made? Similarly, how much knowledge in other fields remains classified?

More important, how much talent and work have we wasted over the last few decades? The advances in physics and technology that were required to cancel atmospheric distortion and to observe transient gamma-ray events are no small achievements; there have clearly been some creative, brilliant minds at work here. How many more such minds are focusing their efforts on ever more accurate cruise missiles or command-and-control software, instead of (let's say) more efficient high-speed trains or better models of climate change? We have used the work of many of our best scientists to make stockpiles of weapons that now have little or no use. I hope that we can recover, intellectually and economically, from this squandered investment.

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US Nuclear Stockpile Safety: Review No. 2

Sidney Drell, in his November 1991 letter (page 9), writes that "last year we [the three-man House Armed Services Committee Panel on Nuclear Weapons Safety that he headed] did the first (*and only*) comprehensive review of the safety of the US nuclear stockpile since World War II and the subsequent buildup to more than 20 000 warheads" (emphasis added).

At the request of several members of the United States Senate and House of Representatives, I also prepared a technical report on the same subject, entitled "Report to Congress: Assessment of the Safety of US Nuclear Weapons and Related Nuclear Test Requirements" (UCRL-LR-107454, Lawrence Livermore National Laboratory, Livermore, California, July 1991). Drell knew that I was preparing such a report and was included among those to whom it was distributed.

My report deals with many, but not all, of the topics dealt with in his report. The converse is also true. In particular, my report discusses in some detail the question of how many nuclear explosive tests would be needed to implement different options under consideration for improving the safety of the US nuclear weapons stockpile, and how long it would take to complete them. His panel's report is silent concerning this politically important technical question.

Copies of my report are available from the National Technical Information Service, US Department of Commerce, 5285 Port Royal Road, Springfield VA 22161.

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Physics Departments: Don't Chop the Shop

After years of watching physics departments being herded down the wrong path by forces they were unable to resist, I finally feel compelled to write. I refer to the virtual disappearance in the US of the open departmental physics machine shop. Before World War II and the advent of government research contracts for university research in physics, physics departments usually had very little money for *buying* things, but they had good university-supported facilities for *making* things. The open physics shop was just as much a part of physics education as the library. As far as I know, the Berkleley physics department is the last bastion of this arrangement in the US, and its members, such as myself, are bloody from the recurrent strife involved in defending it against administrators for whom a university-supported research facility (other than the library), existing outside the usual system where almost everything related to research is charged to a grant, is an anomaly foreign to their experience. My thesis is that everyone is out of step but us. My concern is, Can anything be done about it?

With an open shop, a physicist and his or her students who want to try something new can spend their time designing an apparatus, submitting it to the shop for fabrication, and testing the idea when the shop work is complete. Without the open shop, the physicist has to start by trying to get a grant—a procedure that we all know is long and arduous even if the idea is smashing. The short turnaround time that an open shop permits is especially important to the young assistant professor, who has to involve students and make his or her mark as a productive and innovative researcher within strict time constraints. (Our open shops at Berkeley have given us a real edge in recruiting gifted young experimentalists, by the way.)

And look at it from the other end. In the open shop the mechanicians are busy making *things*, not making *estimates* and keeping books. In the open shop, where orders pile up, the mechanicians' goals are to have the physicists and students satisfied and "off their backs" as soon as possible, a climate that stimulates their ingenuity to make things simpler and easier to fabricate. In the shop that depends on recharges for its existence, the goal (unconsciously, of course) can become one of stretching jobs out to increase revenues.

I understand that in Britain the university grants committees will not even consider funding a project unless the university supports adequate shop facilities independently of the grants. If that is so, our British cousins have been wiser than we.

What can be done? I think this is the sort of issue that the National Academy's Government–University–Industry Roundtable, which has been finding ways to improve the collective national research enterprise, ought to address. A start would be to have those institutions that substantially support research fabrication in their own shops receive automatic and generous credit for that support by the funding agencies when their projects are being evaluated for institutional cost-sharing. I submit that open shops make even more sense for universities than cost-sharing on expensive pieces of equipment. Open shops nurture the research enterprise across the board. And innovative homemade instruments are more apt to lead to scientific and technological advances than off-the-shelf ones.

Nor should one forget the importance of supporting open shops for physics courses. Creative teaching of lower-division courses and of experimental courses in the upper division requires good shop facilities that are freely available as a resource to the instructional staff.

I see no reason why faculty and administrators should be opposed on this question. Our libraries are supported in part by overhead monies derived as legitimate indirect costs of contract research. Why not shops as well?

Maybe other physics departments are fighting the good fight and still maintaining open shops. If so, we would like to hear from them. Solidarity forever! Maybe things can be turned around.

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Don't Omit Population from Energy Equation

In their article "US Energy Transition: Getting from Here to There" (July 1991, page 22), John H. Gibbons

and Peter D. Blair ignore a critical factor in the energy equation: the US population. Energy impact equals total population times energy impact per person. In a nine-page article there is not a single sentence that even mentions exponential population growth (currently 1% a year in the US and nearly 2% a year worldwide). In California, for example, the population doubling time is only 30 years. At such a pace, by the end of the 21st century California's population will equal the present population of the entire US. In the face of such growth, even the most enlightened energy policies will fail.

