SSC: ESSENTIAL SCIENCE OR UNNECESSARY EXPENSE?

John F. Waymouth, an R&D director at GTE Electrical Products in Massachusetts, published a letter in these columns (July, page 9) expressing his strong opposition to the construction of the SSC at this time. Waymouth's arguments are fairly standard but they are couched in an interesting phraseology and call for an answer. Waymouth has come up with a new law: "Tangible benefits to the US economy" are inversely proportional to the energy of the physics involved. Thus "eV" physics has given rise to "radio, television, lasers, radar and microwave ovens" and is consequently the "core science of the modern world." "MeV–GeV" physics has given us radioisotope analysis, medical physics and nuclear energy—with most of the economic benefits still unrealized—and "high-energy physics has to date given us nothing." Waymouth has an explanation for the inverse relationship between economic benefit and energy: "eV" physics pertains to things that happen on Earth; "MeV–GeV" physics to what happens in the Sun, the stars and the Galaxy; while "TeV" physics "has not happened anywhere in the universe since the first few milliseconds of the Big Bang." Ergo, the SSC should not be funded because "it will siphon off funds" from "eV" physics.

Waymouth presents his arguments in such a logical fashion that his conclusion seems inescapable. The problem is that he has omitted one nontrivial parameter from his equations, namely the human mind and its capacity for rational thought and the discovery of physical law. The body of *Homo sapiens* may be confined to the Earth (I am not taking a position on the existence of extraterrestrial life!) but his mind roams over the entire universe, is fascinated by the possibility of formulating universal laws and is eager to understand the conceptual unity that is miraculously emerging in physics (and in other sciences as well).

Let me comment on why the emerging conceptual unity of physics makes me so uneasy about Waymouth's categorization of physics, and then return to the subject of the SSC. More than half a century ago, in 1937, when I became a student of Hans Bethe, we already discussed freely—solely in terms of the four known forces of nature and the common principles of quantum mechanics and special relativity—the physical ideas that could explain the new results in solid-state physics ("eV" physics), nuclear and astrophysics ("MeV–GeV" physics) and cosmic-ray physics ("TeV" physics). It never occurred to us that these fields should be approached within the context of cosmic geography or practical utility. And indeed, several years later, at Los Alamos, we were not surprised that the same concepts that enabled us to understand the internal structure of stars served to explain the behavior of the "gadget" on Earth. During the years since, the revolutionary developments that have taken place in all branches of physics have brought into play additional unifying concepts: between "eV" physics and "MeV–GeV" physics, between "MeV–GeV" physics and "TeV" physics, and, yes, between "eV" and "TeV" physics.

Knowledgeable people are aware of the deep conceptual connection between the spontaneous symmetry breaking of electromagnetic gauge invariance by means of the Cooper pair in superconductivity and the spontaneous symmetry breaking of the electroweak gauge group by means of the Higgs boson in particle physics, despite the fact that superconductivity takes place at the eV level and electroweak breaking at the 0.25-TeV level—a difference of a factor of 10^{11} in energy! They are intrigued by the conceptual relations between the eV soliton in polyacetylene and the MeV–GeV skyrmion in nuclear physics, on the one hand, and between critical phenomena in statis-

