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Like many others, we read Daniel Sarewitz's article with interest.

On one point, we agree with him: That the close coupling between science and technology *can* be enormously beneficial—our own experience in the physical sciences and engineering has taught us this. Examples abound of virtuous cycles in which science and technology have fed each other and accelerated progress in both, including the Nobel Prize–winning and society-transforming scientific discovery of the transistor effect and technological invention of the transistor itself.

On another point, we don't entirely agree with Sarewitz: That the close coupling between science and technology is *always* beneficial, and hence should be forced. Our experience is that the benefit is situational. Research policy prescriptions must allow for the flexibility to couple or not, as appropriate to the mission at hand and its stage of development. That fluidity is exemplified by the evolution of quantum mechanics as a knowledge domain: In its early years, it was driven primarily by intellectual curiosity; in its middle years, it was symbiotic with a wide range of technologies (including the transistor mentioned above); and, in its most recent years, it is entering a new stage of symbiosis with quantum information technology.

That said, we understand why it is tempting to argue for forced coupling.

One argument is long-standing: Because a common (though by no means the only) route by which science impacts society is through technology, close coupling would seem to increase the likelihood that new science will be useful to society. But, as said eloquently by Robert Merton, the distinguished social scientist of science:

> Ideally that empirical object is selected for study which enables one to investigate a scientific problem to particularly good advantage. Often, these intellectually strategic objects hold little intrinsic interest, either for the investigator or anyone else.... It is not an intrinsic interest in the fruit fly or the bacteriophage that leads the geneticist to devote so much attention to them. It is only that they have been found to provide strategic materials for working out selected problems of genetic transmission.

In other words, technological usefulness cannot *always* be the criterion for choosing a particular object for scientific study. The forced coupling between science and technology that such a criterion represents can be counterproductive (as of course can be a forced *separation* between science and technology).

Another argument for the forced coupling of science and technology is newer: It provides a powerful cross-checking that would seem to minimize scientific knowledge that is "contestable, unreliable, unusable, or flat-out wrong," as Sarewitz puts it. Technology is indeed often the ultimate real-world test of scientific understanding! But it is important to remember that, in its earliest stages, research *always* proceeds through a stage in which it is fraught with error, mistakes, and wrong turns. This is true even in the physical sciences and engineering, often thought of as the gold standard for science and engineering knowledge.

The geocentric universe, phlogiston, the luminiferous aether: all of these were not so much wrong turns as symptoms of early-stage exploration of difficult physical-science knowledge domains. The physical-, life-, and social-science knowledge domains that Sarewitz mentions—metastatic cancer, climate change, growth economics, dietary standards—are similarly (if not more) complex, and similar wrong turns can be expected. It is human nature to forget past errors made en route to current knowledge: As Thomas Kuhn argued, once a new paradigm has emerged, we become unable to see, much less remember, old and mistaken paradigms that we once believed. And, by forgetting that in now-more-mature knowledge domains we once made errors, we tend to believe that in less-mature knowledge domains we can avoid them. But 20/20 hindsight does *not* imply a newfound ability for 20/20 foresight.

Now, we do not mean to suggest that research processes, institutions, and policies cannot be improved. Perhaps one can increase the probability that research will be useful to society without undue harm to research itself; and perhaps one can avoid some wrong research turns while enhancing the low-probability but truly transformational research turns. These are grand, timely, and important challenges to the social scientists and engineers of research. In the meantime, we should try to meet those challenges with a nuance appropriate to the mission at hand and to its stage of development: Science and technology will at times benefit enormously from a close coupling, but at other times will benefit just as much from independent development.

Jeff Tsao
Distinguished Member of Technical Staff
Sandia National Labs

Venkatesh Narayanamurti
Technology and Public Policy
Dept. of Engineering and Applied Sciences
Harvard University