namely the government.

So, how well have such investors done over the last 12 years? They have made lots of money in programmed trading, where by using statistical modeling, one can pump money from fluctuations by trading on volatility. They've made lots of money in leveraged buyouts. Basically, they've learned that one can get huge returns on investments without having to compete at all; all one has to do is sell off capacity.

How about the issue of investors' actually exercising control over the corporations? Unless one has the leverage to be a raider, most investors don't have much control at all. Large companies consider most investors nuisances. Management appeals regularly to the Securities and Exchange Commission to have stockholders' access limited, complaining that the staff and support required to handle stockholder requests cost millions annually. One impact stockholders do have is to urge companies to increase immediate quarterly returns at the expense of long-term projects. Companies with lots of these projects thus tend to be somewhat undervalued and look like good takeover targets.

How about the question of the coupling of stock market performance to actual corporate competitiveness? While there have been some very dramatic stock market failures recently, the market has done very well for a nation plagued by problems with international competition. The Dow Jones industrial average, recently in the 3300 range, up from the 1000 range a decade ago, does not look like an aggregate investment picture reflecting serious structural problems with production and competitiveness.

If stockholders do not have significant influence over how production is managed and actually seem to have benefited in the short term from the reduction in competitive capacity, what do they need physicists for? Most applications of discoveries from basic research seem to have taken around two decades to develop. If investors can make lots of money by not making anything, why pay physicists to work 20 years on the kinds of research that take a basic discovery to the market? Remember, this is the same group of investors who profited by giving up TV to the Japanese and who decided that the costs of developing a consumer electronics version of the VCR just could not be justified.

Yet the same voice that favors such investment policies has found expression in the idea that the physics community should be more responsible to society in bringing critical technologies to market. By the standards described above, this responsibility to society is to be measured solely by returns on investment. With attitudes persisting that research is just too expensive and that competitive development takes too much off the short-term returns on investment, it becomes difficult to see how physics can justify itself.

In a way, the idea that physics should be made more accountable to investment interests and that its recent performance has been "pie in the sky" is somewhat mythical. If we examine the last 20 to 40 years, we see that the notion that physics, and basic research in general, has failed to contribute to our economy and the interests of investors is ludicrous: What would be the delta to our economy without semiconductor electronics, laser technology in communications and consumer electronics, not to mention physics applications in health and medicine, magnetic resonance and other imaging technologies, microwave and satellite communications, and so forth? That physicists have somehow changed in the last 20 years in such a way that we don't have anything more to contribute is just as laughable.

What things is physics doing today that will have practical impact? There's mesoscale physics: When chips get dense enough that the thermodynamics of depletion layers starts to verge on the border of dynamics and stochastic fluctuation, and band structures start to look like discrete transitions, there will be significant impact not only on how traditional design is handled but also on what kinds of new devices might be constructible. There are single-electron devices and large-scale problems such as protein folding and other interdisciplinary studies. Nonlinear physics, chaos and dynamical systems show up in a wide range of problems, including everyday systems such as the weather. Lab techniques such as picosecond spectrometry, scanning tunneling microscopy and nanoscale technology are probing and manipulating matter on scales only dreamed of 15 years ago. It's an exciting time to do physics. The community is exploring such a wide range of problems. Yet there are connections between these areas that are often subtle. Any sizable reduction in the population of active researchers would not just seriously do damage to our pursuit of many interesting questions but also cause the mutual contributions to suffer incalculably.

If physics looks so good right now, what is the real problem with technology transfer? I believe the problem has to do not so much with *doing* technology transfer as with *valuing* it. Right now, our investment and corporate culture has a problem when it comes to evaluating returns on investment. This isn't to say there are not some systemic problems: Technology becomes obsolete at very high rates. The cost required to keep at the competitive cutting edge is high and does not maintain its value for long. It is hard to maintain accustomed profit margins in the face of such demands. Intellectual assets also don't have a long shelf life. Yet the most permanent assets companies can have are self-renewing and can remain productive and competitive for 20 years or more. The problem is that they walk around on two legs and go home at night. Their expense looks to investors and management like competition for profit margin rather than worthwhile investment. It is hard to see researchers as involved participants making an investment of their loyalty and careers in developing products and bringing them to market.

I don't think the problem with technology transfer has been the fault of physics. Nor do I feel that as a community we are unwilling to participate in solutions to the problems we've been facing, as some people have accused. I suspect those people have misinterpreted the indignation that many bright people who, having been trying for a long time to make a technology transfer to reluctant investors, feel when told they haven't been trying hard enough. It's becoming clear that our economic health cannot just be measured by return on investment, but that it has to be measured by technological development, employment rates, competitiveness and taking products to market. That's where physicists do have contributions to make.

