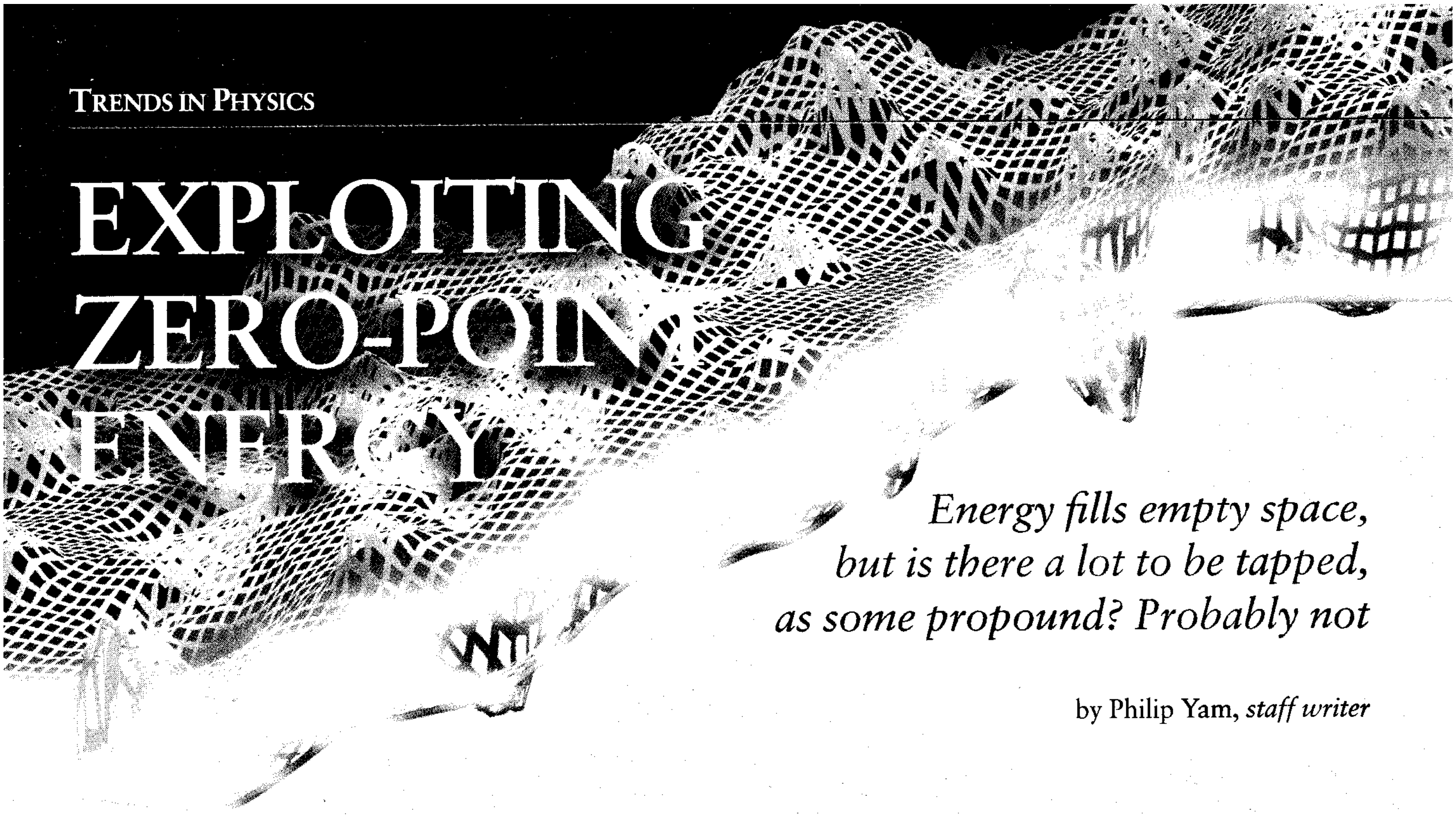


EXPLOITING ZERO-POINT ENERGY

Energy fills empty space, but is there a lot to be tapped, as some propound? Probably not

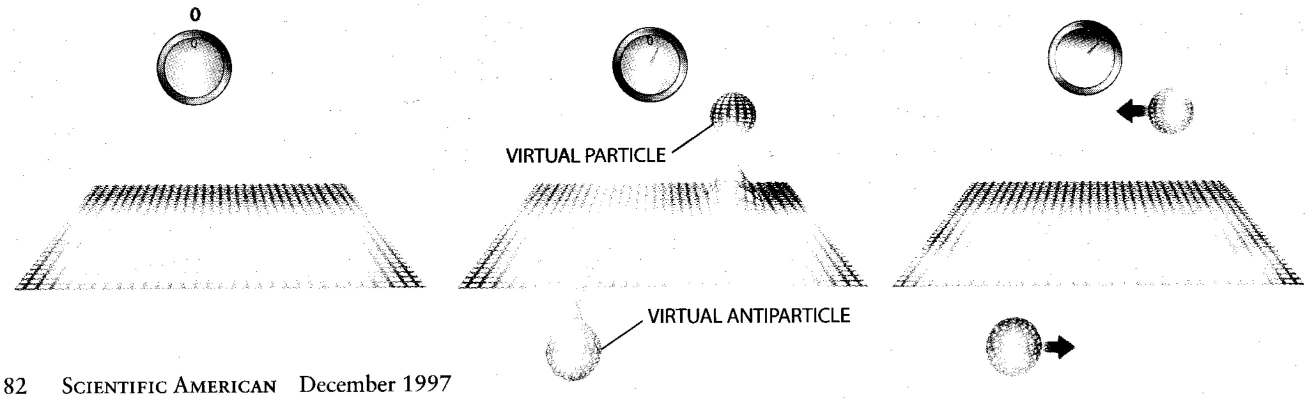
by Philip Yam, *staff writer*

Something for nothing. That's the reason for the gurgling water, ultrasonic transducers, heat-measuring calorimeters, data-plotting software and other technological trappings—some seemingly of the backyard variety—inside the Institute for Advanced Studies in Austin, Tex. One would not confuse this laboratory with the similarly named but far more renowned one in Princeton, N.J., where Albert Einstein and other physicists have probed fundamental secrets of space and time. The one in Austin is more modestly appointed, but its goals are no less revolutionary. The researchers here test machinery that, inventors assert, can extract energy from empty space.

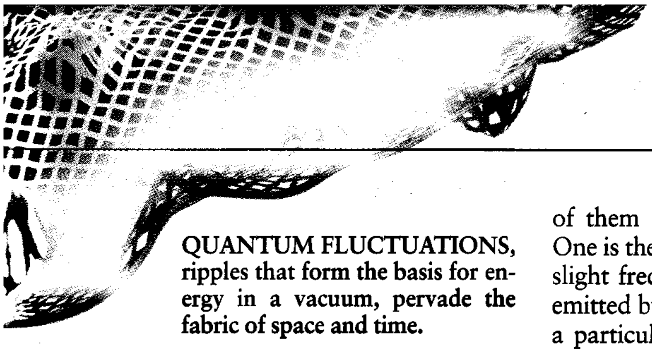
Claims for perpetual-motion machines and other free-energy devices still persist, of course, even though they inevitably turn out to violate at least one law of thermodynamics. Energy in the vacuum, though, is very much real. According to modern physics, a vacuum isn't a pocket of nothingness. It churns with unseen activity even at absolute zero, the temperature defined as the point at which all molecular motion ceases.

Exactly how much "zero-point energy" resides in the vacuum is unknown. Some cosmologists have speculated that at the beginning of the universe, when conditions everywhere were more like those inside a black hole, vacuum energy was high and may have even triggered the big bang. Today the energy level should be lower. But to a few optimists, a rich supply still awaits if only we knew how to tap into it. These maverick proponents have postulated that the zero-point energy could explain "cold fusion," inertia and other phenomena and might someday serve as part of a "negative mass" system for propelling spacecraft. In an interview taped for PBS's *Scientific American Frontiers*, which aired in November, Harold E. Puthoff, the director of the Institute for Advanced Studies, observed: "For the chauvinists in the field like ourselves, we think the 21st century could be the zero-point-energy age."

That conceit is not shared by the majority of physicists; some even regard such optimism as pseudoscience that could leech funds from legitimate research. The conventional view is that the energy in the vacuum is minuscule. In fact, were it infinite, the nature of the universe would be vastly different: you would not be able to see in a straight line beyond a few kilometers. "The vacuum has some mystique about it," remarks Peter W. Milonni, a physicist at Los Alamos National Laboratory who wrote a text on the subject in 1994 called *The Quantum Vacuum*. "One has to be really careful about taking the concept too naively." Steve K. Lamoreaux, also at Los Alamos, is harsher: "The zero-point-energy community is more successful at advertising and self-promotion than they are at carrying out bona fide scientific research."



