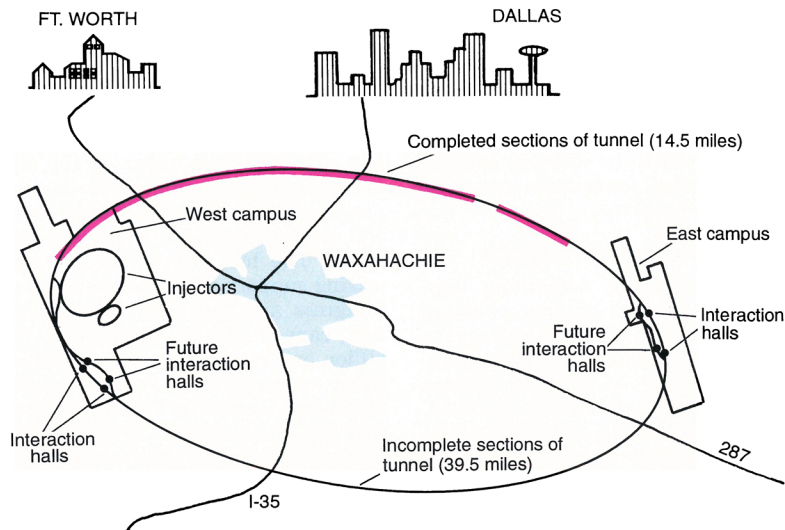


AFTER AGONIZING DEATH IN THE FAMILY, PARTICLE PHYSICS FACES GRIM FUTURE

"Never send to know for whom the bell tolls," wrote John Donne, the 17th century poet and dean of London's St. Paul's Cathedral, "it tolls for thee." For US high-energy physicists the peals sounded discordant when Congress rang the death knell last October for the giant Superconducting Super Collider (PHYSICS TODAY, November, page 77). The cancellation of the SSC came as a stunning blow to the particle physics community. Wolfgang K. H. Panofsky, director emeritus of SLAC, calls Congress's action "a senseless killing." To Leon Lederman, former director of Fermilab and now a professor at the Illinois Institute of Technology, it's "a tragedy for the field and for everyone in it. The government decided, in its wisdom, that high-energy physics has no future in the US." Others, like William Happer, the Princeton University physicist who recently headed the Energy Department's Office of Energy Research, argue that the SSC's debacle is evidence that the nation's commitment to the pursuit of pure knowledge and basic understanding of nature is over.

The SSC has been the target of contentious debate in Congress and the scientific community almost from the afternoon in January 1987 when President Reagan endorsed the project with the admonition "throw deep" (PHYSICS TODAY, March 1987, page 47). If it were completed the accelerator would have been the most powerful of a series of particle accelerators, going back to the 1930s, in quest of understanding the structure of matter. Each of the SSC's counter-rotating beams of protons would have zipped around an elliptical ring 54 miles in circumference at 20 TeV and collided at 40 TeV in the center of mass system. At its death the project had cost the US government \$1.6 billion and the state of Texas another \$409 million. For most members of Congress, the prospect that the SSC would reach a total cost of at least



\$11 billion was the main reason for turning it off. At that price it would have been the world's most expensive purely scientific apparatus.

The remains of the project around the picturesquely gingerbread town of Waxahachie in eastern Texas now consist of completed sections of the tunnel or about 20% of the underground part of the project (see diagram), portions of the linac and low-energy booster complex, a few drab brown buildings constructed for magnet tests, cryogenic work and data processing, and prototypes of the 10 000 dipole and quadrupole magnets that would have been necessary to gently bend the beams of protons around the elliptical ring. In addition, the SSC headquarters, occupying rented quarters in Dallas, contains office furniture, file cabinets, a physics library and about 1300 Apple personal computers for the 2100 scientists, engineers, technicians and staff. (Additional computers are at the site.) Since the SSC's demise last October, virtually every magnet, injector component and pc has been legally "encumbered" by the Texas attorney general, awaiting an "or-

derly termination," the words Congress used in directing how to spend the \$640 million it allocated for fiscal 1994 to guarantee an "optimal return" on the accumulated assets.

