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SUPERCONDUCTING SUPER COLLIDER: ISSUES
IP 384S

In January 1987, President Reagan asked Congress to authorize construction of a Superconducting Super Collider, a particle accelerator to be used by physicists to study the smallest particles of matter. The project will cost billions of dollars, though even its supporters admit that it may not produce any immediate commercial or military benefits. The Superconducting Super Collider would advance man's knowledge in the field of high energy physics, including the testing of theories regarding the beginning of the universe and the composition of matter. This Info Pack gives background information on the pros and cons of building the Superconducting Super Collider.

Members of Congress who want additional information on this topic can call CRS at 287-5700. Other CRS reports can be identified in the Guide to CRS Products (for congressional use only) under "Research and Development" and in Update under "Science and Technology."

Constituents may find additional information on this subject, primarily in periodicals and newspapers, at a local library through the use of indexes such as the Readers' Guide to Periodical Literature, Public Affairs Information Service Bulletin (PAIS), General Science Index, and the New York Times Index.

We hope this information is helpful.

Congressional Reference
Division

Ip384 AS
Bulletin of the Atomic Scientists, May 1986, pp.8,9,10,11

The case for the super collider

The enormous recent progress in particle physics is directly related to the power of accelerators. The next stage requires a superconducting super collider, a project the author believes the U.S. government should support.

by James W. Cronin

PHYSICISTS engaged in the study of the fundamental constituents of matter and their interactions have recently proposed the construction of a particle accelerator which will cost about $4 billion. Particle accelerators are the essential tools that enable physicists to discover the most elementary forms of matter and the nature of their interactions. The new instrument, called the Superconducting Super Collider (SSC), will be required if further progress is to be made in this most fundamental field of science.

This proposal raises questions of national science policy because of the large expense of the project. Among such questions are the following: How would the instrument benefit the people of this nation? Is it even the business of the U.S. government to support such a project? Among many large scientific projects why choose this particular one? What would be the impact on other scientific fields if such an instrument were built? Should it be built by an international collaboration? How can one be sure anything important will be learned with this instrument?

The SSC proposal is the result of the enormous growth in our understanding of the fundamental constituents of matter. This study was resumed 40 years ago after World War II by many of the physicists who had participated in the Manhattan Project. At that time the fundamental constituents of matter were thought to be the neutron and the proton, which comprised the atomic nucleus, and the electrons which formed the outer shells of the atom. Other particles were observed in cosmic radiation, but the role they played was not understood until particle accelerators were used to produce them directly in the laboratory by collisions of the accelerated protons or electrons with stationary targets. Today we know that the neutron and proton are complex structures comprised of apparently more fundamental constituents called quarks.

Forty years ago there appeared to be four basic forces: the strong force, which bound the neutrons and protons into atomic nuclei; the electromagnetic force, which bound the electrons to the atomic nucleus to form the atoms; the weak force, which is responsible for radioactivity; and the gravitational force.

We now know that the weak and electromagnetic forces have a common source. We understand the nature of the strong force and suspect that it has a common origin with the weak and electromagnetic forces. We understand the important role that the fundamental constituents and their interactions have played in the evolution of the universe following the "big bang." Finally, at a deeply theoretical level, very compelling ideas are being developed which suggest a common origin to all four forces.

It is in the context of these successes and the new questions they raise that the SSC proposal has been made. Most of our current understanding about the fundamental nature of matter has come from the use of particle accelerators of ever-increasing energy. In recent years accelerator builders have developed techniques in which two counter-rotating beams of charged particles can be brought into collision with one another. Such collisions make much more effective use of energy than do collisions with stationary targets. As the energy of the particle accelerators has increased, so has their expense.

At present in the United States there are four major high-energy accelerator centers (see table). The total capital investment in these facilities is in excess of $2 billion, and

This image from the "streamer chamber" of the CERN collider in Geneva shows streams of subparticles bursting out from a collision between a proton and an antiproton. A proton collision at the proposed SSC would generate at least five times as many particles as the CERN appartus. The photograph was taken in a collision detector during CERN's UA-5 experiment, conducted by an international consortium of physicists from Bonn, Brussels, Cambridge (England), CERN, and Stockholm. *(Courtesy James W. Cronin and John Rushbrooke)*

James W. Cronin, University Professor of Physics at the University of Chicago, received the Nobel Prize in physics in 1980.

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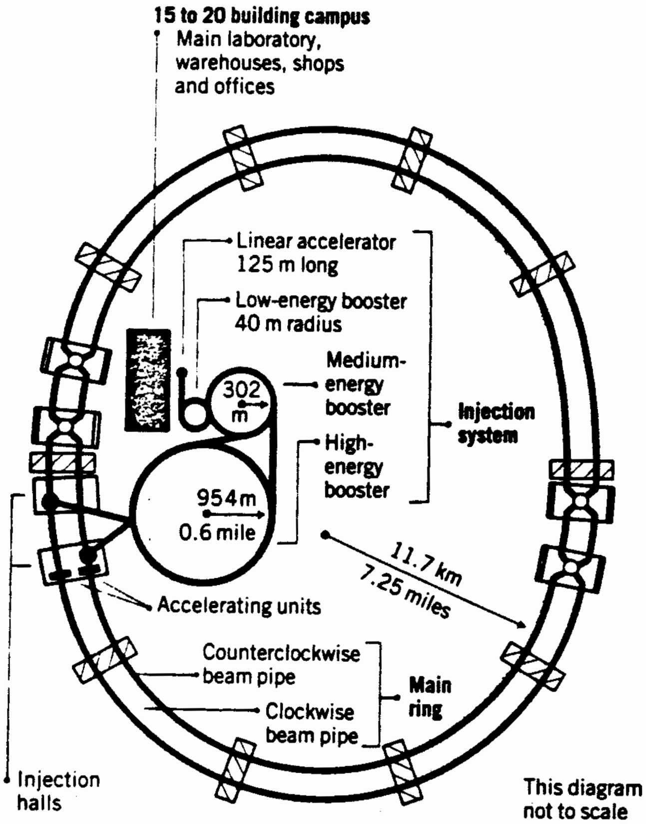
The Superconducting Super Collider (SSC)

SSC anatomy (For scale drawing, see map at bottom right.)

