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and microprocessors tend to thwart such learning. The home computer may bring programming to the general public but it is unlikely to promote an understanding of anything akin to mechanics or classical physics.

While there is little doubt of the importance of science and mathematics education to the future of this country, there is, and should be, controversy over how it can be improved. Unfortunately, both Davis and the House committee advocate continuance of approaches which have failed us in the past. While I take strong exception with the Administration's cuts to the NSF science education program, they do at least provide us with the opportunity to re-evaluate what we are doing. These cuts are in fact a reflection of the support that program has—both at the highest levels of NSF and among the members of the National Science board. In these circles it is generally, and not altogether erroneously, believed that the NSF science education programs were more "of the quality one would expect from a school of education" than of what one would hope to obtain from first-rate scientists. With few but critical exceptions the NSF education programs failed to attract the participation of outstanding talent.

However, eminent scientists such as Frederick Reif and Nobel Laureate Herbert Simon were participants in the new cognitively oriented programs of research in science education. Yet nowhere are these programs mentioned by either Davis or the House committee. NSF educational development programs oriented to the uses of new technology attracted mathematicians like Seymour Papert and physicists like Alfred Bork (see, *PHYSICS TODAY*, September 1981, page 24, for a description of Bork's work). Projects of this type require a decade or more of sustained effort before their results can be put to general use. Papert's LOGO system (which I believe will prove the single most important advancement in mathematics education ever) began in the early seventies and is only this winter becoming widely available. Anyone who compares the educational software generally available for micros with that in LOGO will quickly understand the value of long-term NSF support. Yet research and development programs of this type accounted for only 10% of the education budget.

Thus the danger lies not so much in the size of the cut in NSF education (though that is a serious threat) as in what has been cut (research) and in what remains (graduate fellowships, undergraduate equipment and teacher training). While I favor federal fellow-

ships, any serious shortfall in that area is likely to be picked up by industry. So is funding of essential undergraduate equipment. Furthermore, with the exception of microcomputers, I doubt we need much additional equipment to teach real physics. Gadgets only obfuscate the essential features, and I believe they stimulate the interest of teachers more than that of their students. There can be no doubt of the need to do more to train first-rate teachers, but most of our past efforts in that direction have not worked well. *New programs* are needed that can attract talent adequate to the task. In this regard I find it amusing that in all the concern over Germany, Japan and the Soviet Union, I have never heard it suggested that we look seriously at how their educational systems function. Until the best minds in American science see science education as a problem worthy of investigation, federal programs may not make much difference. The greatest tragedy of the Reagan cuts is that they eliminate those few areas in which serious work was being done.

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Working in defense

In the correspondence (August 1981, page 11) concerning the Panel on Public Affairs of the APS, Louis Rosen remarks that "One obvious way to decrease the probability of a major conflict is to make it extremely unattractive militarily, socially and economically for any nation to start a war. Physicists are certainly helping to do that."

Perhaps, but also many physicists are working on projects that may well enhance the dangers of nuclear war by accident, of pre-emptive nuclear attack, and, most serious of all, of escalation of conventional into nuclear war.

Consider, for example, the miniaturization of fission weapons and development of guidance systems that has led to the deployment in Europe of several thousand "low-yield" (order of a kiloton) high-accuracy battlefield nuclear weapons. Present NATO policy is to meet a conventional attack from the East with such weapons (because, NATO claims, its conventional forces are too weak to hold the line), and so to conduct a limited, or theater, nuclear war. Almost certainly there would be a nuclear response from the other side, and the exchange would then escalate quickly into a major nuclear war, at the very least devastating the whole of Central Europe. This is the conclusion of responsible military analysts and strategists such as the late Lord Mount-

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batten, the former UK Chief of Defence Staff Lord Carver, and the former US Secretary of Defense Harold Brown.

A second example illustrates that passive, apparently purely defensive, technology also can lead to serious destabilization. The doctrine of deterrence by Mutual Assured Destruction rests finally on the invulnerability of submarine-based intercontinental missiles. But now enormous effort is being put into technologies that might be capable of submarine detection and tracking, with, of course, concomitant vast expenditures on yet quieter and less detectable submarines. At best we will end up by paying a lot more for nuclear submarines. (At a time of serious economic recession the UK government is to spend £6000 million—say \$11 billion—on its "independent" force of four Trident submarines. The independent circumstances in which they would be used are vague beyond definition, but the expenditure is real enough, and will come from a weakening of conventional forces, thus encouraging NATO's tendency to plan to resort to nuclear weapons at an early stage of any conflict.). At worst we will lose whatever protection we had from MAD.

Rosen's superficial generalization, that better weapons will make for a safer world, is one that is accepted all too uncritically by scientists and engineers working in defense industries. The aerospace and electronics companies hold to a similar belief, but one that in their case is perhaps not devoid of self interest.

We live in a world that is close to catastrophe; it is essential that we acquire the foresight to see which developments will make it more perilous, and which less so. To then control those developments is a difficult but not impossible task; it has been done before with the Anti-Ballistic Missile Agreement, for example.

As a foreigner, it seems to me that in this direction the US has a particular responsibility, because of its role as a superpower and its immense technological strength, and a particular capability, because of the open nature of its political processes. Therefore, the work of groups such as POPA has a supranational relevance. The necessary information is far more freely available in the US than it is in most West European countries; you have had (at least until recently) a well-funded and well-staffed Arms Control and Disarmament Agency, numerous Congressional hearings, and also the 'Impact' statements from the Department of Defense to Congress on the likely repercussions of proposed weapons and systems.

A substantial fraction of the readers of PHYSICS TODAY are employed directly by defense industries, a further large number in universities and research institutes receive funding in one way or another from defense agencies (I am aware that a great deal of the funding for university research by certain US defense agencies is genuinely non-military in intent, and that this circumstance arises from the history of federal funding of research). A regular review by POPA, published in PHYSICS TODAY, on the directions being taken by research that has military implications, would help to give physicists the information whereby they can make responsible decisions about the work that they do. In the other direction, POPA should be well placed to put soundly based technical representations to government, perhaps through the Arms Control and Disarmament Agency. Both tasks will require a great deal of hard work, but both are responsibilities owed by the physics community to a world that is generally threatened, albeit unwittingly, by the results of physicists' curiosity and insight.

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THE AUTHOR COMMENTS: I have strongly emphasized the high priority I give to arms control, if we are to avoid an eventual catastrophe. However, we must also avoid catastrophe in the near term, and I believe that an adequate defense posture is essential to do that. It is therefore not quite cricket for David Caplin to interpret my remarks as a generalization that "better weapons will make a safer world." What realistic choice have we, aside from deterrence, to buy the world the time it needs to achieve the conditions which will permit arms control? Every care must, of course, be taken to ensure that deterrence doesn't fuel an arms race. It has been my experience that almost all research can have military implications. It is the technology that derives from research which may be specifically targeted and such targeting is almost always transparent.

I can, therefore, see no purpose to be served by POPA attempting to characterize research in terms of its potential military importance. This would seem to me to be a hopeless, as well as useless, expenditure of high-level expertise.

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Optical ebullience

Much as I enjoyed Peter Franken's ebullient article on optics (November,