The saga of the SSC is a cautionary tale for all big science projects in the US. Its ultimate fate might have been different in the period when high-energy physics was preeminent. The field had its origins in investigations of cosmic rays, developments in quantum field theory and extensions of nuclear physics, particularly during the wartime Manhattan Project. In producing the first nuclear bombs, the Manhattan Project became the quintessential model for big science. "Why use lead when gold will do," Enrico Fermi once quipped in asking for research equipment at Los Alamos. So, when the Soviet Union and Europe began building particle accelerators after World War II, US presidents and members of Congress recognized the necessity of constructing more powerful machines in the US to keep ahead of other countries in maintaining the nation's military and scientific leadership.

In Washington, particle physicists

were considered the scientific elite. Of the 55 Nobel Prizes for physics since 1935, 23 were awarded in particle physics, with 16 of those going to Americans. Out of all proportion to their number in the field, high-energy physicists were appointed to influential advisory positions at the White House and Defense Department. Congress consulted high-energy physicists before legislating on nuclear arms, nuclear power and many research programs at universities and national laboratories. Few were surprised, to be sure, when successive Presidents and Congresses approved ever larger and higher priced accelerators for construction in California, New York, Illinois and Texas—states with massive political and economic clout. Under the rubric of “him that has, gets,” the new machines proved to be a wellspring for jobs, education, taxes and—not to be sneezed at—prestige.

A symbol of preeminence

But by the 1980s something happened. Politicians became aware of the importance of biotechnology to human health and global economics. The dominance of particle physics waned. Unfortunately for the field, this occurred at the same time that accelerators and the particle detectors accompanying them became much more complicated and expensive. What's more, with the end of the cold war and the complete collapse of the Soviet Union, the military implications that helped drive high-energy physics no longer seemed so significant. It makes sense, some Washington politicians have now concluded, that projects of that sort—as well as high-cost nondefense space programs—should be undertaken and operated as multinational collaborations. So, having once been a symbol of national preeminence, particle physics is now seen as a symbol of international partnership.

During the cold war, one of the earliest efforts to internationalize high-energy physics was the Rochester Conference, initiated in 1950 by Robert Marshak of the University of Rochester, which attracted scientists from the Soviet bloc and from NATO countries. (See the article by Marshak in *PHYSICSTODAY*, January 1990, page 35.) While there were numerous conferences and exchanges for individual scientists from nations at odds throughout the cold war, the first wholly megascience collaboration was CERN, established in 1953, in a tunnel along Switzerland's border with France, not only to stanch the brain drain from Europe to the

US but to prevent Europe from falling irreversibly behind the US in high-energy physics.

While as many as 20% of the physicists working at CERN are Americans, the accelerators there are supported by 15 European governments (including most recently the old Warsaw Pact countries of Poland, Hungary and the Czech Republic), the amount of their contributions based on the GNP of each. By contrast, the SSC, in the beginning, wasn't meant to be designed, built or paid for by nations other than the US. But as its sticker price escalated from \$4.4 billion, the estimate at the time of Reagan's OK, to \$5.9 billion two years later and then to \$8.3 billion in another two years, some members of Congress agitated for foreign contributors. In 1990, before virtually any work had begun at the site around Waxahachie, the House passed a bill to set specific milestones and requirements for the super collider. The bill, which had the surprising support of SSC proponents in Congress and the Bush Administration, capped Federal spending at \$5 billion and required foreign contributions to cover 20% of the costs. Meantime, voters in Texas approved two SSC bond issues amounting to \$500 million each. But attempts to obtain foreign contributions to the project failed dismally. A few nations offered “in-kind” contributions: Russia actually delivered beam magnets and storage inductors for the low-energy booster and China and India sent quantities of raw materials and finished hardware.

Nevertheless, the Reagan and Bush Administrations always considered Japan, already a partner in NASA's space station, the best source of funds for the SSC because of its lopsided trade balance with the world and its efforts to put to rest US demands on trade barriers. But once again the timing was wrong. Japan encountered a series of political and economic upheavals at the time SSC scientists and DOE officials pitched their requests, and neither Reagan nor Bush directly asked their Japanese counterparts to support the SSC as a partner, possibly supplying components in lieu of cash.