Legend

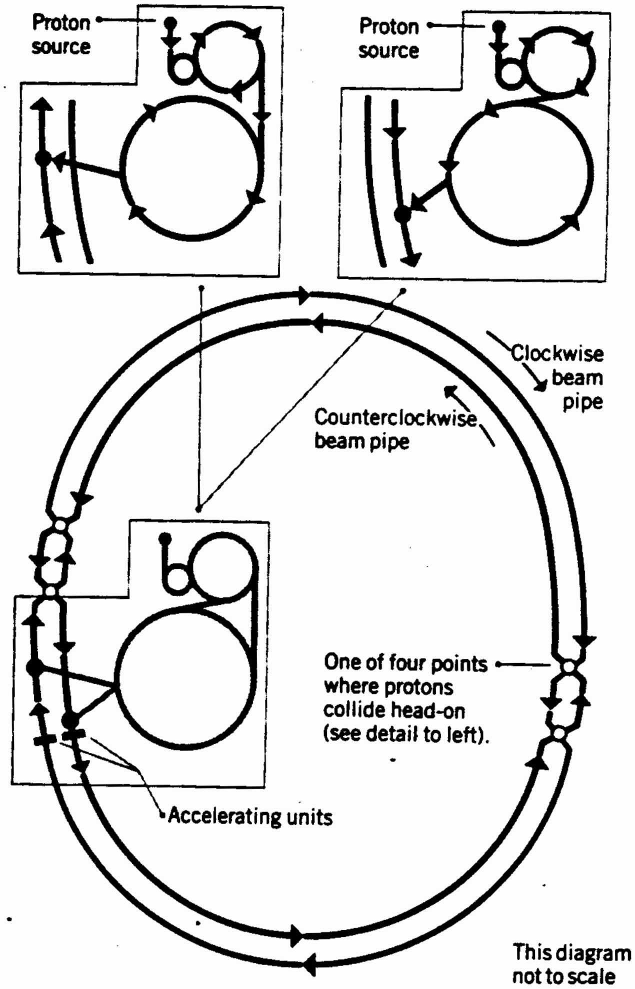
- Power supply and liquid helium refrigeration unit
- Interaction point and associated recording collision detectors
- Interaction hall housing interaction point
- Locations of superconducting magnets



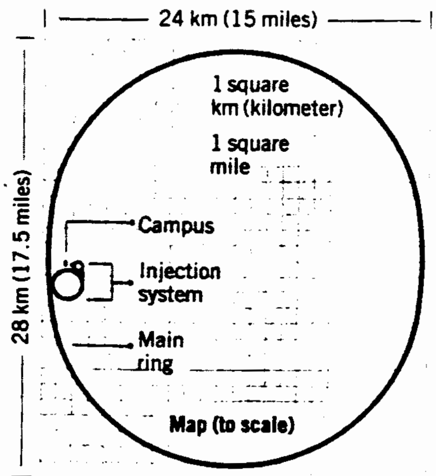
Operation of injection system

Injection system loading protons into clockwise beam pipe of main ring

Injection system loading protons into counterclockwise beam pipe of main ring



Main ring sustaining dual proton beams



The size and power of the underground SSC would allow narrow beams of protons to collide at almost the speed of light, creating new subatomic particles observable only at very high energies that cannot be attained by existing accelerators. This diagram tracks the path of proton beams. Protons are produced by the ionization of hydrogen atoms.

The injection system (upper right), composed of a linear accelerator and three progressively larger circular energy boosters, prepares the protons for the main-ring collisions by accelerating them to higher and higher energies. Some protons are loaded into the clockwise beam pipe (green), then others into the counterclockwise one (black).

Inside the main ring (see central schematics), accelerating units speed the protons to 20 times their energy. The protons are guided in the high-energy booster and main ring by about 10,000 powerful superconducting magnets, refrigerated by liquid helium to 4.35° Kelvin (about –270° centigrade, –455° Fahrenheit). The magnets maintain the beams on their circular paths; special magnets near the interaction points force collisions between protons traveling in opposite directions. Detection apparatuses at each collision site will measure the energy released by the collisions and will trace the paths of particles produced by the collisions. By creating levels of energy similar to those of the "big bang," scientists hope to learn about the fundamental laws of nature that guided the creation of the universe.

Informational graphics: Michael Yanoff the annual operating budget is about $600 million per year. A larger level of activity exists in Western Europe, as well as a comparable effort in the Soviet Union. And Japan has significantly increased its investment in high-energy physics.

The SSC would consist of two concentric magnetic guide fields for protons.* The magnets would be placed in a 60-mile circumference tunnel bored about 30 meters below the surface. The guide fields would intersect at a number of points to allow the counter-rotating beams of protons to collide with energies 20 times greater than now available.

*Charged particles such as protons are deflected by magnetic fields. An arrangement of electromagnets surrounding an evacuated pipe can produce a magnetic guide field which maintains the protons in a circular orbit inside the pipe. Electrical impulses add energy to the particle on each orbit. As the energy of the protons increases, the strength of the magnetic guide field must be increased to keep the proton orbit within the pipe.

The world's major high-energy accelerators

(GeV: Giga electron volt, an energy unit used to measure the mass of subatomic particles. With $E=mc^2$, the mass of the proton is about one GeV.)

