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letters

time, suggests some recluse surrounded by piles of books, blackboards covered with equations, mostly partial differentials, and incapable of conversation with the uneducated. Of course, to be a "real" physicist you must hold a doctorate.

It is sad to say that at least I could find neither money nor time to solidify that image by obtaining my doctorate. Nor do I really know if I had what it takes had I not needed to support a loving wife and four children.

My degree has, however, permitted me a range of occupational freedom I had dreamed of but never hoped to achieve.

Yet when you read "Information Exchange," at the back of *PHYSICS TODAY*, as I have for 21 years, you seldom see BS physicists in demand for positions other than lab supervisors or repairmen. Management becomes the last hurrah in some engineering groups and this is most probably due to the "engineering" achievements you may have had.

Yes indeed, Salem, a bachelor in physics is a person of worth, if only to himself.

MARTIN T. SMITH
Lincoln, Nebraska

7/84

Ballistic missile defense

There has been a considerable amount of recent discussion about a proposed ballistic-missile defense, particularly directed energy (particle beam and laser) systems. Much of the discussion ignores or obscures the most elementary criterion for the viability of a defense system, which is that it must be less costly to shoot down an incoming missile than it is to launch another missile.

The justification can be simply shown. Suppose side A has \$a per year to spend on missile defense at an average cost of \$d per missile killed, that is, on a defense system with the capability to defend against n missiles and having a total cost of \$nd = \$a; side B has N₀ missiles to start with and \$b per year to spend on missiles at a cost of \$m per missile. At the end of Y years, the total number of missiles T which can penetrate the defense, is just the number of missiles owned by B minus the number of missiles which can be killed by A,

$$T = N_0 + bY/m - aY/d.$$

A defense strategy can only succeed if side A can outspend side B by a factor d/m.

In general, we do not expect that one side will be able or willing to outspend the other, year by year by a very large

margin. If we thus assume $b = a$, then the criterion for the feasibility of a defense system is simply $d/m < 1$. A defense system will not work unless it is cheaper to shoot down a missile than it is to build another one.

For more sophisticated models, including allowance for imperfect defense, the analysis is more involved. The general conclusion, that the average cost to shoot down a missile must be less than the cost to the offense of building an additional missile, remains valid. Any system which fails this criterion is not viable regardless of any other technical points, since it can always be saturated by the offensive side.

How do proposed ballistic-missile defense systems rate according to this criterion? Estimates¹ of the cost of a defense against the present Soviet missile force range from \$200 billion to \$500 billion. Because the Soviet missile force comprises² about 2500 missiles, this comes to a cost per kill of \$100 million to \$200 million. In contrast, a currently proposed missile system, "midgetman," is estimated³ to cost between \$10 million and \$70 million per missile. A typical Soviet missile may well be less expensive. Even using the most optimistic numbers, then, the ratio d/m for the proposed ballistic missile defense is 1.4.

Using the more pessimistic (that is, lowest) estimate of missile cost, a ballistic-missile defense would not work unless it could be made to cost less than \$25 billion—an order of magnitude less than currently quoted cost figures.

References

1. J. B. Tucker, *Technology Review*, April 1984, p. 46.
2. B. G. Levi, *PHYSICS TODAY*, March 1983, p. 43.
3. R. Garwin, *Bulletin Atomic Scientists*, August–September 1983, p. 62.

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7/84

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Elephants and mahouts

Frank Herman's description of his work on semiconductor band structure (June, page 56) brought back many memories. I knew Herman when I, too, worked at RCA, from 1950 to 1952. I remember his tales of struggle with the orthogonalized-plane-wave method. In fact, one evening over dinner at Renwick's I sought to dissuade him from his labors. I pointed out that not everyone could win a Nobel Prize! Of course, when he published his work, it came as a revelation to those of us who had learned about semiconductors from William Shockley's well written but somewhat simplistic book¹.