

aerospace companies are happy to do research—if the government pays for it. If space really has payoff potential, much more up-front investment should be forthcoming from the private sector. This consideration leads to larger economic issues: Much of the decline of the US global competitive posture, including our eroding technological leadership, probably results from a preoccupation with symbols over substance.² Additionally, despite lip service to privatization, NASA has responded in the manner of a bureaucracy, defending its turf against entrepreneurs attempting to develop private launching alternatives. Thus private expendable launch vehicles were shut out while public ELVs were phased out.

To conclude, here are two suggestions for the space science community: ▶ Get involved with the private sector. Declining Federal budgets and increasing commercial interest, coupled with rising concerns about the US's declining technological posture, provide a favorable setting. In particular, private capital should be involved in the space station.

The major oil companies may provide useful analogs for such private research. They have traditionally supported students and faculty with scholarships and grants, including a surprising amount of longer-term research. And whatever their undoubted faults, the oil companies have not billed Uncle Sam for such research.

In addition, the hardware (especially electronics) for space science has also gotten much cheaper. It's premature to sigh that the "easy things are all done." For example, the Radio Amateur Satellite Corporation satellite that is to be launched on the Ariane in a few years incorporates much effort by non-profit, nongovernment organizations. ▶ Present space science as part of a general program of research and development to help restore our technological edge. Such a program would enjoy broad-based public and Congressional support.

Popular concern about America's declining technological edge, and companies' reaction to criticism that American business has degenerated into exercises in short-term paper shuffling, should favor sustained support of space science even with dwindling budgets. But silly assertions that manned flight is useless and pronouncements that the public "should" support space research merely generate much heat and little light. They also will not generate any funding.

References

1. R. Reich, *The Next American Frontier*,

Times, New York (1983).

2. S. R. Taylor, *Lunar Sciences: A Post-Apollo View*, Pergamon, Elmsford, N. Y. (1975).

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5/87

The three letters on the shuttle program (November 1986, page 13) present three different views of the future of the US space program. Geoffrey A. Landis is a strong believer in the shuttle program, at least in the interim. Thomas M. Donahue believes that more emphasis should be placed on expendable launch vehicles and less on the shuttle. John Bartel and Tom Coughlin believe that the issue is best settled by privatization of the US space industry. Of the three approaches, privatization is the most sensible and practical.

If the space shuttle, ELV or any other means of space transport is useful, economical and practical, then it can pass the test of privatization. Whatever system does survive the test, competition will force the launching companies to improve capacity, reliability and safety. As a result, it will be possible to lower insurance premiums.

Competing private companies detect a society's economic needs more rapidly and efficiently than a government agency; therefore pharmaceutical, medical, military and many other industries will be able to make tremendous advances as they can choose among more launching facilities for their payloads.

The increased launching capabilities and improved space technology under privatization will increase the demand for scientists, engineers and technicians, which in turn will increase the demand for advanced education.

The US is the leader in private industry and has the experience and skill that are required to accelerate our space industry beyond the imagination of any comparable socialized space industry. With privatization, we have the potential of being remembered in the history books as the 21st-century Phoenician sailors of outer space.

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12/86

Tying nuclear dumping to SSC

The letters on the "social purpose" of the SSC in your February 1987 issue (page 11) were presumably written before a social purpose was proposed in Congress—namely, for the SSC to serve as a carrot to get some state to accept a high-level nuclear waste dump. This

proposal was immediately and forcefully opposed by Energy Secretary John Herrington, and it is doubtful that any SSC supporter would willingly accept the suggested albatross. Nevertheless, and whether or not the proposed tie-in becomes a significant factor in SSC decisions, the physics community should at least reflect on its possible poetic justice.

At the simplistic level, physicists are responsible for the nuclear waste problem, first by having contributed to the discovery of radioactivity, and then by having caused radioactivity to be increased by reinventing the self-sustained chain reaction. I do not view these things as "sins" since it is the responsibility of society as a whole to determine what uses are made of the discoveries of its more inquisitive members. But I consider that The American Physical Society has "sinned" by being at least partially responsible for the exaggerated public apprehensions concerning low-level radiation that make the nuclear waste problem a political hot potato. The APS did this by concocting 20 000 deaths from hypothetical public exposures of 600 millirems/year for 15 years in its 1975 light-water-reactor safety study. [See PHYSICS TODAY, July 1975, page 38.] From a historical perspective, these 20 000 deaths emerged at a critical point in the nuclear power debate and played directly into the hands of the alarmists who were marshaling their forces to combat nuclear power. Whether or not the APS deliberately intended to give credibility to the distorted viewpoints of the nuclear opponents, the failure of the APS to place public exposure to ionizing radiation from different sources in proper perspective, either in its 1975 report or in subsequent actions by its Forum on Physics and Society, has, in my opinion, been inexcusable.

While I would not expect physicists to carry their atonement to the point of allowing the SSC to be jeopardized, it would be refreshing if SSC supporters were at least to become sufficiently aware of the quantitative aspects of radiation in our environment to talk intelligently to politicians and reporters about nuclear wastes if the tie-in proposal ever does gain momentum. For example, the figure of 600 millirems/year used by the APS to concoct the 20 000 deaths is roughly equivalent to the exposure from the Environmental Protection Agency's indoor radon "guideline" of 4 pCi/liter, which has been eagerly interpreted by the public as being "safe." (The latter guideline level of indoor radon leads to a cumulative lifetime radiological exposure comparable to the 54-rem average exposure

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reported by the Russians for evacuees from the 3-7-kilometer zone around Chernobyl.) By comparison, the maximum allowable radiation level at the boundary of a nuclear dump is 25 millirems/year, and the allowable concentration of radon is 0.1 pCi/liter. Therefore I, for one, would not be distressed if some of my grandchildren happen to get jobs at the SSC site, even if it were built around a high-level nuclear dump!