Proposed superconducting supercollider (United States)

20,000 GeV protons colliding with 20,000 GeV protons (1996)

United States

Fermi National Accelerator Laboratory, Batavia, Illinois

900 GeV protons on a stationary target
900 GeV protons colliding with 900 GeV antiprotons

Stanford Linear Accelerator Center, Stanford, California

15 GeV electrons colliding with 15 GeV positrons
50 GeV electrons colliding with 50 GeV positrons (1987)

Brookhaven National Laboratory, Upton, New York

28 GeV protons on a stationary target

Cornell University, Ithaca, New York

5 GeV electrons colliding with 5 GeV positrons

Western Europe

European Organization for Nuclear Research [CERN], Geneva Switzerland

450 GeV protons on stationary targets
330 GeV protons colliding with 330 GeV antiprotons
50 GeV electrons colliding with 50 GeV positrons

German Electron Synchroton Laboratory, Hamburg, West Germany

5 GeV electrons colliding with 5 GeV positrons
23 GeV electrons colliding with 23 GeV positrons
30 GeV electrons colliding with 800 GeV protons (1990)

Soviet Union

Institute of Nuclear Physics, Novosibirsk

5 GeV electrons colliding with 5 GeV positrons

Institute for High Energy Physics, Serpukhov

70 GeV protons on a stationary target
3,000 GeV protons on a stationary target (1990)
3,000 GeV protons colliding with 3,000 antiprotons (1995)

Japan

National Laboratory for High Energy Physics, Tsukuba-gun, Japan

35 GeV electrons colliding with 35 GeV positrons (1987)

Detectors surrounding the collision point would study the result of the interactions.

Coincident with the scientific need for the SSC has been the development and successful implementation of superconducting magnets for accelerator guide fields. These magnets can produce a guide field three times larger than a conventional iron electromagnet. This means that the circumference of the SSC can be one-third the size of an accelerator built with iron magnets. In addition, the electrical current flows in the superconducting windings of the magnets without dissipation of power. Power does have to be supplied for refrigeration since the superconducting property occurs only at liquid helium temperatures (four degrees above absolute zero). This power is only a fraction of what would have been required without superconductivity.

The combination of the scientific imperative for the SSC with the technical feasibility of its construction makes this project the prime goal of the high-energy physicists. Yet the huge cost of the project inevitably attracts national attention.

WHY SHOULD THIS expensive scientific project go ahead? It is difficult to argue that there are any immediate benefits to be felt by the whole population. It should proceed for the simple reason that the exploration and understanding of nature have consistently advanced civilization and are one of its prime features. Discoveries made in the course of fundamental scientific investigations have in time led to new technologies which have profoundly affected life on this planet. One can point to the development of electricity as a power source at the end of the nineteenth century, which was based on discoveries made in the eighteenth and early nineteenth centuries. The development of fast computers can be traced back to investigations of the fundamental properties of solid state materials which were suggested by the discovery of quantum phenomena in the early twentieth century.

I personally believe there are even deeper reasons to support the construction of the SSC. The intellectual achievements of humanity in its relatively brief time on earth are almost beyond belief. Furthermore, they are among the most positive aspects of human nature. The spirit of a nation and the pride of its people can only be enhanced when science, including the exploration of our planet, solar system, galaxy, and universe is among its highest priorities.

The United States is a strong nation, with the intellectual and economic resources to execute major scientific projects. These projects should emphasize the gain of basic knowledge without regard to immediate return on investment. Experience from the past amply documents the long-term benefits. Such idealistic goals are not without practical consequences. A higher priority for fundamental science will naturally improve the level of education. Young people with normal curiosity will be encouraged to take science more seriously. The pool of people prepared to enter a technologically dominated society will be enlarged.

Even in a nation that places a high priority on fundamental science, a project on the scale of the SSC cannot proceed without scrutiny. Aside from economic factors, the proponents of the SSC should be able to convince scientific colleagues in other disciplines of the intellectual value of the project and thereby gain their support. Moreover, we must convince our elected representatives of the value of the project in these general terms. We are probing the most fundamental building blocks of matter and the nature of the interactions among them. We have already made enormous progress and are proposing to build this large new machine because we are confident that we will learn a great deal more. The technology to build the SSC exists and has been demonstrated to work effectively.

The size of the project—$4 billion spent over seven years of construction—is not large on the scale of government expenditures. However, because of its lack of immediate economic benefit, it is inconceivable that it would be built without government support. It has been suggested that the SSC could be built by international collaboration with Western Europe, Japan, or the Soviet Union.

Although these suggestions have some merit, in practice long delays will be required before such a collaboration can be realized. At present, both Western Europe and the Soviet Union have commitments to build new accelerators complementary to the SSC. An international agreement to establish an intercontinental laboratory and begin construction of an SSC could only occur well after 1990. If an intercontinental collaboration were to be formed, the site of the machine could be chosen outside the United States. In such a situation it may be difficult for the U.S. government to agree to pay for its share (about 50 percent) of the facility. Significant international contributions to the SSC, especially in the intellectual resources of people, will occur if the United States decides to proceed with the project on its own.

Consideration of international support is very important to scientific colleagues in other fields. While they can be convinced of the intellectual value of the SSC, they are concerned that funding by the United States alone will have an adverse impact on their own fields. In the past, as the support of particle physics has grown or receded significantly, there has been no evidence that other scientific fields have suffered, or profited. The principal criterion for support of any field of science has been its intellectual vitality.

Many critics ask how one can be sure that this new instrument will lead to new fundamental knowledge. As with any new accelerator of higher energy, there are no guarantees. Nonetheless, the single most important parameter responsible for the enormous progress in particle physics has been the energy of the accelerator. The pace of discovery has been a consequence of the steady increase in the energy of particle collisions provided by the accelerator. While previous accelerators have provided answers to the scientific questions which they were specifically designed to address, the most important discoveries have been those that were completely unanticipated. If we wish ultimately to understand the properties of the fundamental building blocks of nature, the SSC will have to be built. □

IP384 AS

States Spend Millions in Stiff Competition to Provide Site for Proposed Supercollider

$4.4-billion, 52-mile circular accelerator would be most expensive federal science project ever

By KIM McDONALD

WASHINGTON

Prodded by leaders of business and higher education, about two dozen states have declared their intention to enter the race to win the largest and most expensive federal science project ever proposed—a $4.4-billion, 52-mile circular particle accelerator known as the Superconducting Supercollider.

With promises of creating as many as 4,500 new jobs, attracting new high-technology ventures, and bringing in billions of dollars in revenues, the supercollider is considered a major plum by many state legislatures and governors, who are convinced they can win the political battle for it.

The race officially began last week, when the Energy Department issued a formal invitation for bids. But in many respects the competition was already well under way.

Half a dozen states have spent a year or more working on their proposals, and many more have been lured into risking large sums of money just to stay in the running.

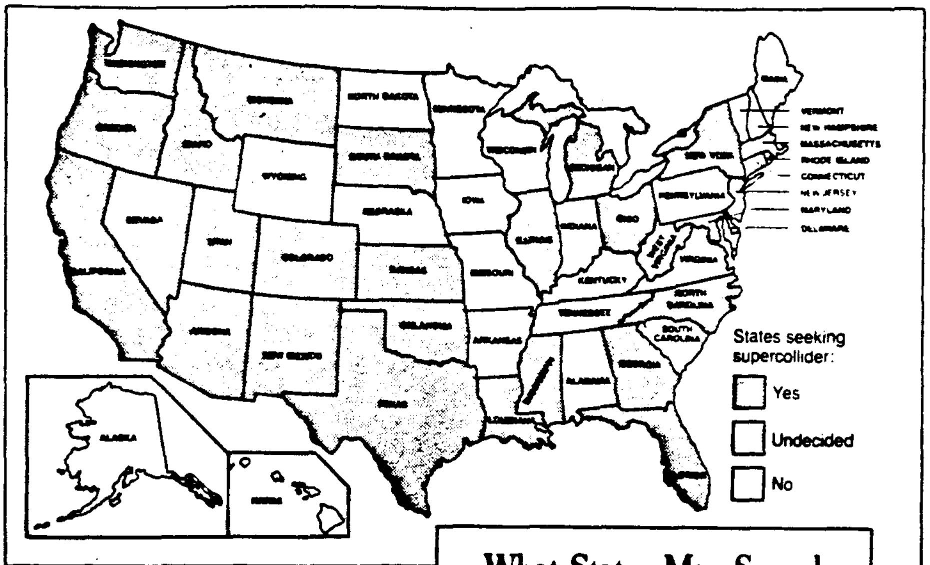
"A lot of states are going to end up with egg on their faces when this is over," said George Ormiston, associate director of Nevada's commission on economic development, who is developing his state's proposal. "Only one state is going to end up with the supercollider."

14 Decide Against Direct Bids

According to a state-by-state survey by *The Chronicle*, at least a dozen states are gearing up to spend millions of dollars for geological surveys, environmental reviews, political lobbying efforts, and other services that are considered necessary for a successful bid.

As many as 13 states, concerned about the cost of entering the competition and the risk that Congress may never approve the supercollider because of its high price tag, remain on the sidelines, undecided over whether to throw their hats into the ring.

Fourteen states have decided against bidding directly for the project, but many of them, the survey found, are discussing agreements that would allow them to enter the race through regional coalitions or by lending their political or financial support to another state's proposal.



"This is a competition that is unrivaled in the history of our country," said Christopher Coburn, science-and-technology adviser to the Governor of Ohio. "The s.s.c. is a prize that goes beyond money, new jobs, and economic revival. The state that gets this will become the centerpiece of the commitment of the United States to improving its scientific and technical competitiveness into the next century."

With 10,000 superconducting magnets accelerating matter to nearly the speed of light, the supercollider would be 20 times more powerful than the largest particle accelerator in existence—the Tevatron Collider at the Fermi National Accelerator Laboratory in Batavia, Ill.

Beams of protons would travel in opposite directions around the supercollider's 52-mile oval tunnel, then collide in gigantic explosions out of which massive particles are expected to emerge, carrying secrets of the universe.

High-energy physicists say the supercollider will not only assure U.S. leadership in their frontier scientific field, but also produce technological spinoffs that will improve the country's economic competitiveness in world markets.

To politicians, however, particularly those from economically depressed regions of the country, the main attractions are the thousands of jobs and billions of dollars that the supercollider will generate.

A study done for California's s.s.c. task force by the graduate management school at the University of California at Los Angeles estimated that the winning state would reap 177,000 permanent jobs and $8-billion from 1988 to the year 2000.

Governors and lieutenant governors of the leading contenders in the supercollider competition view the project as so impor-

What States May Spend to Win the Supercollider

Arizona	$2.5-million
California	$2.5-million
Colorado	$2-million
Florida	$1.6-million
Georgia	$25,000
Idaho	$400,000
Illinois	$4.5-million
Kansas	Amount not specified
Louisiana	Amount not specified
Michigan	$500,000
Mississippi	As much as $1-million
Montana	$1-million
Nevada	$100,000-$250,000
New Mexico	$850,000
New York	$1.5-million
North Carolina	$1.15-million
Ohio	$2.5-million
Oklahoma	Amount not specified
Oregon	$750,000 to $1-million
South Dakota	More than $1-million
Texas	More than $1-million
Utah	$1-million
Washington	$450,000

SOURCE: CHRONICLE SURVEY

The Chronicle of Higher Education, April 8, 1987, pp.4,5,6

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tant that many of them will travel to Washington this week to plead for Congressional approval at a series of hearings scheduled in the Senate and House of Representatives.

4 States Thought to Be in Lead

California, Colorado, Illinois, and Texas, which have been developing their proposals for several years in anticipation that President Reagan would give the supercollider his blessing, are considered to be the early leaders in the competition.

Other states that have officially announced plans to send proposals to the Department of Energy, which will manage the supercollider and make the final decision on its location, are Arizona, Florida, Georgia, Idaho, Kansas, Louisiana, Michigan, Mississippi, Montana, Nevada, New Mexico, New York, North Carolina, Ohio, Oklahoma, Oregon, South Dakota, Utah, and Washington.

In announcing Mr. Reagan's decision in February to complete the supercollider by 1996, Energy Secretary John S. Herrington noted that the process for the selection of the site by 1989 was "designed to be fair, equitable to all parties—absolutely open and above board."

States planning to submit bids, he said, would have to demonstrate that their proposed site met the necessary geological, climate, seismic-safety, and other criteria that are necessary for the construction and operation of the supercollider. The criteria were outlined in a 77-page invitation sent to prospective applicants last week by the Energy Department's Office of Energy Research.