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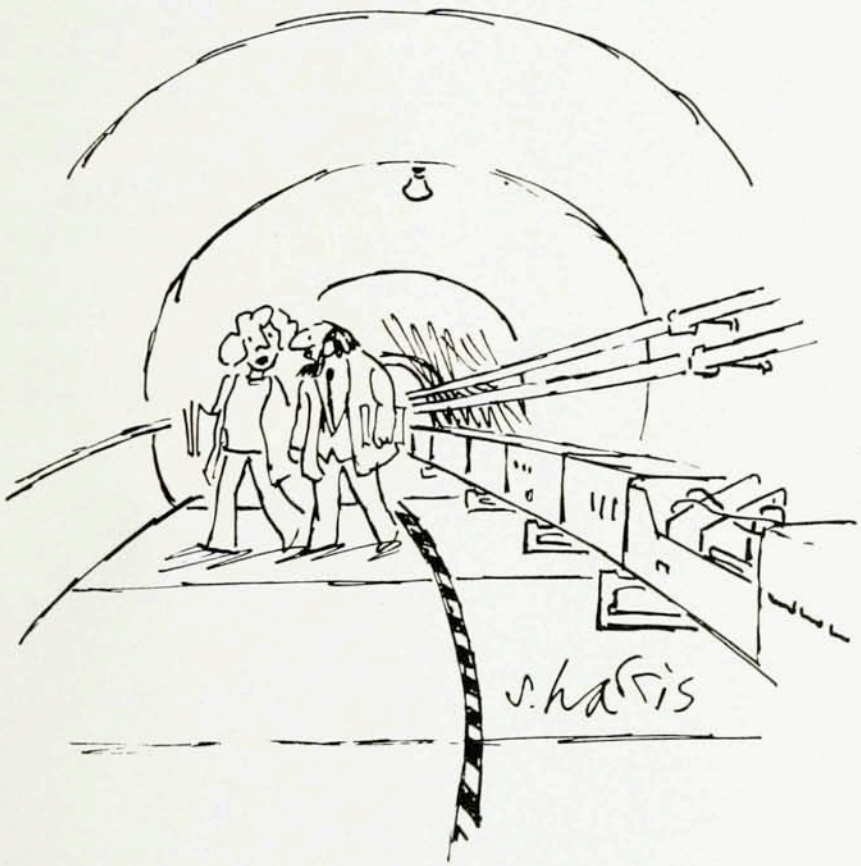
tical physics and conformal field theory in particle physics, on the other. The spontaneous symmetry-breaking phase transitions, the "kinks" and "lumps," and the "less than four"-dimensional models that are considered for nonrelativistic many-body systems and quantum field theory illuminate and simplify our understanding of numerous and fascinating phenomena at the low and high ends of the energy spectrum. And if there is a deep-going conceptual unity, how does one disentangle the origin of an idea—and is it really important? It is quite conceivable that the breakthrough in the theory of high-T_c superconductivity might come from someone who is an expert in superstring theory, and what happens then? To an old-timer like myself, Waymouth's energy categories make increasingly less intellectual sense as ever-deeper relationships among the various branches of physics continue to unfold.

Furthermore it seems to me that Waymouth's practical-utility approach is simply unworthy of the American physics community after so many decades of high achievement. Warren Weaver understood the difference between science and technology when he told us, in his famous 1960 essay entitled "A Great Age for Science": "Pure science is not technology, it is not gadgetry, it is not some mysterious cult, it is not a great mechanical monster. Science is an adventure of the human spirit; it is an essentially artistic enterprise stimulated largely by disciplined imagination, and based largely on faith in the reasonableness, order and beauty of the universe of which man is a part."

That was the spirit that animated the American scientific community more than a quarter of a century ago and led to the awe-inspiring "man on the Moon" project—a project that was well conceived, stirred people's imaginations and intellects, and made a significant contribution to our understanding of the "universe of which man is a part." The same spirit should motivate the American physics community at a time when a basic-

continued on page 114



"WHAT IF WE SPEND ALL THESE BILLIONS, AND THERE JUST AREN'T ANY MORE PARTICLES TO FIND?"

continued from page 15

science project of grand design, the SSC, has been proposed that is well conceived, fires up our collective imagination and will contribute significantly to our understanding of the cosmos. It would be a tragic irony of history if the views of Waymouth and his "eV" colleagues opposing the SSC are permitted to prevail when the supposedly materialistic and utilitarian Soviet Union recently undertook an expensive Mars program of grand design because of sheer curiosity about our universe. The Soviet Union has done well in space and its scientists are ready for major cosmic conquests, and they would welcome large-scale cooperation from American space scientists. The same statement can be made about American excellence in particle physics, American eagerness to meet new challenges in particle physics with the SSC, and American willingness to be joined by their Soviet particle physics counterparts. What better way to deal with the financial crunch on both sides than to work out a dramatic and equitable scientific exchange agreement between the US and the Soviet Union whereby the Soviet Union joins in the SSC in return for our joining in the Mars and other Soviet space programs of grand proportions. This is the sense of high adventure that should guide our basic research endeavors in physics as we close out the century of its greatest achievements.