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2/87

THE CHAIRMAN OF THE APS STUDY GROUP ON LIGHT-WATER REACTOR SAFETY REPLIES: I don't honestly know what's bothering Henry Hurwitz, but I do feel that as chairman of the 1975 APS study group, I owe something to the fine group of people we were able to assemble for that pioneering effort, and therefore I need to reply.

It seems to me that Hurwitz raises an important point, the public impact of a scientific study, and ends up on the wrong side of it. Nearly all physicists recognize that much of the public has an inordinate terror of radiation, carefully nurtured by squadrons of lawyers and show business personalities parading as consumer advocates and troubled scientists. Some of us therefore spend a great deal of time speaking, testifying and otherwise trying to contribute to the education of the body politic, and indeed of the press. It is no secret that we have had limited success—Gresham's law is as applicable to ideas as it is to money—and radiophobia persists, with all the classic symptoms of a phobia.

Depressing though that may be, one right it does not give us is that of adjusting our scientific work to meet our public objectives. Hurwitz accuses us of "concocting" our results, which is a pretty strong (and completely improper) assertion. In fact, our references for what we did were clearly stated, and were the standard authorities, the National Academy of Sciences and the National Council on Radiation Protection. Everyone knew that the linear model favored at that time by both these authorities was a prudent upper bound on the effects of radiation, and we said so several times in the report. As it turns out, our estimated doses for the hypothetical case of complete containment failure are not all that far from the Soviet estimates of the dosage at Chernobyl, where it actually happened.

We've learned a lot in the 12 years since 1975, and the 1983 update of the 1972 Academy study that we used

departs, for the first time, from the linearity hypothesis. The study of radiation goes on, and in 12 more years we will know even more. At each moment in time, responsible scientists should do their work with the best information available, and let the results appear as they must. What they should not do is concoct their results to fit a social objective. Yet Hurwitz accuses us of "sin" for not having done just that. *Honi soit qui mal y pense.*

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6/87

'Fundamental' distinctions

I was rather amazed to learn from Sheldon Glashow's letter (December 1986, page 13) that we are rapidly approaching the time when fundamental physics will no longer be possible (unless funding is received for the Geotron or Lunatron). Once the SSC is built its corridors will echo the last pronouncements by humanity on the nature of nature. We truly live in awe-inspiring times.

What a baffling word: fundamental. It seems to have many false definitions. It certainly can't mean "essential to the existence of." If that were the case then solid-state physics and materials science would be fundamental to the creation of the SSC, and thus to its fruition, as the magnets owe their existence to the Bardeen-Cooper-Schrieffer theory and high-critical-temperature alloys.

One might argue that fundamental means "basic or primary." It might then be supposed that a fifth force of nature (or even the possibility of such a force) would be of fundamental interest. [See PHYSICS TODAY, October 1986, page 17.] But the instruments used in searching for supportive evidence of that force are reminiscent of a turn-of-the-century baron's basement or a 17th-century heretic's tower. The price tag of such investigations is certainly not as fundamental, in the sense that our trade deficit is fundamental, as that of the SSC.

Does fundamental mean "of most basic importance," as Glashow suggests? Then are not the axiomatic precepts of quantum mechanics fundamental? Then Alain Aspect's empirical proof of Bell's theorem and the work by a couple of groups resulting in the direct observation of quantized decay with Penning traps would lead to fundamental understanding. (And, as asked above, does this make ultrahigh-vacuum and laser technology fundamental?) Obviously such studies must not be fundamental by reason of scale,

or else they are too fundamental (they lead to better philosophy as well as to better physics).

Mathematicians are much more precise about definitions (just ask one) than physicists and many of them see nothing at all fundamental about physics. Yet they too have trouble with a working definition of "fundamental" within their own discipline. Is a proof in the *Principia Mathematica* more fundamental than the solution to the four-color problem? (It is certainly more in line with reductionism.) In fact, a mathematician would probably feel that "fundamental" sounds too plebeian and use the word "elegant" in its stead.

Perhaps this semantic debate will save the physics community some money in the long run. As Henry Barschall pointed out (December 1986, page 34) humanities journals are much less costly to produce than physical science journals. *Reviews of Modern Physics* could combine with *Reviews of Metaphysics*, *Physical Review Letters* could shorten its title to *Review Letters*, and *Vacuum* could keep its name but drop its price.

Political science journals would not be excluded. Thus Glashow would have a more appropriate forum.

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1/87

Sheldon Glashow has a quick way with words, but he might take a little more time to contemplate the world around him. What my friend Pedro Echenique was trying to explain to him is the existence of emergent properties: properties that are reducible to simpler entities, but not deducible from them.

For instance, it is well known that one may make a computer from vacuum tubes, from semiconductor devices or from neurons. The fundamental physics of these objects is very different, yet the computer works in each case. Rigidity, life, consciousness are all emergent properties, not deducible from the individual atoms or quarks of which their components are made and in fact achievable in different ways. Chaos is exhibited by thousands of totally different physical and biological systems. Computer theory reveals other extensive hierarchies of complexity. The SSC will add to our knowledge of any of these fundamental phenomena no more and no less than they have contributed to particle theory, namely a broadening of our regrettably narrow intellectual horizons.

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