Bids that meet those qualifications would then be reviewed by a committee of the National Academies of Science and Engineering. The panel would recommend the best-qualified sites by December, and by January 1989, following an exhaustive environmental review of the Energy Department's preferred site, the Energy Secretary would select and announce the winner.

While Mr. Herrington denied that his timetable would provide an advantage to states that are well along in their proposals, some representatives of regions that have only recently entered the competition are expected to ask lawmakers at the Congressional hearings this week to put off the deadline, now set for August 3, to allow them time to develop competitive proposals.

Loss of Momentum Feared

"I don't see how you can put together a proposal that early," said one official working on his state's supercollider bid. "You've got to have time to get the drilling permits to survey all the potential sites."

Many proponents of the supercollider, however, worry that such a delay could destroy the momentum developing in Congress to approve the project. It may also allow Mr. Reagan's successor in the White House to reconsider the government's commitment to build the device. With some estimates placing the cost at \$6-billion to \$8-billion, a number of lawmakers have already expressed concern about whether the country can afford to begin construction.

Hoping to counter such opposition, governors, university presidents, business leaders, Congressmen, and scientists are expected to try to persuade subcommittees of the House Science, Space, and Technology Committee and the Senate Energy and Natural Resources Committee in this week's hearings that the new accelerator is well worth the cost.

C. William Fischer, vice-president for budget and finance at the University of Colorado, said a group of Western state representatives meeting in Boulder several weeks ago had agreed to work together to demonstrate at the hearings that the supercollider was necessary to advance the country's scientific leadership and technological competitiveness.

Advisers Meeting this Week

"We quickly came to the conclusion that you can't have a foot race without a prize," he said.

A group of governors' science-and-technology advisers meeting in Washington this week to discuss the supercollider's site-selection process may also try to persuade Congress to approve the project.

In the hope that one of them will become the beneficiary of the prize, representatives of the Western states will meet again at the University of Utah in the first week in May to discuss the possible formation of a coalition that would throw their collective political support to any member of their group that reaches the finals.

"If it's located in the high-plains region," said Mr. Fischer, "the benefits would flow to more than one state."

Although Mr. Herrington said his selection process would not favor states that wage the most visible or expensive political campaigns, state and university officials acknowledge that politics will play a major role in the selection.

Most of the leading contenders have obtained the support of powerful political figures and the services of Washington lobbyists who are being paid as much as \$300,000 a year to represent their clients, according to several sources.

California, Colorado, Illinois, and Texas are among the states that reportedly have already signed high-priced lobbyists, while Ohio is among those now negotiating contracts with Washington firms. Lobbyists see the high-stakes competition for the supercollider as a lucrative business and are drumming up as much work as they can.

"We're being deluged with letters and phone calls," said Richard Tremblay, S.S.C. coordinator for Idaho's Department of Commerce.

Powerful political figures are also being asked to take charge of supercollider commissions, task forces, and coalitions in each state.

California's effort is headed by Clair Burgener, an ex-Congressman and former state Republican chairman, while Arizona's is being managed by Sam Steiger, a former Congressman who is a special assistant to the governor.

The first political battle among competitors could start this week. At issue is the Energy Department's decision to favor proposals that offer to reduce the federal government's cost in building the supercollider.

While each state must be prepared to provide 16,000 acres of land for the supercollider at no cost, some plan to "sweeten" their proposals with offers of free electricity, water, labor, outright cash, and other inducements to gain an advantage over their competitors.

"What we can offer is only limited by our creativity," said Colleen Murphy, director of the Colorado S.S.C. Project.

Concerns of Smaller States

Colorado, like many other states, is putting together an "incentive task force" just for that purpose, Ms. Murphy said, and some of the incentives "could include endowed chairs, multipurpose buildings, and tuition breaks for families."

Representatives of smaller states

and financially strapped regions, however, say consideration of those incentives would be unfair. Some may ask Congress this week to change that part of the selection process, arguing that it would provide an insurmountable advantage to larger and more economically powerful regions.

"A lot of people are buzzing about this," said one state official who asked not to be named. "Why have the states fight amongst themselves to pick up the tab, if this is a national priority? The next time a military base is proposed, will the states have to come up with the money to buy an F-14?"

Fears of a Bidding War

Most proponents of the supercollider, however, believe that some cost-sharing is needed to make the huge federal contribution palatable to Congress. But those planning to submit proposals are worried that giving a lot of weight to sweeteners could lead to an all-out bidding war, with the prize going not to the most qualified, but to the highest spender.

Whatever deals are cut this summer when the states submit their proposals, the process is expected to look more like a high-stakes poker game than a public auction. Many state officials have already anted up millions of dollars for their proposals and gathered pledges of support from state legislatures and business leaders to raise their wagers should they reach the final round. Throughout the process, they are generally playing their cards close to their chests.

Louisiana and a number of other states bidding for the supercollider, for instance, refuse to disclose publicly any specifics of their proposals, contending that the information could be used by their competitors.

"We would lose our competitive advantage," argued Kay Jackson, Louisiana's secretary of commerce, who is drafting her state's proposal.

But while information about sweeteners remains closely guarded, state officials are generally more than willing to extol the virtues of the sites they have selected.

Illinois has picked an area near Batavia so that the Fermilab accelerator could serve as the proton "injector" to the supercollider, a move officials there estimated would save the federal government $500-million in construction costs.

Not only is the site adjacent to a large concentration of accelerator scientists and particle physicists, but it is flat, free of seismic hazards, close to a major international airport and a number of leading research institutions, and well supplied with electrical power.

California, where the main drawback is earthquakes, has selected a seismically safe rural area near Stockton that offers a moderate year-round climate and is close to physics research centers in the San Francisco Bay area and a large number of high-technology companies in Silicon Valley.

"It has all of the things to make this thing go, all of the amenities," said Jesse D. Shaw, a University of California administrator.