Had Japan and other governments helped pay for the SSC, Congress might have considered the project affordable, claims the SSC's most prominent proponent on Capitol Hill, Senator J. Bennett Johnston, the Louisiana Democrat who is chairman of the Senate energy and water appropriations subcommittee. The irony in Johnston's position is that

he, like many in Congress and in the Reagan and Bush Administrations thought the US was rich enough to pay for the SSC on its own. They hadn't figured on the economic downturn and the clamor to reduce the budget deficit that became a key issue in the 1992 election campaign. Although Federal deficits of around \$300 billion are not unique in recent years, the 103rd Congress was particularly worried about it. “Overwhelmingly, many members needed a symbolic act of budget cutting,” says Steven Weinberg of the University of Texas at Austin, who visited dozens of legislators on behalf of the project. “The SSC was a project that could be cut because neither the Congress nor their constituents understood it or cared about it.”

Even among legislators who appreciated particle physics, \$11 billion seemed profligate in a period of fiscal restraint when Congress was debating how to reduce social programs that affected the poor and the elderly. Senator Dale Bumpers, an Arkansas Democrat who opposed the SSC from the start, asserts that high-energy physicists “just never accepted the reality of the Federal budget.” Happer acknowledges that the SSC's price tag “kept ratcheting up and we tested the limits of Congress's endurance. The SSC showed us just how far we could go.”

Significance to business

Throughout it all, Senator Johnston rejected attacks on the SSC and stressed the project's significance to science. He also had a political interest. General Dynamics was tooling up to produce dipole magnets in the senator's home state, at a huge factory in Hammond, Louisiana. In Texas, Westinghouse was working on dipole magnets in Round Rock, and another company in San Antonio was under contract to provide components for the medium-energy booster. Other states also had SSC agreements: Babcock and Wilcox was gearing up to produce quadrupole magnets in Virginia, for instance, and refrigeration systems were under development in Pennsylvania. While the SSC lab boasted that it had placed some 20 000 orders amounting to nearly \$800 million in 46 states and Puerto Rico, most of the deals were small and did little to convince legislators that their constituents would profit. Actual and aspiring contractors organized a lobbying group that called on Congress and conducted conferences to win the hearts and minds of the news media. SSC backers attempted to emphasize

the practical benefits, from jobs to supercomputing technology and even the application of particle beams for cancer treatment. This tactic backfired when it left the impression with some lawmakers that the project's key practical purpose was to cure cancer.

A dispiriting end

When the end came it was, as T.S. Eliot wrote in "The Waste Land," not with a bang but a whimper. Neither the high-energy physics community nor the politicians and business leaders from states and corporations that stood to benefit from building and operating the SSC could protect the project from assaults by a hard core of critics in Congress joined by more than two-thirds of the 114 rookie members of the House who were intent on cutting the budget deficits and reducing the Federal debt.

During weeks of acrimonious floor debates on the SSC in Congress, neither President Clinton nor Energy Secretary Hazel O'Leary came courting opponents or undecided members. Both sent letters to members extolling the project but didn't make phone calls, twist any arms or offer new concessions. The Texas delegation, which wielded immense power in Congress in the early days of the SSC, fought hard but could not restore its influence on lawmakers after the loss of House majority leader Jim Wright, Senate finance committee chairman Lloyd Bentsen and the occupant of the White House, George Bush. Senator Johnston remains disappointed, say sources close to him, that many of the country's high-energy physicists weren't engaged politically in the fight for the project.

In the wake of the SSC's debacle, questions have been asked about the rise and fall of the project and about the causes and consequences of its demise.

The feasibility of a multi-TeV proton-proton accelerator to reveal a qualitative new domain of physics was first discussed at workshops sponsored by the International Committee on Future Accelerators, meeting at Fermilab in 1978 and a year later at CERN. At those sessions and at the 1982 Snowmass Summer Study of the American Physical Society's Division of Particles and Fields a few visionaries proposed the SSC. It would be designed and built to produce an energy approaching the energy of the universe immediately after the Big Bang and would create a shower of particles that is most likely to answer questions left open by the Standard Model—including such

crucial puzzles as why the known particles come in a seemingly random assortment of masses and whether symmetry breaking will manifest itself in a particle called the Higgs boson, named after Oxford theorist Peter Higgs. At the time of the Snowmass meeting the very preliminary cost of such an accelerator was estimated between \$2 billion and \$3 billion.

