1961	-	Salado
1962	-	Salado
1963	-	Nacogdoches
1964	-	Austin
1965	-	Salado
1966	-	Salado
1967	-	Arlington
1968	-	San Antonio
1969	-	Salado
1970	-	Salado
1971	-	Nacogdoches
1972	-	Dallas
1973	-	Austin (Lakeway Inn)
1974	-	Austin
1975	-	Fort Worth
1976	-	San Antonio
1977	-	Galveston
1978	-	Houston
1979	-	Austin
1980	-	San Antonio
1981	-	Dallas
1982	-	Galveston
1983	-	Fort Worth
1984	-	Houston
1985	-	College Station
1986	-	Austin
1987	-	Kerrville
1988	-	Dallas
1989	-	San Antonio
1990	-	Houston
1991	-	Galveston
1992	-	Dallas
1993	-	Laredo

MEMBERS OF THE SOCIETY

(NAME OF SPOUSE APPEARS IN PARENTHESES)

ADKISSON, PERRY L. (FRANCES), chancellor, Texas A&M University System, distinguished professor of entomology, Texas A&M University .... *College Station*

ALLBRITTON, JOE LEWIS (BARBARA), lawyer; board chairman, Riggs National Corporation .... *Houston*

ANDERSON, THOMAS D. (HELEN), lawyer .... *Houston*

ARMSTRONG, ANNE LEGENDRE (MRS. TOBIN), former U.S. ambassador to Great Britain .... *Armstrong*

ASHBY, LYNN COX (DOROTHY), editor, Houston *Post;* member, Houston Philosophical Society and Houston Economic Development Council; author .... *Houston*

ASHWORTH, KENNETH H., commissioner of higher education, Texas College and University System .... *Austin*

ATLAS, MORRIS (RITA), lawyer, senior partner, Atlas and Hall .... *McAllen*

BAKER, JAMES ADDISON, III (SUSAN), former U.S. secretary of state; former U.S. secretary of the treasury; White House chief of staff .... *Houston* and *Washington, D.C.*

BAKER, REX. G., JR., lawyer .... *Houston*

BARROW, THOMAS D. (JANICE), vice-chairman, Standard Oil Company (Ohio) .... *Houston*

BARTON, DEREK HAROLD RICHARD (CHRISTIANE), professor of chemistry, Texas A&M University; Nobel Prize in chemistry .... *College Station*

BASS, GEORGE FLETCHER (ANN), scientific director, Institute of Nautical Archaeology, Texas A&M University .... *College Station*

BELL, HENRY M., JR. (NELL), senior chairman of the board, First City Texas, Tyler N.A.; chairman of the board, East Texas Medical Center Foundation .... *Tyler*

BELL, PAUL GERVAIS (SUE), president, Bell Construction Company; president, San Jacinto Museum of History .... *Houston*

BENNETT, JOHN MIRZA, JR. (ELEANOR), member, University of Texas Centennial Commission and Texas Historical Records Advisor Board; director, Texas and Southwestern Cattlemen's Association; Major General, USAFR .... *San Antonio*

BENTSEN, LLOYD (BERYL ANN; "B.A."), United States senator .... *Houston* and *Washington, D.C.*

BLANTON, JACK S. (LAURA LEE), president, Scurlock Oil Company .... *Houston*

BOLTON, FRANK C., JR., lawyer; former head of legal department of Mobil Oil Company .... *Houston*

BRANDT, EDWARD N., JR. (PATRICIA), physician—medical educator; executive dean, Oklahoma City Campus—Health Sciences Center, University of Oklahoma .... *Oklahoma City, OK*

BRINKERHOFF, ANN BARBER, chairman, Liberal Arts Foundation, University of Texas at Austin .... *Houston*

BROWN, JOHN R. (VERA), judge, Fifth Circuit Court of Appeals .... *Houston*

BRYAN, J. P., JR. (MARY JON), president, Schroeder Torch; former president, Texas State Historical Association .... *Houston*

BUSH, GEORGE (BARBARA), president of the United States; former director, Central Intelligence Agency; former ambassador to United Nations; former congressman .... *Houston* and *Washington, D.C.*

CALDWELL, JOHN CLIFTON (SHIRLEY), rancher; former chairman, Texas Historical Commission; director, Texas Historical Foundation .... *Albany*

CALGAARD, RONALD KEITH (GENIE), president of Trinity University .... *San Antonio*

CARMACK, GEORGE (BONNIE), former editor, Houston *Press, Albuquerque Tribune and Travel,* and editorial writer San Antonio *Express-News* .... *San Antonio*

CARPENTER, ELIZABETH "LIZ," former assistant secretary of education, Washington correspondent, White House press secretary; consultant, LBJ Library; author .... *Austin*

CARROLL, MARY JOE DURNING (MRS. H. BAILEY), lawyer; board member, *Texas Law Review;* ed. staff, *Handbook of Texas* (1952); former parliamentarian, Texas Senate; Governor's Committee, 1969 Codification of Texas School Laws .... *Austin*

CARSON, RONALD (UTA), Harris L. Kempner Professor in the Humanities in Medicine and director of the Institute for Medical Humanities, University of Texas Medical Branch at Galveston .... *Galveston*

CASEY, ALBERT V., former United States postmaster general; chairman and C.E.O., AMR Corp. and American Airlines, Inc.; director, Colgate-Palmolive Co. .... *Dallas*

CAVAZOS, LAURO F. (PEGGY ANN), former secretary of education; former president, Texas Tech University and Texas Tech University Health Sciences Center .... *Washington, D.C.*

CHRISTIAN, GEORGE (JO ANN), writer and political consultant; former press secretary and special assistant to President Lyndon B. Johnson .... *Austin*

CISNEROS, HENRY G. (MARY ALICE), former mayor, San Antonio, faculty member, Trinity University .... *San Antonio*

CLARK, RANDOLPH LEE (BERTHA), former president, University of Texas System Cancer Center M.D. Anderson Hospital and Tumor Institute .... *Houston*

CLEMENTS, WILLIAM P., JR. (RITA), former governor of Texas; former chairman, SEDCO, Inc.; former deputy secretary of defense .... *Dallas*

CONGER, ROGER N. (LACY ROSE), retired executive; former mayor of Waco; former president, Texas State Historical Association .... *Waco*

COOK, C. W. W. (FRANCES), company director, former chairman, General Foods Corp. .... *Austin*

COOPER, JOHN H. (DOROTHY), headmaster emeritus, KinKaid School; educational consultant .... *The Woodlands*

COUSINS, MARGARET, writer and editor .... *San Antonio*

CRAVEN, JUDITH LYNN BERWICK (MORITZ), professor of public health administration, University of Texas Health Science Center, Houston; Director of Public Health, Houston .... *Houston*

CRIM, WILLIAM ROBERT (MARGARET), investments .... *Kilgore*

CROOK, WILLIAM HERBERT, former U.S. ambassador to Australia; former president San Marcos Academy; commissioner, U.S.-Mexican Border Development .... *San Marcos*

CUNNINGHAM, WILLIAM H. (ISABELLA), former president, University of Texas at Austin; chancellor, University of Texas at Austin .... *Austin*

CURTIS, GREGORY (TRACY), editor, *Texas Monthly;* author .... *Austin*

DARDEN, WILLIAM E., president, William E. Darden Lumber Company; former regent, University of Texas .... *Waco*

DEBAKEY, MICHAEL E., surgeon; chancellor, Baylor College of Medicine .... *Houston*

DECHERD, ROBERT W. (MAUREEN), president, A. H. Belo Corporation .... *Dallas*

DENIUS, FRANKLIN W. (CHARMAINE), lawyer; former president, University of Texas Ex-Students' Association; member, Constitutional Revision Committee .... *Austin*

DENMAN, GILBERT M., JR., lawyer, partner Denman, Franklin & Denman; chairman of the board, Southwest Texas Corporation and Ewing Halsell Foundation .... *San Antonio*

DICK, JAMES, founder-director of the International Festival-Institute at Round Top; concert pianist and teacher .... *Round Top*

DOTY, EZRA WILLIAM (ELINOR), emeritus professor of music and founding dean of the College of Fine Arts, University of Texas at Austin .... *Austin*

DOUGHERTY, J. CHRYS (SARAH), attorney; Honorary French Consul in Austin; trustee, St. Stephen's Episcopal School, Austin; University of Texas Law School Foundation .... *Austin*

DOYLE, GERRY (KATHERINE), former chairman, foreign trade committee, Rice Millers Association .... *Beaumont*

DUFF, KATHARYN, communication consultant, author .... *Abilene*

DUGGER, RONNIE E. (PATRICIA BLAKE), publisher, *The Texas Observer;* author .... *Wellfleet, MA*

DUNAGAN, J. CONRAD (KATHLYN), president, Dunagan Foundation, Inc.; chairman, Permian Honor Scholarship Foundation, Inc. .... *Monahans*

DUNCAN, A. BAKER (SALLY), president, Duncan-Smith Company .... *San Antonio*

DUNCAN, CHARLES WILLIAM, JR. (ANNE), chairman, Duncan, Cook & Co.; former secretary of U.S. Energy Department, deputy secretary of U.S. Defense Department; president of The Coca-Cola Company, and chairman of Rotan Mosle Financial Corp. .... *Houston*

DUNCAN, JOHN HOUSE (BRENDA), businessman; chairman, Board of Trustees, Southwestern University .... *Houston*

ELKINS, JAMES A., JR., chairman, First City Bancorporation of Texas, Inc.; trustee, Baylor College of Medicine .... *Houston*

ERICKSON, JOHN R. (KRISTINE), author, lecturer; owner of Maverick Books publishing company .... *Perryton*

EVANS, STERLING C., ranching and investments .... *Castroville*

FARABEE, KENNETH RAY (MARY MARGARET), vice chancellor and general counsel, University of Texas System; former member, Texas State Senate .... *Austin*

FEHRENBACH, T. R. (LILLIAN), author, historian; chairman, Texas Historical Commission; chairman, Texas Antiquities Committee; member, Texas Capitol Centennial Celebration Committee .... *San Antonio*

FINCH, WILLIAM CARRINGTON, retired dean, Vanderbilt Divinity School; former president, Southwestern University .... *Nashville, TN*

FISHER, JOE J. (KATHLEEN), chief judge emeritus of the U.S. District Court for the Eastern District of Texas, former district attorney and state district judge for the First Judicial District of Texas .... *Beaumont*

FISHER, RICHARD (NANCY), managing partner, Fisher Capital Management; former executive assistant to U.S. Secretary of the Treasury .... *Dallas*

FLAWN, PETER T. (PRISCILLA), president emeritus, University of Texas at Austin .... *Austin*

FLEMING, DURWOOD (LURLYN), former president and chancellor, Southwestern University .... *Dallas*

FLEMING, JON HUGH (ANN), educator, consultant, businessman; former president, Texas Wesleyan College; former member, Governor's Select Committee on Public Education .... *Dallas*

FONKEN, GERHARD JOSEPH (CAROLYN), executive vice-president and provost, University of Texas at Austin .... *Austin*

FRANTZ, JOE B. (BETSY), Turnbull professor of history, Corpus Christi State University; former director, Texas State Historical Association; former president, Texas Institute of Letters .... *Corpus Christi*

FRIEND, LLERENA BEAUFORT, professor emeritus of history, University of Texas at Austin .... *Wichita Falls*

FROST, TOM C. (PAT), chairman of the board, Cullen/Frost Bankers, Inc. .... *San Antonio*

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