Idaho's Cheap Electricity

Idaho, meanwhile, has picked a site near the Idaho National Engineering Laboratory that would allow the state to take advantage of cheap electricity, federal land into which tunnels can be dug at little cost, and 10,000 technicians and scientists who now live there.

"If we can save half a billion dollars or more on construction and $50-million or more annually in operation expenses, we'd have a good shot at it," said Mr. Tremblay, Idaho's s.s.c. coordinator.

Like Idaho, Western states generally regard their pleasant climates and large areas of federal land as their main advantages, while Southern and Midwestern states extol their cheap land, lower living costs, and the large numbers of unemployed workers who are eager to take jobs.

Some states are even pitching the message about the cultural, educational, and recreational benefits of their region in slick pamphlets that resemble travel brochures.

"This is a place where physicists will want to spend their summers," said Joel Cohen, director of policy and research for the Colorado Governor's office.

'God Made Ohio for the SSC'

"People have observed," said Mr. Coburn of Ohio, "that God made Ohio for the s.s.c."

Although Southern, Western, and Midwestern states are scouring their landscapes for potential supercollider sites, New England states are generally uninterested in the competition.

Massachusetts is investigating several potential sites and Gov. John H. Sununu of New Hampshire has held meetings recently with representatives of several New England states to try to persuade them to submit a regional proposal. But most New England officials are not interested in becoming involved in any regional effort.

Other joint proposals may come from North Carolina, South Carolina, Virginia, and West Virginia; Idaho, Oregon, and Washington; Nebraska, North Dakota, and South Dakota; and New York, New Jersey, and Canada (for a site in New York near the Canadian border).

While Energy Department officials will allow more than one proposal from any state, some states are having trouble deciding which of their numerous potential sites to back.

Montana is examining seven sites, and Texas, which will submit proposals for at least two, has nine localities vying for the state's political and economic support.

"Our big objective now is to get on that state proposal," said Charles Bernhard, director of economic development for the Odessa, Tex., chamber of commerce.

Mr. Bernhard noted that winning the supercollider was so important to the four cities in his economically depressed oil region that each had paid $92,000 to prepare a proposal for the Governor's consideration.

Texas Confident

"We can build a site here cheaper than anywhere else in the country," he said. "You can buy the whole dang 11,000 acres here for what you would pay for a city block in Dallas. Because of the oil problems in the state, we also have a lot of machine-shop technicians and oil drillers that are sitting idle here. That's another very strong factor we have going for us here, and it will make the operating costs less expensive."

Texas is so hungry for the supercollider that the Legislature is considering a bill that would authorize $500-million in bonds to use as a sweetener in luring the Energy Department into selecting one of its sites.

"There aren't very many big federal projects that are going on these days," said Dillard S. Hammett, energy adviser to Gov. William P. Clements, Jr. The willingness of the state to throw into its proposals whatever incentives it takes to win the supercollider, he said, is unmatched anywhere else.

"Texas," Mr. Hammett said confidently, "is going to win."

Some other states are also talking pretty tough.

"We'll probably make as many concessions as any other state and probably a lot more," said Mr. Steiger of Arizona. "We are very, very serious about this."

IP384 AS

New York Times February 3, 1987, pp.C1,C4

Atom-Smashing Now and in the Future: A New Era Begins

In 1990's: 52-mile colossus should take lead into next century.

By WILLIAM J. BROAD

A new era of spending and experimentation in particle physics is on the horizon with the start of beam collisions at Fermilab's four-mile Tevatron accelerator near Chicago and the announcement last week of Presidential approval for a monumental 52-mile atom smasher costing $4 billion to $6 billion.

By hurling subatomic particles to greater energies than ever before and smashing them together, the new machines will address fundamental questions about matter and energy, space and time, the beginning and end of the universe.

For a while it looked as though the Tevatron might come to symbolize the end of the line instead of the beginning of a new era. As the cost and size of atom smashers soared in the 1980's, some experts came to believe that the quest for new particles had grown too expensive to pursue any further.

But gloom has turned to glee for many physicists with the announcement of the Presidential go-ahead for the Superconducting Super Collider, or S.S.C. If Congress goes along, the colossus, planned for the 1990's, is to boost proton beams to energies 20 times higher than ever before achieved on earth, opening an era of discovery that particle physicists hope will stretch well into the next century.

"We're at a critical juncture," Dr. David Schramm, a physicist at the University of Chicago who backs the project, said in an interview. "The Tevatron and the current generation of accelerators can only go so far. We're at a great threshold in physics and need the S.S.C. to cross it."

Physicists say the new frontier may hold answers to some of the deepest questions ever posed by scientists. The finding of elusive particles, for instance, may show whether the four basic forces of nature (strong, weak, electromagetic and gravitational) can be united in a Grand Unified Theory — a set of equations that, as one physicist put it, fit neatly on a T-shirt. Einstein sought such a theory in his final years, and researchers today say they see hints of one on the horizon.

Indeed, theoretical physicists, drawing on recent findings, have invented dozens of new ways to explain the workings of the cosmos, their theories bearing such odd names as Technicolor, Supersymmetry and Compositeness. There's just one problem. No one knows which is correct — a plight physicists say might be solved by the super collider's discoveries.

"Then again, we may be in for a great surprise," said Dr. Leon M. Lederman, head of the Fermi National Accelerator Laboratory who is a strong advocate of the super collider. "A totally new conception of reality may emerge."

Skeptics say the great surprise may be that the machine finds little, and certainly not enough to warrant its great expense.

Since their invention a half century ago, atom smashers have undergone a revolution in size and power. Today they are usually vast tunnels in which beams of particles are locked in circular paths by powerful magnets, whirled in opposite directions to ever higher energies, and are collided head on in a burst of energy. The S.S.C. is to be the biggest machine of all.

As energies of collision have increased over the years, so have the number of particles discovered amid the debris. To date, physicists have found nearly 100 kinds of subatomic particles. Many of these, especially quarks and leptons, are "building blocks" that combine to make up the larger and more familiar particles such as protons, neutrons and whole atoms. But atom smashers have also revealed a shadowy class of particles that transmit forces at the heart of the atom.