ROBERT E. MARSHAK
Virginia Polytechnic Institute and State University
Blacksburg, Virginia

7/88

After reading numerous, almost self-serving letters of narrow perspective concerning the fate of funding for the Superconducting Super Collider, I was surprised and enlightened by the letter in the July issue by John F. Waymouth.

As a nonphysicist, an architect—an ordinary citizen in comparison with your normal contributor or reader—I am perhaps more like the voter who must eventually rule on the "value" of this tool so fervently desired and so despised by differing factions within the physics community.

Waymouth's letter contained much down-to-earth reasoning. While there is the danger that an overly pragmatic viewpoint may result in a lack of fortuitous foresight or discovery, the strength of his assessment rests on the fundamental nature of energy and man's manipulation and use of it. I have tried to think of any benefit held out to an ordinary citizen by the world of highest-energy physics. I am at a loss to think of any, other than a certain elegance of reasoning and various uncertain hypotheses on the nature of the universe. As a voter who pays taxes, these are endeavors I wish to support at much the same level as the National Endowment for the Arts: Brilliant theoretical scientists are as beautiful to society as excellent playwrights or sculptors.

Physicists may find most voters have similar views. It is not that we wish to "zero out" the SSC, but the level of funding must reflect the reality of human needs, taxation and public budgets. I have found little merit in the many letters arguing the various sites, energy consumption and scientific productivity of this potentially marvelous tool. All of those issues are technical ones that reflect various prejudices of the writers. For a project as large as the SSC, the real crux of the matter is *political*—whether it reflects the interests, welfare and power of the public. As Waymouth points out, you may be certain that the public does *not* recognize "new money" for theoretical research; it is just more of *our* money! We know quite clearly that there is real competition for funding: Ever heard of Star Wars vs housing for the poor? You can bet the future will bring more such debates!

Waymouth admirably clarified the interests and welfare of the public as few other contributors to the discussion have. I suggest that the members of the physics community—high-energy, subnuclear physicists, in particular—must take a broader view, or else they will surely be left in the dust of their labs by the public weal.

NELS L. LARSON
Greenbelt, Maryland

8/88

In his letter against funding the Superconducting Super Collider, John F. Waymouth seems to have missed the point about physics and society. Throughout the history of civilization man's curiosity about the universe and its origins has been a major force in his life. For that reason, for example, every major religion has a cosmology. With the end of the Middle Ages science took over as the universal effort of mankind to uncover the mystery of nature, an effort and a search that has spanned all nations and has continued, cumulatively, from generation to generation. This curiosity and this search play a crucial role in inspiring and encouraging interest in science throughout the entire educational

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system, and are essential for developing and keeping alive the scientific imagination.

Some of the tools of high-energy experimental physics and astrophysics are very expensive, so priorities have to be set and sacrifices made. Two of the major considerations in such cases are how important the data that are being sought are in telling us how to think about nature and how ready we are technically and financially to build and use these tools. The key role of high-energy physics in understanding the structure of the universe, and the commitment of the high-energy physics community to the SSC as an absolute first priority, should satisfy the first criterion. The magnitude of our gross national product should satisfy the second.

MICHAEL J. GLAUBMAN
Northeastern University
8/88 *Boston, Massachusetts*

John Waymouth makes a vigorous argument against funding the SSC with the telling point that "TeV physics has not happened anywhere in the universe since the first few milliseconds of the Big Bang." That seems to me to put the burden on *intangible gains* as the main justification for going forward with the SSC, and that in turn prompts an invidious comparison with the project of putting a man on the Moon.