ILLUSTRATIONS BY MICHAEL GOODMAN



QUANTUM FLUCTUATIONS, **ripples that form the basis for energy in a vacuum, pervade the fabric of space and time.**

The concept of zero-point energy derives from a well-known idea in quantum mechanics, the science that accounts for the behavior of particles near the atom's size. Specifically, zero-point energy emerges from Heisenberg's uncertainty principle, which limits the accuracy of measurements. The German physicist Werner Heisenberg determined in 1927 that it is impossible to learn both the position and the momentum of a particle to some high degree of accuracy: if the position is known perfectly, then the momentum is completely unknown, and vice versa. That's why at absolute zero, a particle must still be jittering about: if it were at a complete standstill, its momentum and position would both be known precisely and simultaneously, violating the uncertainty principle.

Energy and Uncertainty

Like position and momentum, energy and time also obey Heisenberg's rule. Residual energy must therefore exist in empty space: to be certain that the energy was zero, one would have to take energy measurements in that volume of space forever. And given the equivalence of mass and energy expressed by Einstein's $E = mc^2$, the vacuum energy must be able to create particles. They flash briefly into existence and expire within an interval dictated by the uncertainty principle.

This zero-point energy (which comes from all the types of force fields—electromagnetic, gravitational and nuclear) makes itself felt in several ways, most of them obvious only to a physicist. One is the Lamb shift, which refers to a slight frequency alteration in the light emitted by an excited atom. Another is a particular kind of inescapable, low-level noise that registers in electronic and optical equipment.

Perhaps the most dramatic example, though, is the Casimir effect. In 1948 the Dutch physicist H.B.G. Casimir calculated that two metal plates brought sufficiently close together will attract each other very slightly. The reason is that the narrow distance between the plates allows only small, high-frequency electromagnetic "modes" of the vacuum energy to squeeze in between. The plates block out most of the other, bigger modes. In a way, each plate acts as an airplane wing, which creates low pressure on one side and high pressure on the other. The difference in force knocks the plates toward each other.

While at the University of Washington, Lamoreaux conducted the most precise measurement of the Casimir effect. Helped by his student Dev Sen, Lamoreaux used gold-coated quartz surfaces as his plates. One plate was attached to the end of a sensitive torsion pendulum; if that plate moved toward the other, the pendulum would twist. A laser could measure the twisting of the pendulum down to 0.01-micron accuracy. A current applied to a stack of piezoelectric components moved one Casimir plate; an electronic feedback system countered that movement, keeping the pendulum still. Zero-point-energy effects showed up as changes in the amount of current needed to maintain the pendulum's position. Lamoreaux found that the plates generated about 100 microdynes (one nanonewton) of force. That "corresponds to the weight of a blood cell in the earth's gravitational field," Lamoreaux states. The result falls within 5 percent of Casimir's prediction for that particular plate separation and geometry.

Zero for Zero-Point Devices

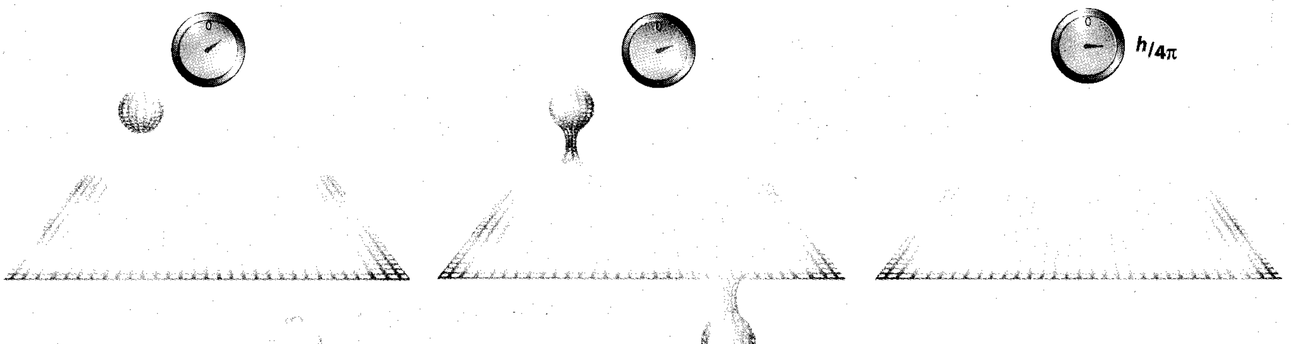
Demonstrating the existence of zero-point energy is one thing; extracting useful amounts is another. Puthoff's institute, which he likens to a mini Bureau of Standards, has examined about 10 devices over the past 10 years and found nothing workable.

One contraption, whose Russian inventor claimed could produce kilowatts of excess heat, supposedly relied on sonoluminescence, the conversion of sound into light. Bombarding water with sound to create air bubbles can, under the right conditions, lead to bubbles that collapse and give off flashes of light. Conventional thinking explains sonoluminescence in terms of a shock wave launched within the collapsing bubble, which heats the interior to a flash point.

Following up on the work of the late Nobelist Julian Schwinger, a few workers cite zero-point energy as the cause. Basically, the surface of the bubble is supposed to act as the Casimir force plates; as the bubble shrinks, it starts to exclude the bigger modes of the vacuum energy, which is converted to light. That theory notwithstanding, Puthoff and his colleague Scott Little tested the device and changed the details a number of times but never found excess energy.

Puthoff believes atoms, not bubbles, offer a better approach. His idea hinges

VIRTUAL PARTICLES **can spontaneously flash into existence from the energy of quantum fluctuations. The particles, which arise as matter-antimatter twins, can interact but must, in accordance with Heisenberg's uncertainty principle, disappear within an interval set by Planck's constant, *h*.**



on an unproved hypothesis: that zero-point energy is what keeps electrons in an atom orbiting the nucleus. In classical physics, circulating charges like an orbiting electron lose energy through radiation; what keeps the electron zipping around the nucleus is, to Puthoff, zero-point energy that the electron continuously absorbs. (Quantum mechanics as originally formulated simply states that an electron in an atom must have some minimum, ground-state energy.)

Physicists have demonstrated that a small enough cavity can suppress the natural inclination of a trapped, excited particle to give up some energy and drop to a lower energy state [see "Cavity Quantum Electrodynamics," by Serge Haroche and Jean-Michel Raimond; Scientific American, April 1993]. Basically, the cavity is so small that it can exclude some of the lower-frequency vacuum fluctuations, which the excited atom needs to emit light and drop to a lower energy level. The cavity in effect controls the vacuum fluctuations.

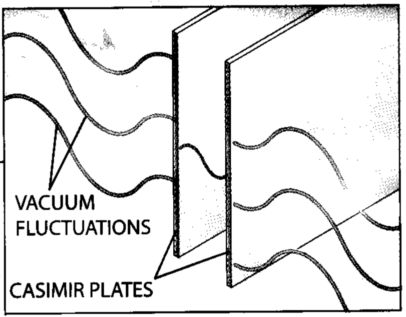
Under the right circumstances, Puthoff reasons, one could effectively manipulate the vacuum so that a new, lower ground state appears. The electron would then drop to the lower ground state—in effect, the atom would become smaller—and give up some energy in the process. "It implies that hydrogen or deuterium injected into cavities might produce excess energy," Puthoff says. This possibility might explain cold-fusion experiments, he notes—in other words, the occasional positive results reported in cold-fusion tests might really be indicators of zero-point energy (rather than, one would assume, wishful thinking).

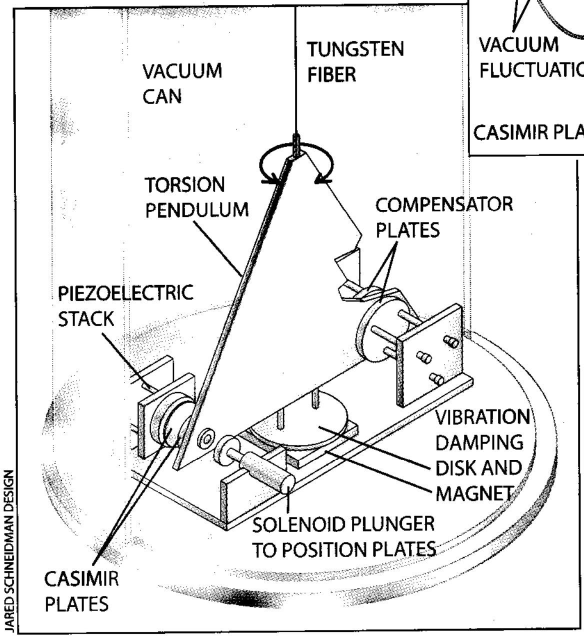
Work in cavity quantum electrodynamics is experimentally challenging in its own right, however, so it is not clear how practical an energy supply from "shrinking atoms" could be. The Austin institute is testing a device that could be interpreted as manipulating the vacuum, although Puthoff declines to provide details, citing proprietary nondisclosure agreements with its designers.