The greatest such discovery occurred in the early 1980's at CERN, the European Laboratory for Particle Physics, near Geneva. Theorists had predicted that at extremely high energies, two of the four basic forces in nature, the weak nuclear force and electromagnetism, wouldunite into one entity known as the "electroweak" force, advancing the quest for grand unification.

All forces in nature are believed to be transmitted, or "vectored," by particles. The photon, for has been shown to mediate electromagnetism, while the gluon the strong force. So,

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too, theorists predicted that an electroweak force would be mediated by an electroweak particle. The discovery at CERN, in collisions of a monstrous new atom smasher, confirmed the prediction, with evidence of a particle known as the intermediate vector boson.

Such unifications are today at the cutting edge of particle physics. And the superconducting colossus, like no previous machine, is viewed as the best way to see whether all the forces of nature are payoffs in the same way that the 19th century mathematical unification of electricity and magnetism laid the foundation for today's electronic products, including radio and television.

Dr. Schramm of the University of Chicago said the huge accelerator might find particles to prove the seductive new theory of Supersymmetry. In one deft stroke, this theory would unite those twin pillars of modern science, quantum physics, which describes the workings of the atom, and relativity theory, which describes gravity and the workings of the cosmos.

Further, the massive particles predicted by Supersymmetry, with such bizarre names as photinos, squarks, gluinos, zinos and winos, might explain one of the great riddles of astrophysics: missing mass. As astronomers have charted the powerful gravitational pulls evident in galaxies, they have discovered that more than 90 percent of the mass needed to explain such movements is missing. No one currently knows the nature of such "dark" matter. Moreover, its discovery would help scientists calculate whether the universe is to expand forever, or have enough mass to start to contract.

So, too, the super collider would help solve some of the riddles surrounding the birth of the universe because the enormous energies of particle collision would resemble those of the primordial "Big Bang" 10 billion to 20 billion years ago.

Dr. George F. Chapline Jr., a physicist at the Lawrence Livermore National Laboratory in California, said, borrowing from space launching terminology, "You could explore the physics back much closer to T equals zero." One finding he and other physicists anticipate from the super collider is that the known universe of four dimensions (three spacial and one temporal) might have an additional six or seven hidden dimensions.

Finally, the super collider, if the Tevatron accelerator fails to do so first, may also find evidence for a massive particle known as the Higgs Boson. This particle would help explain one of the most fundamental mysteries of physics — how particles get their masses and why the photon has no mass at all.

> 'Then again, we may be in for a great surprise.'
> Leon Lederman

In general, physicists hope the super collider will simplify the baffling complexity that has been found in the subatomic world. Dr. Lederman said the growing particle "zoo" is evidence of a failure of the "simplicity that has proved to be so powerful a guide in the history of high-energy physics." A deeper exploration of matter, he said, may simplify things again, by revealing a relative few primordial objects behind the apparent complexity.

Critics of the super collider, while acknowledging its potential for discovery, say the price tag is so high that it will sap the Federal budget other fields of science. Dr. Arno Penzias, a Nobel laureate at AT&T Bell Laboratories, has written, "The super collider's capital cost will clearly squeeze capital expenditures for other sciences." The impact may be especially strong, he said, on small but important physics teams at universities around the nation.

Other critics say the super collider's potential for discovery does not warrant the huge cost. "These devices are becoming so expensive, and what they're trying to find is so obscure, that we may be at the point where scientists can no longer justify the cost," said John E. Pike, associate directorof the Federation of American Scientists, a private policy evaluation group in Washington.

The price tag of $4 billion to $6 billion rivals the $5 billion spent so far on President Reagan's hotly debated antimissile research program. For next year, in the biggest expansion yet of the "Star Wars" program, the Administration is asking Congress for an additional $5.9 billion.

Dr. Henry W. Kendall, a physicist at the Massachusetts Institute of Technology and chairman of the Union of Concerned Scientists, which opposes Star Wars, criticized the antimissile effort as threatening the super collider. "Huge overblown projects like Star Wars have a deleterious effect on the remainder of the budget structure," he said.

The S.S.C., he added, was a good thing to pursue. "American science and education have been suffering really badly over a long time and many people in the academic community sense this as a bellwether of revitalization," he said.

Advocates of the super collider warn that its rejection could forfeit the international race in particle physics to European or Russian rivals who could then win an anticipated treasure of scientific discoveries, industrial spinoffs and Nobel prizes.

Physicists also say the vast machine will have educational spinoffs as it becomes a lure for the best scientific brains in the world. "Our young folks will be able to mingle with these people," said Dr. Maury Tigner, director of the Super Collider design group, which is situated at the Lawrence Berkeley Laboratory of the University of California.

For the discipline of physics as a whole, Dr. Lederman of Fermilab warned that rejection of the super collider would mean scientists would "drown in speculative literature with only distant vistas of confronting speculation with fact."

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Recent discoveries stir debate over Superconducting Super Collider

The waves of superconductivity discoveries announced during recent weeks have stirred considerable debate over whether the government should proceed with its present plans to build the newest high-energy particle accelerator, the proposed $6 billion to $8 billion Superconducting Super Collider (SSC).

Last January President Reagan gave approval to the Department of Energy to fund the big facility, coveted by several states as an economic bonanza. DOE, after an initial screening process done by a National Academy of Sciences panel, will choose the final site a few weeks after the 1988 election. Present scheduling calls for completion of the project in 1996.

But a large segment of the scientific community, mostly physicists, sees the SSC as such an intensively expensive project that DOE will be forced to sacrifice support for other areas of research. So this group is using the new superconductivity findings as ammunition in arguments to slow down the project. They believe the new discoveries could lead to a cheaper, smaller, and more powerful SSC than the one being planned.

Their arguments revolve around the design of the enormously powerful magnets. About 10,000 such superconducting magnets will precisely steer two parallel beams of protons streaming in opposite directions around the 53-mile-long, 10-foot-wide circular tunnel. Tremendous currents flowing through the superconducting wires will produce the magnetic forces needed to control the beams.

