If you think your odds of winning the lottery are about the same as getting

Struck by Lightning *...think again...*

by **Trudy E. Bell**

A powerful electrical storm created an eerie tapestry of light in the hours preceding the launch of STS-8, August 31, 1983 at Kennedy Space Center.

BANG! BANG!

A quarter to three on the morning of August 26, 2003, in the midst of an unusually violent thunderstorm that had my 12-year-old daughter Roxana quivering against me, came two fast blinding flashes and simultaneously two fast, deafening cracks like a rapid pair of cosmically loud pistol shots. "My God, that was close!" I exclaimed, watching the nightlight across the second-floor bedroom flicker, fade, and die. Just how close was it?

When I walked downstairs at dawn as usual to check my email, my freelance writer's office looked as though a small bomb had exploded in the fireplace. Its brass frame had been blasted out of its three-inch masonry bolts and one of its glass doors launched 10 feet away. The foot-wide inch-thick marble slabs on the sides of the fireplace had been blown out to a 45 degree angle, one of them split in half *[Fig. 1]*. Soot and gray plaster/brick/concrete grit coated carpet, curtains, computer, desk, papers, books, and vertical files, and a burnt smell permeated the large room. Fortunately for me, the computer booted normally—praise be to its battery-backup uninterruptible power supply/surge protector (UPS)—but the UPS itself had taken a hit through the phone line, because the computer's modem could not get a dial tone through its jack. My color inkjet printer/scanner/photocopier was totally dead; my black-and-white laser printer would turn on, but not respond to print commands.

Nor was the damage limited to my office. In the kitchen, my microwave oven was fried. Upstairs, the cordless telephone was cooked. Throughout the house, several electric fans, nightlights, and dimmer switches were stone dead. Outdoors, the automatic garage door had frozen a foot above the concrete floor and no longer responded to the hard-wired button from the kitchen or the radio-activated remote controls. Most tellingly, on the roof directly above my office and bedroom, the tapering concrete upper part of the chimney had been sheared in two, and concrete chunks lay around my driveway.

Lightning had struck my house.

As curious neighbors paraded through to see what lightning damage looked like, followed by insurance adjustors and workmen giving estimates, it seemed everyone either had a personal lightning-damage story or directly knew someone with a story. One had a computer zapped when lightning struck several houses away. Another had nearly been struck as a teenager playing ball during a

Figure 1 Lightning struck the author's chimney on August 26, 2003, shearing the masonry holding the metal damper (upper left), and blasting a fireplace into a first-floor office (lower right). The strike also fried the automatic garage-door opener mechanism (lower left) and appliances throughout the house.

thunderstorm in a half-flooded field. A third felt his hair curl over his entire body just before a bolt cleaved a tree outside the window, not 10 feet away. The chimney bricklayer himself was working simultaneously on another house 15 miles east of mine that had been struck in the same storm that had struck mine. A month after my experience, Cleveland's *Plain Dealer* ran an essay by a local woman shaken by the experience of seeing her living room wall punctured by a lightning bolt that entered and exploded her television set without disturbing anything else.

Advice came fast and contradictory. "Should I put up lightning rods?" I asked the electrician. Immediately he shook his head and responded: "Absolutely not! Lightning rods actually *attract* lightning!" And no one could answer my basic question: "*Why* did the lightning strike my house instead of any of the much taller trees nearby?" The best answer was harrumphed by one insurance adjustor who'd seen it all: "Lightning does what it wants to do. There's no accounting."

If you live through it, write about it—that's my journalist's motto. And since no one seemed to have straight answers—at least not ones satisfying to someone with scientific curiosity—it was clear there must be a story in the frequency and physics of lightning strikes.

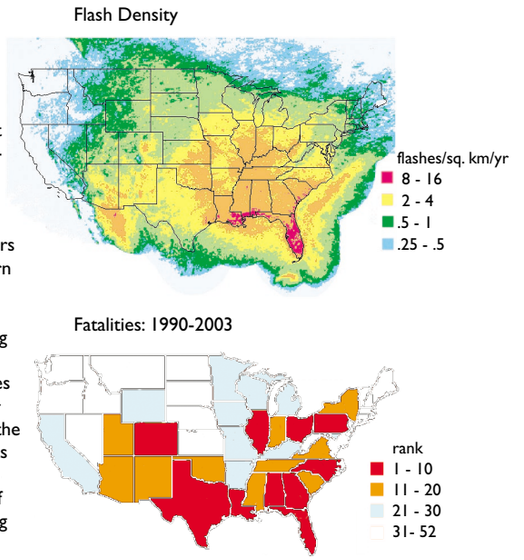


Figure 2
Approximately 22 million lightning flashes occur over the U.S. per year, amounting to about 30 million cloud-to-ground strikes because half of lightning is forked. Most lightning occurs over the midwestern and southeastern states, with Florida the nation's lightning capital, averaging more than 25 strikes per square mile per year—three times the national average—as well as a disproportionate one-sixth of the nation's lightning fatalities.

WHAT ARE THE ODDS?

The single most astonishing fact is just how *often* lightning strikes the earth. Numbers vary widely with the source, but the order of magnitude is clear: ever since the National Lightning Detection Network across the continental United States was installed in 1989 by Global Atmospherics—now the worldwide Vaisala Group, headquartered in Finland—something like 20 to 25 million cloud-to-ground flashes are detected annually over the nation. Because about half of lightning bolts are forked, that means lightning strikes more than *30 million points* in the U.S. *each year*. That translates into a nationwide annual average of some four strikes per square kilometer or 10 per square mile. True, arid desert areas suffer fewer strikes, but subtropical Florida is the all-American capital, annually averaging 10 strikes per square kilometer or more than 25 per square mile *[Fig. 2]*. