

The national crisis in scientific equipment

John H. Marburger

When physicists become administrators, they sometimes muse upon their past careers and wonder where they went wrong. I remember, for example, that when I taught quantum mechanics, I loved to point out the conceptual puzzles it solved and to trace its history through theoretical evolutions. Now I regret that approach, because it misrepresents how physics really moves ahead. The quantum mechanical revolution owed at least as much to the explosive improvement of experimental technique as it did to theoretical puzzling. The profound insights come only after long scrutiny of nature's actual behavior. And that requires apparatus: apparatus both to aid the eye and to stimulate something worth seeing.

This inescapable dependency of physics upon apparatus has strongly influenced the course of science in America, and poses today the most difficult questions of science strategy. The cost of apparatus has grown large in inverse proportion to the scale of observation or manipulation, and one wonders when a closer look becomes too dear. We have not, it seems to me, reached the point of diminishing returns and, in both the classroom and the research laboratory, society must continue to invest in the apparatus which extends our perceptions into the deeper layers of reality. We are *not* making an adequate investment now, and the situation is growing rapidly worse.

In their report last April to the National Science Foundation, the Commission on Human Resources of the National Research Council said that "The state of scientific instrumentation for both teaching and research (which at advanced levels are intertwined) is deplorable; there is no other word for it. Yet, despite the gravity of the situation, we find no evidence of coherent actions and sustained leadership from the federal government."¹

The situation did not deteriorate to this state overnight. In the "State of Academic Science" report to NSF wide-



Isabelle accelerator under construction at Brookhaven National Laboratory. Funds for its completion are uncertain; if the project is cancelled the US will lose a unique research tool.

ly publicized in 1977, the authors (Bruce L. R. Smith and Joseph J. Karlesky) state that

"Of all expenditure items, permanent equipment funds have shown the sharpest declines. In fact, the amount . . . spent on permanent equipment per senior personnel man month has declined by almost 65% between 1968 and 1974."²

The most recent NSF data on capital expenditures for physical science activities at universities and colleges show a drop by a factor of 4.4, from \$284 million in 1968 to \$64.5 million in 1979.³

The Association of American Universities' study issued a year earlier ("The Scientific Instrumentation Needs of Research Universities") stated that

"The quality of research instrumentation in major university laboratories has seriously eroded. Not all, but many researchers in the nation's best-funded universities are strug-

gling to work effectively with obsolete tools. The equipment used in the top-ranked universities has a median age twice that of the instrumentation available to leading industrial research laboratories."⁴

The same report also declares that "The time and labor cost of fabricating the instrumentation required for a single experiment in high-energy physics is passing beyond the capacity of any one university. . . Other areas of physics are still within the reach of university laboratories, but instrumentation has become more sophisticated and expensive. Because of the cost of instrumentation, even in some of the best-supported universities there is a tendency for physics departments to become increasingly theoretical."⁴

Let us reflect upon this observation. Throughout the early history of higher education in America, physics was

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viewed as a subject similar to Latin, or classical Greek, whose study would 'discipline the mind.' Experiments and laboratories were not a part of the curriculum, and what was taught in lectures resembled geometry in its indifference to relevance. The situation, and its reform, are admirably described in Daniel J. Kevles' book *The Physicists*, a history of the institution of physics in America.⁵

We now deplore this approach to physics pedagogy, but it is possible to teach physics this way today. We can derive our mathematical laws from a

relatively small number of mathematically expressed propositions, and teach the entire subject deductively, even "deducing" the results of the key experiments which in the real world provided the key to the theory, and not the other way around.

Physics is actually taught this way in many countries whose resources do not allow their students access to anything but rudimentary apparatus. Those of us who have worked with students from such countries know under what serious handicaps they labor compound to their more fortunate peers. The problems are not simply with manipulative skill. There are also difficulties in attitude regarding what science itself is all about.

I am afraid that some of the same symptoms are beginning to appear in our own students. It is not only the research programs of American physics departments that are getting more theoretical. The curriculum itself is slipping back toward that nineteenth-century situation when science instruction was decoupled from laboratory experience.

The greatest problem is not in the mainstream courses for scientists and engineers, but in the general education courses for non-majors, where my own informal sampling indicates that laboratory work is rare. Efforts to reform the curriculum to require laboratory courses of all students are hampered by inadequate funds for instructional laboratory equipment and by high personnel costs.

Our non-science majors are certainly not learning experimental techniques that they may or may not find useful in later life. But what is more important, they are not seeing for themselves how the orderliness of nature is manifest in practice. They are not convinced that it is even necessary to look at nature in order to understand it.

We are producing students with oddly flawed views of science. Some of them think that our understanding of ordinary phenomena implies the ability to control phenomena. Others believe the relation between theory and experiment to be much simpler than it is. Still others see the theories they have learned in lectures and textbooks as more or less human constructs similar to philosophical systems or bodies of literacy criticism. They literally do not know how these laws come into existence. The consequences for the public understanding of science are grim.

Unfortunately, lab work is expensive. It requires people as well as equipment. Federal funding policy in the past has focused upon personnel. The AAU study points out that

"Principal investigators, peer review committees and program officers ... preferentially preserve research

manpower and trim instrumentation and support equipment from proposals in order to accommodate restricted budgets. This is a necessary and defensible short-term tactic. . . . However, the continued choice of personnel over instrumentation will lead to even further deterioration in instrumentation available to carry out research."⁴

This is equally true if the word "research" is replaced by the word "instruction."

In the economic context which is being created by the current national administration, I believe it is imperative for the corporate sector to assume some responsibility for improving the quality of instructional apparatus in the nation's colleges and universities. In the short run, national productivity suffers from inadequately skilled technical personnel in the workforce. In the longer run, the lopsided science education toward which we are drifting inhibits the effective application of physical knowledge to the comprehension and solution of problems affecting society. These are ample reasons for corporate involvement.

Models for effective mechanisms of corporate support to higher education are plentiful, but I would suggest a foundation with multiple corporate sponsors, devoted exclusively to the capital equipment needs of scientific higher education. It is not only in physics that the need is critical, but organizations such as the American Institute of Physics could play a role in the formation of such a foundation.

The more general problem of deteriorating research equipment is too large for any but the public sector to address. In my opinion, it always was unrealistic to expect that private support alone could carry a competitive national research effort in physics. Kevles's study exhibits much evidence to support the notion that American physics never became competitive until the federal government began funding it. He makes it clear that Karl Compton and others helped to found AIP fifty years ago not only to reduce the cost of producing journals, but also to act as "a trade association in defense of science and all its works."

It seems strikingly appropriate to me that at the inaugural meeting of AIP in New York City, Robert Van de Graaff demonstrated his new electrostatic generator. A. H. Compton's talk at that meeting and the 1.5-MeV Van de Graaff machine received front page coverage in *The New York Times*. In the struggle to discover the microscopic structure of matter, no apparatus is more important than the particle accelerators that began with this device (the first to develop more than 1 MeV), and none is more expensive. Although the

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early models of E. O. Lawrence's machines, and some of the others, were funded privately, funding was a serious problem already by the mid 1930s. With the exception of those early versions, the entire history of submicroscopic physics has been one of government funding.

When we talk about the deterioration of research apparatus, it is not possible to avoid mentioning these great machines of particle physics. In the Smithsonian Museum of History and Technology, there is a magnificent display of the history of American high-energy particle accelerators. It begins with the crude 19th-century gas discharge tubes and ends, prematurely, with a striking display on the Fermilab machine.

The history is incomplete. The ring of a later-model device is decidedly visible from the air over Brookhaven National Laboratory on Long Island. It is the only accelerator currently under construction that is capable of maintaining American competitiveness in high-energy physics. (This rather bold statement has something of the quality of an opinion because of the indefiniteness of the notion of competitiveness, but I believe it can be supported.) Up until now, we have been talking about equipment problems involving large numbers of devices in many laboratories. Some labs are well equipped, others are not. Funding problems created a condition of gradual deterioration. Research effectiveness is impaired but not demolished. In the case of Isabelle at Brookhaven, the competitive edge in an entire field can be lost at a single stroke.

There no longer appears to be any technical barrier to the construction of Isabelle to original specifications. Federal funding adequate for her completion is well within the capabilities of even a belt-tightening US. It only needs to be allocated appropriately. Unfortunately, there is a good chance that such a pattern of allocation will not occur, in an effort to maximize the effectiveness of high-energy programs on machines already in existence. (This is the approach suggested by an interim report of a committee of physicists advisory to the High-Energy Physics Advisory Panel which offers guidance to the Department of Energy.)

It was Allan Bromley in a *Science* magazine editorial who applied the phrase "eating one's seed corn" to the phenomenon of industry hiring away engineering faculty and graduate students to lucrative commercial practice. The phrase has appeared so often since that he probably regrets that he thought of it. But it is apt, and it applies to the plight of Isabelle. If, in an effort to run existing programs, we delay construction of the only next-

generation machine we have until it cannot be completed in time to be useful (or until it becomes too expensive to complete at all), then the seed that contains the sustenance of future generations of American particle physics will have been consumed. That would amount to a research equipment shortage on the grandest scale. I will not argue here the pragmatism of constructing such a device for pure research. My own opinion is that the benefits of such machines to society are large, and that the cost of not sacrificing now to build Isabelle will be enormously great.

My remarks to this point have all addressed the diminishing tools for basic physics instruction and research in America. We are in a period of crisis not unlike that in the early thirties when physics pushed bravely ahead in the face of incredible economic difficulties. The Second World War intervened to help, and I pray that salvation does not come again in such a dreadful form. But we who believe in the value of our work must press vigorously to secure the tools which enable us to do it. Instructional apparatus, basic research equipment, the unique particle machines, all are aging or inadequate. It is not too late to save them within budgets that this nation can afford. For Isabelle and for other programs, including much of the valuable scientific research supported by NASA, current budget plans will spell disaster.

The tale is a gloomy one, but the end of the story has not been written. Let us bend our efforts to make it a happy one.

* * *

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