The wires, made of niobium-titanium filaments, will be twisted, wound, and braided into cables. "More superconducting material will be used in these magnets," says Westinghouse Corp.'s director of research John K. Hulm, "than for all superconducting magnets built in history." Magnet costs, he says, will run to fully 25% of the total cost of the SSC. Westinghouse was one of the pioneers in superconductivity research.

But James A. Krumhansl, professor of physics at Cornell University, is one scientist who thinks DOE should rethink its scheduling in light of the new discoveries. Krumhansl believes many areas of science will suffer funding shortages if DOE continues to commit itself to the present materials at the current fast pace of SSC development. "With these new materials and the tremendous competition," he says, "there is now even more reason to re-establish vigorous program support immediately at the individual project and graduate level, especially in condensed matter physics, theoretical physics, inorganic chemistry, and ceramics."

The American Association for the Advancement of Science also opposes present SSC scheduling policy. And AAAS president Sheila E. Widnall in testimony last month before the House Science, Space & Technology Committee, urged that Congress look into "stretching out" the SSC's schedule.

Westinghouse's Hulm agrees that with the new higher-temperature materials "considerable savings" could be achieved in the inital cost and the operating expense of refrigerators for the SSC. But he says it would be "irresponsible to stop the engineering development of the existing niobium-titanium magnet coil material simply because of the recent superconductor discoveries.

The reason, he says, is that too little is known about those new materials. They are "too brittle," like the niobium-tin alloy that was previously considered for superconducting cyclotrons, and could present mechanical difficulties.

"In addition," he says, "it has been widely observed in preliminary experiments that the current-carrying capacity of the new superconductors is between 10 and 100 times less than that of the niobium-titanium alloys." The niobium-titanium material at 4.5 to 9 K carries 10^5 amp per sq cm. In the new materials, currents flow at only a few hundred amperes per square centimeter.

Thus, Hulm thinks research on the new materials for magnetic uses would take too long and inordinately delay the SSC. He says large numbers of prototype magnets would be required to achieve reliable performance before designers could even think of building the 10,000 units needed for the SSC. But he urges further research on them because "the knowledge gained will almost certainly be applicable to other types of magnets if these are selected later."

A DOE official, speaking for background, says niobium-tin is a proven material, since it already is used in magnet coils on the Fermi Laboratory accelerator in Illinois. "For years," he says, "we've been hoping to replace niobium-titanium with higher-temperature materials. . . . But we don't think there will be anything to replace the current materials for 10 to 20 years."

Wil Lepkowski, Washington

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Daniel S. Greenberg

$6 Billion Toy

The Super Collider would smash the rest of scientific research.

It's no contest when the colossal comes up against the merely sensible on the political playing fields of Washington. The latest example is the White House's decision to build a goliath atom smasher, the Superconducting Super Collider.

Fifty-two miles in circumference, $6 billion to build and $500 million a year to run, it would dwarf existing facilities in this field. Along the way, however, it would draw scarce money and genius to esoteric research remote from down-to-earth problems, particularly the nation's mounting industrial woes. That's why the proposed atom smasher has aroused several respected scientists into rare departures from the live-and-let-rule protocol that generally governs the politics of research money.

"The Super Collider's capital cost will clearly squeeze capital expenditures for other sciences," Arno Penzias, a Nobel laureate in physics at AT&T Bell Laboratories, has warned, adding that he doubts the potential for new knowledge is worth the cost. And Roland R. Schmitt, chief scientist of General Electric, has critically asked, "Do you fix the multi-billion-dollar health of university research and education, or do you build a Superconducting Super Collider?" The answer from Schmitt, who also chairs the board of the National Science Foundation, the principal federal agency for university-based science: "I think the top priority is getting the academic research and education base fixed first."

Why, given these sober doubts—not to mention budget-pinching efforts on cancer and heart research—has the tight-fisted Reagan White House committed itself to this venture? And why has it done so in the absence of foreign cost-sharing agreements that Congress has been urging to relieve the strain on American research budgets?

For answers, it's necessary to turn to the mystique of atom-smashing, or high-energy, physics—an elite discipline that for 50 years has employed bigger and costlier machines to probe the basic building blocks of matter. The field is intellectually exciting, it regularly attracts the very brightest of scientific recruits, and its superstars are heavily represented in the ranks of Nobel laureates.

Thus, scientific glory and national prestige have long been associated with high-energy physics, which is why Western Europe, the Soviet Union and Japan operate big accelerators, though none on the scale of the proposed $6 billion machine. Close collaboration among scientists from different nations, including the Soviet Union, adds an agreeable dimension to the research. And unlike most other branches of the physical sciences, atom smashing is so remote from military applications that all of its work is openly conducted and the results are freely published.

Unfortunately, there's a downside to this grand venture in cosmopolitan science, which is that by its very nature it reveals more and more about less and less—so much so, in fact, that industry spends not a penny on atom smashing, since there's no way to make it back. The research is, of course, fascinating. But, in these hard times, it is regrettably not very useful—certainly not by the measure of value for money.

Some technological spinoffs have ensued from accelerator designs and operations, and the research has probably had some stimulating effect on other fields of science. But only a perversion of scientific and social priorities could account for the United States' going it alone on this monumental undertaking at a time when university laboratories are pleading for more money and health-research agencies are turning down over half the grant applications deemed worthy of support.

Since all the world will be able to share in results of research on the super machine, at least some of the world should share in the costs. Eager for funds to build what will be a wondrous plaything for a relative handful of scientists, leaders of the project have advised Congress that other countries may eventually join in financially. But some congressmen have their doubts about how diligently American scientific leaders have pursued foreign partnerships that would dilute their control over the machine. So far, no European nation has pledged anything for the project. Japan has expressed interest but has not offered any money. And there's a wariness about collaboration with the Soviets, even with Mikhail Gorbachev's call for closer scientific relations.

American physicists complain that internationally run research facilities tend to be bureaucratically cumbersome. Often they are. But the $6 billion atom smasher is in the category of science that's too important to be left to the scientists. If they want this fascinating toy, let them round up their foreign friends to help pay for it.

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