To requote the ancient Chinese saying quoted by Gibbons and Blair: "If you do not change your direction, you are very likely to end up where you are heading."

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2/92

Has Psychokinesis Met Science's Measure?

Philip Anderson (October 1991, page 146) says, "[W]ithin my competence as a theorist . . . physics as it is practiced, and specifically precise mensuration, is not compatible with [Robert G.] Jahn's claims" (that is, claims of the existence of psychokinesis). Anderson's idea is, no doubt, that if mind affected matter, this would disturb the results of laboratory experiments. An equivalent argument applied to chemistry would lead to the following: "Chemistry as it is practiced rests on the principle of the invariance of atoms, and so is incompatible with the idea that elements can be transmuted." The latter conclusion is not, I suspect, one whose truth Anderson would be as eager to assert in the columns of PHYSICS TODAY as the one quoted above.

Equally suspect is Anderson's second argument designed to persuade his readers to disregard Jahn's results, that is, Anderson's reference to the use of Bayesian statistical methods. I am willing to accept his claim that the use of such methods would make Jahn's numbers less favorable. But unfortunately the argument stops short at that point; Anderson does not inform us what the result would be if Bayesian methods were applied, and especially does not tell us the answer to the crucial question, Do Jahn's results remain significant if this analysis is done, or not? Why this reticence?

For Anderson and for other skeptics, belief in the paranormal is irrational. But very often skeptics, in their uncritical attempts to persuade others of their point of view, fall back on inadequate arguments themselves. Those examined above provide clear illustrations.

What, then, about irrationality? Is it irrational to assert that under special conditions psychokinesis can occur, although most of the time it does not? No more irrational, I think, than to assert that while for most people walking on a tightrope across a ravine is an impossible task, it may nevertheless be possible under sufficiently favorable conditions (for example, with suitable dedication, training and concentration); again, I suggest, no more irrational than to assert that while an amount of uranium of mass on the order of a kilogram generates spontaneously an amount of heat requiring sensitive instruments to detect at all, a suitably larger amount can generate enough energy to provide power for a large city. (Further, as one of my collaborators, social anthropologist and parapsychologist Marilyn Schlitz, of the Mind Science Foundation, San Antonio, Texas, has noted, there exist analogies that may be more directly relevant in the field of social systems, an example being the way under special conditions in a society particular ideas that individuals have may spread widely, although in the vast majority of cases the effects of individuals' ideas remain localized close to their sources.) Finally, is it really irrational or unscientific, as some skeptics seem to think, to suggest that a relationship may exist between John Bell's nonlocal connections and telepathy? In this regard, I wish to draw attention to the publication in a reputable physics journal of a paper[1] that gives a rational account of how the two could be related and of why the latter kind of coupling should be possible in biosystems but not under the conditions of the normal physics experiment.

I hope that some readers may by now have picked up a message that skeptics might prefer they did not pick up: that psychic phenomena may be both consistent with physics and conceivable in rational terms; and, as a corollary, that many of the experiments on the paranormal may be measuring genuine phenomena that it should be the goal of science to try to understand.

Finally, I should like to recommend to readers not wanting to be caught in a paradigm that may be outliving its relevance to our understanding of the natural world that they read David Bohm's elegant discussion of his concept "soma-significance."[2]

References

1. B. D. Josephson, F. Pallikari-Viras, Found. Phys. **21**, 197 (1991).
2. D. Bohm, in *The Search for Meaning*, P. Pylkkänen, ed., Crucible, Wellingborough, Northants, England (1989), p. 43.

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ANDERSON REPLIES: The non sequitur in Brian's first paragraph gives us an object lesson in the scientific method. Artificial transmutation of elements was accepted almost instantly after the first observation, as the history of science goes, because the effects were reliably predictable and totally reproducible. I am not aware of any psychokinetic effects that have been reliably predicted in advance as to nature, sign and magnitude.

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How Tiny Bubbles Can Cause Big Booms

I read with interest the news story "Light Comes from Ultrasonic Cavitation in Picosecond Pulses," by Barbara Goss Levi (November 1991, page 17), which describes, among other things, the generation of high temperatures during the collapse of cavitation bubbles and how these high temperatures have been thought to produce metallic glass when iron pentacarbonyl is irradiated with ultrasound. One area of considerable practical interest not mentioned in the story or in the references is the sensitization of explosives by microscopic bubbles.[1] Over two decades ago, Frank Philip Bowden and I showed, using high-speed photography, that when a microscopic bubble is rapidly compressed onto an explosive crystal, it can cause the initiation of an explosion in less than a microsecond.[2] The crystal acts as a fast-response thermometer: As soon as its temperature is high enough, an explosion results. Some scientists working in the field of explosives have argued, however, that not enough heat transfer can occur from the compressed gas to an adjacent surface in such a short time.[3] In view of the formation of metallic glass by cavitation, the work mentioned above and some other work on the sensitivity of explosives,[4] it appears quite clear that the heat

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