Several events defined the Snowmass discussion: CERN's proton-antiproton collider had won the competition with US accelerators to discover the W and Z⁰ particles and to confirm the unification of weak and electromagnetic forces. The Europeans were starting construction of a large electron-positron collider at CERN and of an electron-proton collider at DESY in Hamburg. US physicists were sure that their undisputed lead in high-energy physics had been surpassed. Some were already depressed that Isabelle, a low-energy but high-intensity proton collider, under construction at Brookhaven, was in technical trouble over its superconducting magnets. When Westinghouse declared that it could not provide magnets built to Brookhaven's specifications, adding to the considerable delay, many high-energy physicists regarded the project as too little too late.

But George Keyworth, then science adviser to President Reagan, suggested to members of DOE's High Energy Physics Advisory Panel that if they would recommend cancelling Isabelle, he would support its replacement by an order-of-magnitude more expensive machine, the SSC. The motivation for the Reagan Administration was that the accelerator would be a conspicuous way to reassert American scientific supremacy. HEPAP accepted Keyworth's offer unanimously but with some despondency over abandoning Isabelle, and in 1984 DOE named a central design group under the supervision of Universities Research Association, which was already managing Fermilab.

To lead the design team, URA picked Maury Tigner of Cornell, one of the country's most highly regarded accelerator builders. Tigner assembled an experienced group of physicists and engineers to work at the Lawrence Berkeley Laboratory and established collaborations with teams at Brookhaven and Fermilab to design and build prototype superconducting magnets that would meet the requirement of 6.8 tesla for the proposed mammoth machine. By 1986 Tigner's team had produced a design report and cost estimate, which pro-

vided the basis for Reagan's approval.

By the end of 1988, after an intense competition among 25 states proposing 43 different locations for the SSC, a sparsely populated cotton growing and cattle grazing region near Waxahachie, about 25 miles south of Dallas, was selected by DOE for the new national laboratory and accelerator. One of the principal contenders for the lab was Fermilab, which had a laboratory complex with a 1 TeV machine that would serve as an injector for the SSC. Another early entry in the race for the new ring was a site in upstate New York that would extend across the border with Canada. This proposal called for Canada to provide cheap electrical power to operate the accelerator. But DOE's director of the Office of Energy Research, Alvin W. Trivelpiece, ruled the cross-border proposal out of bounds because it would give the site an unfair advantage over the rest of the locations, which were entirely within a single state.

The ostensible reason for the choice of Texas was the terrain and the availability of 16 000 acres of relatively uninhabited prairie. But the decision was clouded by the need of the Reagan Administration to maintain solid political relations with Texas politicians in Congress. DOE announced the site the day after the election of George Bush, an adopted Texan, as President. Within days DOE also announced that the SSC would henceforth be known as the Ronald Reagan National Accelerator Laboratory, which wags instantly dubbed the "Gippertron."

'A whiff of pork'

Once the choice of Texas was made, other key members of Congress and several governors of states who had lost out came to oppose the machine and its projected cost, suggesting that the project had "a whiff of pork" about it. The dissenters also included some prominent scientists, including physicists like James Krumhansl of Cornell and Philip Anderson of Princeton and a feisty materials scientist, Rustum Roy of Pennsylvania State University. The criticism of academics was mainly over priorities: big science or bench science, crisis response or attention to long-term research, national preeminence versus international collaboration. Representative Sherwood Boehlert, a New York Republican, says he became a vocal opponent after Krumhansl, president of the American Physical Society in 1989, told him the value of the SSC was "highly over-

rated." The discord over the SSC became so heated that it motivated Frank Press, then president of the National Academy of Sciences, to use it as his theme for an unusually as-tringent address at the organization's 125th annual meeting in 1988. At a time when scientists should be celebrating their "dazzling progress in almost every field," said Press, "this sniping and carping . . . is disturbing and destructive." He argued that "our internal dissension and the mixed conflicting and self-serving advice emanating from our community are threatening our ability to inform wise policymaking." (PHYSICS TODAY, May 1988, page 69).

Scientific debates over particle accelerators are not new. In the 1960s such respected physicists as Eugene Wigner and Alvin Weinberg argued against building big accelerators as unwisely depriving other fields of money and manpower, with little practical return. In a controversial article in *Science* in 1961, Weinberg likened accelerators to the pyramids and cathedrals of earlier societies that "devoted too much of their talents to monuments which had nothing to do with the real issues of human well-being. . . . We must not allow ourselves, by shortsighted seeking after fragile monuments of big science, to be diverted from our real purpose, which is the enriching and broadening of human life."