The manned lunar landing of 1969 has produced no momentous scientific knowledge, but it was a watershed event in human history, the deepest meaning of which could be grasped by virtually every man, woman and child on Earth. In contrast, the SSC would produce knowledge incomparably arcane, so remote from common human experience that the few people in the whole world who could ever hope to have an easy familiarity with it could be seated comfortably in one small room.

Indeed, the funding of the SSC is quite analogous to building a $5 billion spacecraft, putting a few Weinbergs and Glashows and Hawkings aboard, and sending them off toward some extragalactic fount of transcendental knowledge, with the understanding from the outset that *we on Earth would never hear from them again.*

DANIEL M. SMITH
8/88 *Austin, Texas*

STEVEN WEINBERG REPLIES: I suppose we can all agree that it is not worth $5 billion just to get rid of "a

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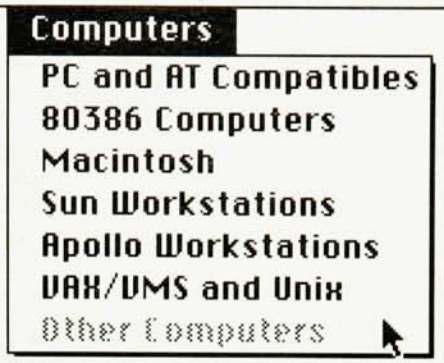

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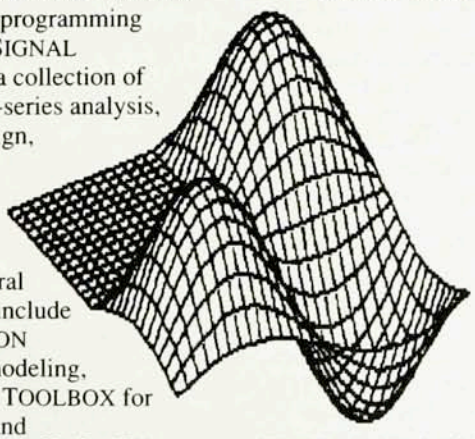

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few Weinbergs and Glashows and Hawkings." However, I don't agree at all that the people who would understand the knowledge produced by the SSC "could be seated comfortably in one small room." This knowledge will be immediately significant not only for thousands of theoretical and experimental physicists, but for scientists in other fields as well. Just to take one example, any astronomer who worries about the structure and evolution of galaxies or the universe needs to know whether dark-matter candidate particles, such as the photino, actually exist. A wider circle of applied physicists and engineers will be interested in the technological spinoffs from the SSC, in areas like on-line computing, magnet design, cryogenics, vacuum technology, superconductivity technology and so on. But the really important intellectual impact of the SSC will not be in its immediate impact on professional scientists or technologists. Discoveries at the frontiers of scientific knowledge have historically led to profound changes in the way that educated people in general think about our world and why it is the way it is. This was true, for instance, of Newton's work, yet it was as "arcane" in its day as elementary-particle physics is in ours.

STEVEN WEINBERG
9/88 *University of Texas, Austin*

WAYMOUTH REPLIES: Robert E. Marshak does not dispute my observation that TeV physics has been and is likely to continue to be relatively unproductive of economic benefits to society in comparison with eV physics. He:

▷ Credits me with having come up with a new law (of economics and physics) positing an inverse relationship between benefits to society and the energy of the physics involved.

▷ Argues that the "conceptual unity of physics" means that discovery of concepts in any area of physics benefits all others. Therefore TeV physics research will have indirect benefits to eV physics even if it has no direct output of developments economically useful to society.

▷ States that my insistence on the necessity of a "practical-utility approach" (to ensure continued funding by society) is "simply unworthy of the American physics community after so many decades of high achievement." By inference, all of physics deserves society's trust on the basis of past performance.

