technology commercial concern.

Over the years the multiprogram national labs have collected projects, groups and program remnants that are weakly related to their ostensible missions. This situation is not the fault of the labs *per se*. Changing national priorities coupled with the primal institutional survival instinct led them to ride the ebb and flow of program opportunities over the years (for example, nuclear power, solar energy, strategic defense and environmental restoration). These labs now possess outstanding human resources, many interesting technologies and impressive facilities. What they lack are missions that justify their present sizes.

Reliance on lab–industry technology transfer and partnerships as a new mission is at best a short-term solution. At worst, it will fail because of a simple but profound cultural mismatch. The missing ingredient is, in my view, the desire of the national lab researcher to accept the primacy of the customer. Without this, the researcher finds it very difficult to put satisfaction of the customer requirements above his or her favorite technical interests. No criticism of the lab researcher is intended here; indeed he or she would be justified in complaining of a rule change in midgame if such a customer culture were imposed.

It is, however, a fact of business life that responding to the market's pull leads to commercial success more often than does doggedly pushing a technology. The vast majority of technologies, however interesting they may be in and of themselves, are incremental advances that have commercial relevance only when they find a market niche. Of course technologies do appear that are so revolutionary as to create new industries, but these are clearly the exceptions. The more likely path to success involves understanding the market; assembling a team with the relevant technical, business and customer relations skills; and developing a solution or product design that uses whatever technologies offer the best value. Hoping a technology will create a market is a risky approach to making it in the commercial world.

The total challenge, then, is to size the labs to address bona fide missions, maximize the return on the existing technology backlog and provide career opportunities for affected scientists and engineers. The flood of recent CRADA (cooperative research and development agreement) signings notwithstanding, industry partnerships and technology transfer will contribute little to these objectives if ideas, technologies and the odd researcher are simply tossed over the transom into the commercial sea to sink or swim.

We might well do better by borrowing from the proven venture formula that combines a motivated technical and business team, a visionary entrepreneur and a clear focus on the market. Why not empower the multiprogram labs to "right-size" by shedding small teams or units that would find natural homes as small companies or parts of larger companies? One could accomplish this by allowing proven entrepreneurs and business builders to work within the labs to gather teams with the skills and capabilities that are relevant to particular markets. Researchers could "export" technologies and patent rights to their new homes as appropriate.

Management might be initially uncomfortable with the idea of divesting itself of talent (and associated funding, however meager). However, if one is serious about "right-sizing" the labs in a humane manner that returns something for the very significant taxpayer investment made over the years, there could be no more effective way than creating viable, growth-oriented businesses. Perhaps then someday we will be able to follow a chain of growth companies back to the present-day labs, in the same way the computer and electronics industry traces its genealogy to the mainframe behemoths of the 1960s.

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Arms (One vs Two) and the Physicist

In these last decades of the 20th century, physics is at a crossroads. One alternative, in its extreme form, is to define (or continue to define) physics as the most fundamental of all natural sciences. In this view the mandate of a "real" physicist is to find new knowledge, while those in the more specialized disciplines (ranging from materials engineering through medicine) put this new knowledge to use in the context of practical goals within the human community and the global economy. I refer to this as the "one-armed physicist" approach.

My sense of the matter is that while this time-honored paradigm reserves an appropriate place for physics as a foundation discipline, it also lies at the heart of the limited choices that new physicists encounter when trying to find a place for themselves in the economy. Having worked in more than one globally competitive industry, I sense further that this alternative harms our collective problem-solving ability by leaving modern industry, except in the most fundamental physical science areas, without an established way to hire "guaranteed-useful" researchers.

The other alternative is to make the distinction between engineering and physics on the basis not of goals but of methods. A physicist (or a scientist in general) then becomes redefined as a researcher equipped to apply *basic insight* in her or his field(s) of expertise to the solution of applied as well as fundamental problems, while an engineer is trained in the application of *established methods* (again to the solution of either type of problem).

To turn out bona fide "two-armed physicists" (those trained to use their basic insights in the solution of both fundamental and applied problems), educational institutions must provide their physics students with:

▷ intellectual relish for the solution of problems posed from without as well as from within

▷ the skills and inclination for getting work done and communicated by a specified time, especially within the context of externally imposed deadlines

▷ knowledge of and experience with tools of general use in the modern global community, including communication, fund-raising and management strategies

▷ experience in work on interdisciplinary and interinstitutional teams of the sort commonly required for the solution of problems posed by the outside world

▷ training in the temperament and skills helpful for synergistically solving short-term interdisciplinary problems posed from without while *at the same time* (and at their own initiative, if need be) making progress in more fundamental matters.

(A "natural philosophy" emphasis in each department might be established for those students who want to stick with the one-armed route.)

How many institutions provide and test for these things in their advanced degree programs in physics? I submit that those institutions that focus on "both arms" provide graduates who will be successful in a much wider range of places than will graduates of those institutions (many among the most respected) that do not.

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Accelerators for Neutron Therapy

Henry G. Blosser's article "Medical Cyclotrons" (October 1993, page 70) mentions the importance of linear accelerators as radiation sources for photon therapy of cancer but omits mention of their importance for neutron therapy.

In fact, the scientific work that underlies neutron therapy was done with a homemade, 400-kV Cockcroft–Walton accelerator in Britain during World War II by Louis H. Gray and coworkers using monoenergetic D–D neutrons.[1] Among the several important results of that work is knowledge of the strong dependence of the relative biological effectiveness (RBE) of neutrons on their energy, so that the energy spectrum of neutrons used for treatment is essential for determination of the neutron dose.[2] Hence methods of neutron spectrometry (which I wrote about in PHYSICS TODAY, August 1967, page 39) must play an important role when using cyclotron neutron sources, which irradiate patients with polyergic neutrons whose penetration and biological effectiveness vary greatly depending on their energy. I have discussed the respective roles of cyclotrons and linear accelerators for neutron therapy in the medical literature.[3]

For almost 20 years a facility at the University Hospital in Hamburg–Eppendorf, Germany, has been treating patients with 14-MeV D–T neutrons from a compact, inexpensive 500-kV machine built and installed by Marshall R. Cleland and Radiation Dynamics Inc.[4] Since 1985 that machine has been fitted with a unique, American-patented beam-handling and target system[5] that provides an order-of-magnitude increase in the life of solid tritiated targets—a critical feature of such machines—under deuteron bombardment. The failure thus far to produce a usable, low-voltage accelerator for neutron therapy in the US has recently received critical attention[6] and presents an important challenge to American accelerator management and technology.

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