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Cosmic Background: No Conflict with Relativity

In a letter that appeared with the headline "Reconciling COBE Data with Relativity" (March, page 13) Robert J. Yaes asks why the cosmic microwave background does not constitute a privileged reference frame.

If it does, he argues, it would appear to violate the relativity principle of both special and general relativity, which is often taken to be the assertion that no such frame exists. Unfortunately there is some confusion about the content of the principle of relativity, just as there is about the principle of general covariance, which underlies the general theory of relativity.

The resolution of this apparent dichotomy comes from the realization that the relativity principle is in fact a statement about the invariance properties of the *laws* governing the behavior of physical systems and not about the invariance properties of particular *states* of those systems. In general the invariance properties of such states are a subset of the invariance properties of the laws governing those systems. No one is bothered, for example, by the fact that the underlying invariance of the laws of motion with respect to arbitrary spatial rotations is violated on the surface of the Earth. One recognizes that the Earth itself must be considered a part of the system and that the laws that describe it and the systems on it together are rotationally invariant. Likewise, the totality of laws—general relativity, hydrodynamics and so on—that together govern the large-scale behavior of the universe are invariant under local Lorentz transformations, while a particular state of the universe allowed by those laws is in general not.

In point of fact, one does not need the cosmic microwave background to define a global reference frame. In principle one could have used the average distribution of matter in the universe to define such a frame and could have measured the velocity of the Earth with respect to this frame long before the cosmic microwave background was discovered.

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An important feature of the relativity principle can be illustrated in response to the concern expressed in Robert J. Yaes's recent letter. As Yaes notes, the principle states that "no experiment . . . can determine a preferred reference frame," and he wonders whether the cosmic microwave background's anisotropy in all but one reference frame does not violate this principle. It does not, because a preference of the type implied in the principle is not established by the shape of the microwave background. The reference frame in which the distribution is isotropic can be said to constitute a preferred frame, but only in respect to the particular way in which the expansion began. There must be some frame in which the general expansion is most symmetrically viewed, and in this frame the background radiation is, unsurprisingly, isotropic.

What the relativity principle rules out is a reference frame that is preferred on the basis of how the *laws* of physics work. Preferential status of this type would exist, for example, if electromagnetic radiation in empty space traveled at the speed predicted by Maxwell's equations only as measured in one particular frame.

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Robert Yaes raises the question of whether the existence of the cosmic microwave background, now observed so precisely with the Cosmic Background Explorer, is compatible with the principle of relativity, which Einstein phrased as follows: "The laws by which the states of physical systems undergo change are not affected, whether these changes of state be referred to the one or the other of two systems of coordinates in uniform translatory motion."[1] Although I do not claim to provide an "expert" response to that question, as desired by Yaes, it is my understanding that the principle of relativity is not necessarily violated by the mere existence of a universal reference frame. The laws of physics can still be invariant under some transformation of coordinates. This transformation is not specified by the principle of relativity itself, although we have discovered so far that Nature respects Lorentz invariance (the principle of the constancy of the velocity of light). What is really at issue here is whether an observer can perform purely local measurements to reveal his state of motion with respect to a universal reference frame. If there existed some *interaction* that violated Lorentz invariance, then velocity-dependent effects could become locally apparent to a moving observer. It is an open question as to whether such an interaction exists and, if it does, what defines the true rest frame respected by this interaction. It has become commonplace in tests of special and general relativity to assume that this rest frame is defined by the cosmic microwave background, but that need not be the case.

Nevertheless, our knowledge of the existence of the microwave background (which was unknown to Einstein) compels us to perform new tests of relativity that could reveal a local dependence upon our apparent motion defined by the dipole anisotropy. Recently a group of us at the Jet Propulsion Laboratory have devised a new test of relativity involving atomic frequency standards and fiber optic instrumentation developed by the NASA Deep Space Network.[2] In the experiment, an atomic frequency standard is used to modulate a laser carrier signal that is propagated along an optical fiber to another atomic frequency standard several kilometers away. Unlike in the Michelson–Morley experiment, the signal is propagated directly from one point in space to another. A violation of relativity would be apparent as a variation in the phase delay of the signal as the orientation of the system varies from the rotation of the Earth. It is possible to achieve a high degree of precision with this test, provided that adequate funding can be obtained for necessary refinements.

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SSC: Of Finances and Fundamentality

Five hundred years after Copernicus directed our view away from the Earth and toward the larger universe, it seems that certain physicists still feel that they are the center of the universe. The letter to members of Congress urging the approval of funds for the Superconducting Super Collider (see PHYSICS TODAY, August 1992, page 59) is hardly a testimony to the broad-mindedness of physicists.

The authors of that letter wrote, "The approval of the SSC project in 1990 was widely acclaimed as our nation's firm commitment to be a leader in this scientific age." As a physicist working in a biological science environment, I can assure you that not every scientist, nor for that matter every other citizen, believes that spending tens of billions of dol-

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