has thus far attained."[4]

The 1990s mark a juncture between Bush's vision and reality. Bush has continued to inspire computer scientists and engineers.[5] Science and engineering have embraced computational science as a way of working alongside theory and experiment. Vast quantities of data flow freely. Network navigating software enables one to travel in cyberspace to find and use data, journals, and experiments, and to interact with other scientists and engineers. Web communications are a way of life for increasing numbers of individuals and in many business sectors. Electronic commerce is growing rapidly. Few in science and public policy have been as prescient as Bush about a technological advance that has truly transformed human affairs.

References

1. V. Bush, Atlantic Monthly, June 1945, p. 101.
2. V. Bush, *Science Is Not Enough*, Morrow, New York (1967).
3. Bush, *Science Is Not Enough*, pp. 98–99.
4. Bush, *Science Is Not Enough*, p. 99.
5. See, for example, J. M. Nyce, P. Kahn, eds., *From Memex to Hypertext: Vannevar Bush and the Mind's Machine*, Academic, New York (1992), especially essay by T. Oren, "Memex: Getting Back on the Trail."

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In her book review, Jessica Wang reports that, based on author Pascal Zachary's account, "Bush appears not to have worked from theory; he was a gadgeteer who operated from a purely mechanical sensibility." Many of us who, as students in the early 1940s, used Bush's *Operational Circuit Analysis* (first published in 1929) as a course textbook know that he was not purely a gadgeteer; at the time, that was one of the toughest theory texts in electrical engineering.

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WANG REPLIES: I thank Philip Smith and Ronald Bracewell for their insightful remarks. In reality, their argument is really with G. Pascal Zachary and not with me, and I hope they will contact him directly and continue the discussion about Vannevar Bush and his legacy.

I do think, however, that Smith has missed some of the subtleties of Zachary's argument. No doubt, Bush envisioned the potential for personal computing at a time when virtually no one else could even imagine the possibility, and he rightly deserves credit for his foresight. At the same time, he failed as a hardware visionary. From the perspective of Norbert Wiener and other pioneers of the digital age in the 1940s and 1950s, Bush was technologically conservative, unsupportive, overly attached to analog machines, and unable to appreciate the power of digital computing.

Zachary's biography presents the reader with the Bush of history: a contradictory, complex figure guided simultaneously by daring creativity and stubborn orthodoxy. Bush had great ideas, and he made great errors. Pointing out those errors does not undermine his accomplishments; rather, it reminds us that error is an unavoidable part of imagination and invention.

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Atmospheric Electric Field Is Too Small for Humans to Feel

The Global Electric Circuit" by Edgar Bering, Arthur Few, and James Benbrook (PHYSICS TODAY, October 1998, page 24) is a highly welcome article that is masterfully written and gives an excellent picture of this scientific area, but I want to take issue with one specific point.

In spite of its strength of about 100 V/m, we do not feel the atmospheric electric field. It is not sufficient to explain this phenomenon, as the authors do, by stating that the electric resistance of the human body is so much less than that of the atmosphere; indeed, that fact alone could even increase the current flowing through the body. Rather, the basic reason is that the atmospheric electric current and, consequently, the current flowing through our bodies are much smaller than the "biological" electric currents in us. In spite of a potential difference of more than 100 kV, the atmospheric electric current density is very small—on the order of 10^{-12} A/m^2—because, as in any electric circuit, the current is determined not only by the potential produced by the generator but also by the relationship between the inner resistance of the generator and the outer resistance in the circuit. In Earth's atmosphere, that relationship does not permit larger currents.

Atmospheric electricity is a fascinating, if complex, scientific phenome-

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non that is not very well known because its practical applications are still rather few (but that may slowly change). Therefore, I hope that someone will soon undertake the task of writing a comprehensive up-to-date book on the subject, in that the potential for practical applications can best be promoted by providing a complete, concise, and accurate background.

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More on History of Applied Correlated-Photon Metrology

Regarding the article "Correlated-Photon Metrology without Absolute Standards" in your January issue (page 41), I would like to point out that the general principle behind the idea of a "free lunch" in determining efficiencies of detectors has a history that goes back considerably further than author Alan Migdall indicates. It is a principle that has been used for many years by people in atomic physics engaged in photon–photon and particle–photon coincidence experiments.

The earliest work of which I am aware that used coincidence techniques to determine photon detector efficiencies was that of Eric Brannen and colleagues in 1955.[1] A similar method was employed by F. Cristofori and colleagues in 1963.[2] Later that decade, our research group at the University of Nebraska routinely used the same concept to measure the absolute efficiencies of energetic hydrogen atom detectors.[3]

There is a general principle in all such measurements: An electronic flag raised by the first detector tells the second detector that a photon or particle is on its way; when one measures the signal from the second detector in coincidence with the flag, one obtains the absolute efficiency, including all solid angle factors.

References

1. E. Brannen, F. R. Hunt, R. H. Adlington, R. W. Nicholls, Nature **175**, 810 (1955).
2. F. Cristofori, P. Fenici, G. E. Frigerio, N. Molho, P. G. Sona, Phys. Lett. **6**, 171 (1963).
3. R. H. McKnight, D. H. Crandall, D. H. Jaecks, Rev. Sci. Inst. **41**, 1282 (1970).

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MIGDALL REPLIES: I thank Duane Jaecks for pointing out earlier origins of the first of the correlated-photon metrology applications described in my article—namely, absolute detector quantum efficiency. The work described in those early references is helpful in putting the technique in a better historical context, although the researchers did not use the high directionality of phase matching that greatly aids the application of the method.

It is interesting to follow Jaecks's leads back to even earlier times, specifically to a mention made in the late 1930s by N. Feather and J. V. Dunworth[1] of the possibility of observing coincidences "visually" in a scintillator initiated by two alpha particles emitted from the same nucleus.

Reference

1. N. Feather, J. V. Dunworth, Proc. R. Soc. London, Ser. A **168**, 566 (1938).

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Faculty Retirement Has a FERP Piece to Go in California

To continue the discussion of faculty retirement in your pages, I would like to describe a program that the California State University System instituted in the 1980s and that, though badly diminished, is still in effect. It is called the Faculty Early Retirement Program (FERP).

When I retired in 1985 at the age of 62, I was a participant in the program. At that time, anyone in my status could retire with full retirement pay but was permitted to enter FERP and teach half-time and receive halftime pay until the age of 70. This program proved to be of great help to the university system as it was utilized by aging faculty, thus releasing space that could be used to hire younger faculty. Many colleagues have told me that they would not retire early if they could not participate in FERP.

In my case, I found that I did get slower and tired out more easily as I aged, and that a halftime teaching load was perfect for me and my students. My student evaluations remained high and included positive remarks about my high energy level (that is still the case, in that I'm one of the ex-FERP participants lucky enough to be needed, albeit less than