"There is enough blame for the death of the project for many people to share," says Happer. Accusations of mismanagement eroded the confidence of many members of Congress that the project could be completed for even the upwardly revised budget or on the considerably stretched out schedule. Reports by the General Accounting Office, the investigative arm of Congress, and the DOE's own inspector general accused the department's project managers and URA's oversight officials of not maintaining accurate cost and schedule records. This created a sense that the project was not being handled well. In fact, the physicists at the SSC had been cut out of the administrative loop by a management group brought in by James D. Watkins, a retired admiral who was the DOE secretary during the active life of the SSC.

SSC as a procurement

When the Bush Administration took over in 1989, John Herrington, who had become one of the SSC's toughest defenders, gave way to Watkins, who was suspicious of academic scientists running any project. Watkins was accustomed to Navy procurement



THE DALLAS MORNING NEWS/CINDY YAMANAKA

SSC termination

discussions involve John Peoples, director of Fermilab, and lawyers representing the demands of Texas to recoup the state's monetary loss.

practices and to getting his way. He brought in Edward Siskin, a former vice president of Stone and Webster, a large construction company that built many power plants, over the objections of URA, which proposed to appoint Paul Reardon, an experienced accelerator engineer who had worked at Brookhaven, Fermilab and SAIC Inc, to be project manager. Watkins also assigned a local DOE project director, Joseph Cipriano, to report directly on the SSC's operations to the department's director of energy research as well as to the secretary himself. Serious problems of micromanagement and friction followed: Cipriano bypassed the SSC director, Roy Schwitters, a Harvard physicist who had been co-director of the team that built the Collider Detector Facility for Fermilab's Tevatron collider. Cipriano's office consisted of about 60 permanent staffers and 40 more on temporary assignment from DOE headquarters. After O'Leary succeeded Watkins and found herself at odds with some members of Congress on questions about SSC management practices, she assigned another 30 people to look into the matter. This resulted in a perplexing paradox: SSC and URA leaders criticized DOE for too much oversight and authority, but O'Leary told Congress that the department had exercised too little oversight and authority.

Schwitters and other SSC officials

took to the trenches to fend off the invasion of skeptical government auditors and adversarial department managers, only to face new charges of adopting a "bunker mentality." GAO and DOE officials accused the physicists of arrogance and belligerence. By all accounts the atmosphere at the lab was "them versus us." The situation flared up last year when Schwitters was reported as telling a *New York Times* interviewer that DOE's oversight activities amounted to "the revenge of the C students."

The termination process

While rejecting the plan to build the SSC, Congress allocated \$640 million for its "orderly termination" and directed DOE to "maximize the value" of the project so far and to "minimize the loss" to the nation. On 5 November, Schwitters submitted his resignation to URA. He told friends he was uncomfortable and inexperienced operating as a "funeral director." URA appointed John Peoples, director of Fermilab, to the additional job of running SSC's termination. "It's the saddest thing I've ever been asked to do," said Peoples. Between Thanksgiving and Christmas, the lab sent termination notices to nearly 2000 scientists and staff. Peoples said he would hire 18 of the SSC's 150 high-energy physicists for Fermilab, where 120 people would retire or leave for other reasons in the next few months. Many of the physicists

who had worked on the SSC had not been on the lab's payroll but continued to be employed at a DOE national laboratory or a university. Peoples also met with members of the International Committee for Future Accelerators and with officials at CERN to discuss whether the US might form an interregional collaboration of some sort.

The issue of US collaboration with CERN also is high on the agenda of O'Leary, who asked HEPAP at its meeting in Washington on 9 November to "turn its attention immediately to the task of defining a long-term program to pursue the most important high-energy physics goals now that the SSC has been terminated." She asked that the panel consider the options for "a truly international framework for construction, operation and utilization of future high-energy physics research facilities." To HEPAP O'Leary's request was a metaphor for whether the US should join CERN in building the proposed Large Hadron Collider (see page 93).

Seeking a future

HEPAP chairman Stanley Wojcicki of Stanford University named a 16-member subpanel on the "future vision for high-energy physics" under the leadership of Sidney D. Drell, deputy director of SLAC. One of the panel's ex-officio members is Roberto D. Peccei of UCLA, who heads a committee of APS's Division of Particle and Fields that also is deliberating on the same topic. O'Leary asked the Drell group to deliver an initial report to HEPAP by 28 February and a final report by 30 May, so that her department will be able to inform Congress by 1 July "on future options for high-energy research which the department plans to support and on utilization of assets at the SSC site."

Drell is personally enthusiastic about an international collaboration that includes the US and perhaps some Asian nations to build and operate the LHC. He worries, though, that Europe is likely to be unwilling for the US to have a large say in the LHC if it does not help pay to build the machine. One alternative is for the US to become a member of CERN through a bilateral agreement. Drell, for his part, would prefer CERN to transform itself into CERN—a Centre for International Nuclear Research. "High-energy physicists should agree on scientific goals as an international community," Drell is quoted as telling *Physics World*, the British monthly, "and work with governments on how best to get there. It's time to stop skirting

the issue. Time is precious."

When D. Allan Bromley was President Bush's science adviser, he attempted to get the Europeans to come to grips with the internationalization of big science projects. Frustrated by the unsuccessful attempts to get Japan or other governments to help fund the SSC, Bromley convinced the Organization of Economic Cooperation and Development in 1992 to set up a Megaprojects Forum, which would advance the cause of international collaboration in big science. The OECD forum is still considering how to best go about this and would prefer that governments sign a treaty or otherwise binding agreement that enforces participation in a megascience project. In any expensive project, many European countries will commit a specific sum over a given period to pay for construction and operation, as Britain and France did, in fact, for the Channel tunnel. Congress, on the other hand, appropriates money year by year, which works against a costly project that may take five to ten years to complete.

Like DOE and HEPAP, Texas is trying to figure out what to do with the remnants of the SSC. A special state committee appointed by the governor recently asked the National Research Council for recommendations on how to use the facilities. The Research Council's committee, led by Robert M. White, president of the National Academy of Engineering, suggested that a research and education center be built around the site near Waxahachie, some 30 miles south of Dallas. In a letter to Jess T. Hay, a Texas financial executive who serves on the board of several corporations and heads the governor's SSC committee, White apologized for not having time to fully evaluate the options available for the lab and for not being able to provide detailed costs for either converting or operating the facilities in any of its possible uses. Nevertheless, White's committee said it was in the interest of Texas and the nation to keep open all options "at minimal cost."

The first thing that needs to be done, says White's letter, is to hold onto some highly skilled scientists and engineers who know most about magnet development and computer operations. With some of the best SSC staff leaving for other jobs, says the panel, it is essential to keep "the right people"—perhaps as few as 100 "well chosen scientists and engineers who are willing to stay"—"to ensure that when uses are identified the technical expertise is on site to ex-

ploit these complex facilities. The facilities alone are not enough . . . A failure to maintain a minimum cadre of knowledgeable people will severely limit other actions to exploit the remaining assets of the super collider. The window of opportunity—measured in terms of a few months—is closing rapidly." This should not cost more than \$20 million to \$30 million per year—a sum that equals no more than 3% to 5% of the \$640 million appropriated by Congress for fiscal 1994 to terminate the SSC.

Recommending options

White's panel then offered two possible options: Despite Congress's cancellation of the SSC, White's committee believes the US "will continue to strive to be among nations at the forefront of high-energy physics research." Thus, existing magnet and cryogenic facilities, and possibly the computer center with its massively parallel capability, should be maintained, for possible use in high-energy physics research and as a possible bargaining chip in any discussions and negotiations involving US participation in CERN's proposed LHC.

Another option is to explore the proposal advanced by Peter Rosen of the University of Texas at Arlington to turn the facilities into a science research and education center. This concept is endorsed by 150 faculty members at 12 universities in Texas, says the panel's letter. Such a center would subsume other proposed applications, including an institute for superconductivity, a cryogenic test facility and an energy storage research facility—though the cost of these enterprises eludes the panel.

The White committee rejected the idea of completing the collider's linear accelerator for use in cancer therapy or for producing medical isotopes, citing the substantial expense and the inaccessibility of such a proposed facility from established medical centers in the region.

The SSC is a case study of the changed relationship between physics research and the political system in the 1990s. At the HEPAP meeting last November, Nicholas Samios, director of Brookhaven, characterized the history of the SSC as a Greek tragedy—high drama involving contentious heroic figures who are brought down by hubris but leave a permanent mark on the culture and history of their time.

—IRWIN GOODWIN ■