How Much in Nothing?

Underlying these attempts to tap the vacuum is the assumption that empty space holds enough energy to be tapped. Considering just the fluctuations in the electromagnetic force, the mathematics of quantum mechanics suggest that any given volume of empty space could contain an infinite number of vacuum-energy frequencies—and hence, an infinite supply of energy. (That does not even count the contributions from other forces.) This sea of energy is largely invisible to us, according to the zero-point-energy chauvinists, because it is completely uniform, bombarding us from all directions such that the net force acting on any object is zero.

But just because equations produce an infinity does not mean that an infinity exists in any practical sense. In fact, physicists quite often "renormalize" equations to get rid of infinities, so that they can ascribe physical meaning to their numbers. An example is the calculation of the electron's mass from theoretical principles, which at face value leads to an unrealistic, infinite mass. The same kind of mathematical sleight-of-hand might need to be done for vacuum-energy calculations. "Somehow the notion that the energy is infinite is too naive," Milonni says.





JARED SCHNEIDMAN DESIGN

CASIMIR EFFECT is the motion of two parallel plates because of quantum fluctuations in a vacuum. The plates are so close together that only small fluctuations fit in between; the bigger modes are excluded (*above*). They exert a total force greater than that by the smaller modes and hence push the plates together. The effect was observed by Steve K. Lamoreaux, now at Los Alamos National Laboratory, who relied on a torsion pendulum (*left*). A current applied to the piezoelectric stack tried to move the Casimir plate on the pendulum; the compensator plates held the pendulum still. The voltage needed to prevent any twisting served as a measure of the Casimir effect.

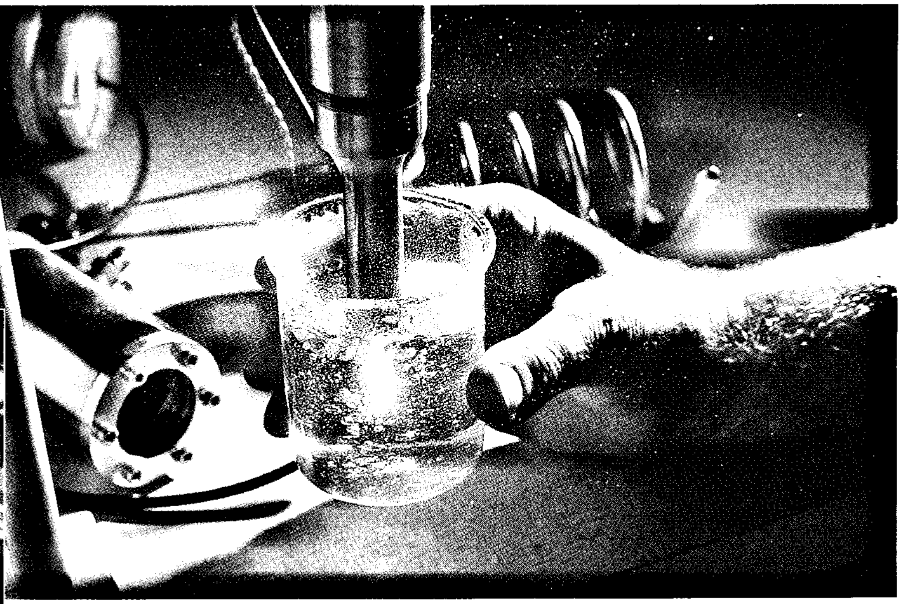
In fact, several signs indicate that the amount of energy in the vacuum isn't worth writing home about. Lamoreaux's experiment could roughly be considered to have extracted 10^{-15} joule. That paltry quantity would seem to be damning evidence that not much can be extracted from empty space. But Puthoff counters that Casimir plates are macroscopic objects. What is needed for practical energy extraction are many plates, say, some 10^{23} of them. That might be possible with systems that rely on small particles, such as atoms. "What you lose in energy per interaction, you gain in the number of interactions," he asserts.

Milonni replies by noting that Lamoreaux's plates themselves are made of atoms, so that effectively there were 10^{23} particles involved. The low Casimir result still indicates, by his figures, that the plates would need to be kilometers long to generate even a kilogram of force. Moreover, there is a cost in extracting the energy of the plates coming together, Milonni says: "You have to pull the plates apart, too."