My comments in reply are:

▷ I respectfully decline credit for discovering a new law. I merely reported my own empirical observations. Marshak has apparently plotted one variable against the inverse of the other, drawn a straight line and deduced the hyperbolic relationship. Therefore this should be known as Marshak's law. After all, when Tycho Brahe's data on planetary positions were replotted to extract new insights, the results became known as Kepler's laws of planetary motion, not Brahe's.

▷ The conceptual unity of physics is indeed a powerful argument. However, the leading example cited by Marshak perhaps demonstrates the inverse of what he intended. The BCS theory of superconductivity, and its concept of symmetry breaking by Cooper pairs, predated the development of the Higgs boson concept (which Marshak has identified as the same thing in a different guise) by about a decade, if memory serves me correctly. At least one history of particle physics I have read suggests that the Higgs mechanism (subsequently extended by Steven Weinberg and Abdus Salam) was developed by analogy with the BCS postulate. It would seem that the benefit in this case flowed from eV physics to TeV physics rather than the reverse. Society has already benefited considerably from the BCS theory, its prompt experimental verification and the guidance it gave toward the development of alloy superconductors. Society has yet to see a Higgs boson, and will experience no economic benefit if it does.

▷ The concept that society should support TeV physics solely as a great leap of the human imagination, and trust that its practitioners will deliver future benefits, has already been dealt with in my letter. The knocking down of this concept on two grounds was in fact the fundamental point of that letter: First, in my opinion physics should receive no greater support on this basis than music, philosophy or ballet. I believe this view is shared by many thoughtful members of the nonscientific intelligentsia; see for example the letter by Nels L. Larson. Second, in my further opinion, the likelihood of economic benefit to society from expanded support of TeV physics in the form of the SSC is so remote as to be not worth considering.

A further observation along these lines is that, as large and expensive as the SSC is, its construction cost is not the whole bill, and the thing isn't big enough to begin with. It will presumably be capable of creating Higgs

bosons; what is the detector to find one in the midst of all the rest of the subnuclear detritus of a 1-erg-per-particle collision going to cost—half a billion dollars? Finally, it falls more than a few orders of magnitude short of the energy range needed to test the grand unification concepts of the superstring theorists. In the year 2000+, the high-energy requirement may well be for a 1-joule-per-particle accelerator girdling the Moon at its equator, because there is free real estate, free vacuum and free cold up there, and the technology to build vast structures in space will presumably exist. The same arguments for such a machine will be equally valid then, but they clearly lead to an absurd result in cost–benefit terms.

The main point of Michael J. Glaubman's letter can be summarized as follows: "We in the high-energy physics community have set our priorities; we recognize that sacrifices must be made to provide the necessary resources, but we are sure that *the rest of you* will gladly make them in order for us to proceed with this grand adventure of the human spirit. Good luck with your future efforts to obtain funding for your own, less important work."

The point of my letter was that there exists a rational basis for disagreeing with these priorities. To Glaubman's two criteria, I believe a third should be added: the potential for future benefit to the society that funds the program. Other potential programs, such as massive expansion of the search for room-temperature superconductivity and the cracking of the human genetic code, offer at least as great an opportunity for wonderful science, satisfaction of man's innate curiosity, and enormous intellectual challenge as does the proposed SSC program. Being intimately connected with things that happen on Earth, even the life process itself, they offer infinitely more potential of future benefit to the society that masters them.

Finally, even after seven and a half years of "Reaganomics," the total expenditure of Federal, state and local governments still consumes one-third of the gross national product. Economists may disagree on whether this is already too much, but I believe most would subscribe to the view that extracting any more would be most unwise.

I thank Larson for his letter. To Daniel M. Smith I reply: Perhaps I can suggest a few more passengers for your spacecraft.

JOHN F. WAYMOUTH
9/88 *Marblehead, Massachusetts*