Another argument for a minuscule vacuum energy is that the fabric of space and time, though slightly curved near objects, is pretty much flat overall. Draw a triangle in space and the sum of its angles is 180 degrees, as it would be on a flat piece of paper. (The angles of a triangle on a sphere, conversely, sum to more than 180 degrees.) Because energy is equivalent to matter, and matter exerts a gravitational force, cosmologists expect that an energy-rich vacuum would create a strong gravity field that distorts space and time as it is seen today. The whole universe would be evolving in a different manner.

That argument ties into

ZERO-POINT ENERGY was purportedly tapped with a machine that made use of ultrasonically generated bubbles (*right*). Such devices are tested by Harold E. Puthoff (*below*), director of the Institute for Advanced Studies in Austin, Tex. So far no apparatus has been found to produce a net gain in energy.



PHOTOGRAPHS BY WILL VAN OVERBEEK

the cosmological constant, a concept that Einstein first developed, then discarded. In the equations that describe the state of the universe, the cosmological constant—which incorporates zero-point energy—is in a sense a term that can counteract gravity. Astronomical observations suggest the constant must be nearly zero. Consequently, if the vacuum energy really is large, then some other force that contributes to the constant must offset it. And as physicist Steven Weinberg of the University of Texas notes in his 1992 book *Dreams of a Final Theory,* that offset feels unnatural: calculations that sidestep the infinity terms produce a vacuum energy 120 orders of magnitude greater than the nearly zero value of the cosmological constant, so that other force must be opposite but identical in magnitude to the vacuum energy out to 120 decimal places.

Puthoff replies that the connection between the cosmological constant and zero-point energy is more complex than is often realized. "Obviously, the zero-point-energy problem and the cosmological constant, though related, are really different problems," Puthoff argues, noting that predictions of quantum mechanics have proved correct time and again and that instead something is still missing from cosmologists' thinking.

Such disagreements in science are not unusual, especially considering how little is really known about zero-point energy. But those would-be utility moguls who think tapping zero-point energy is a worthwhile pursuit irritate some mainstream scientists. "I was rather dismayed at the attention from what I consider a kook community," Lamoreaux says of his celebrity status among zero-point aficionados after publishing his Casimir effect result. "It trivializes and abuses my work." More galling, though, is that these "pseudoscientists secure funding, perhaps governmental, to carry on with their research," he charges.

Puthoff's institute receives a little government money but gets most of its funds from contracts with private firms. Others are backed more explicitly by public money. This past August the National Aeronautics and Space Administration sponsored a meeting called the "Breakthrough Propulsion Physics Workshop." According to participants, zero-point energy became a high priority among those trying to figure out which "breakthroughs" should be pursued.

The propulsion application depends on a speculation put forth in 1994 by Puthoff, Bernhard Haisch of Lockheed Palo Alto Research Laboratory and Alfonso Rueda of California State University at Long Beach. They suggested that inertia—the resistance that objects put up when they are accelerated—stems from the drag effects of moving through the zero-point field. Because the zero-point field can be manipulated in quantum experiments, Puthoff reasons, it should be possible to lessen an object's inertia and hence, for a rocket, reduce the fuel burden. Puthoff and his colleagues have been trying to prove this inertia-origin hypothesis—a sensitive pendulum should be able to detect a zero-point-energy "wake" left by a moving object—but Puthoff says they have not managed to isolate their system well enough to do so.

More conventional scientists decried the channeling of NASA funds to a meeting where real science was lacking. "We hardly talked about the physics" of the proposals, complained Milonni, adding that during one of the breakout sessions "there was a guy talking about astral projection."

Certainly, there should be room for far-out, potentially revolutionary ideas, but not at the expense of solid science. "One has to keep an open mind, but the concepts I've seen so far would violate energy conservation," Milonni concludes. In sizing up zero-point-energy schemes, it may be best to keep in mind the old caveat emptor: if it sounds too good to be true, it probably is.

Further Reading

DEMONSTRATION OF THE CASIMIR FORCE IN THE 0.6 TO 6 μm RANGE. S. K. Lamoreaux in *Physical Review Letters,* Vol. 78, No. 1, pages 5–8; January 6, 1997.

QUANTUM FLUCTUATIONS OF EMPTY SPACE: A NEW ROSETTA STONE IN PHYSICS? Harold E. Puthoff. Available at http://www.livelinks.com/sumeria/free/zpe1.html on the World Wide Web.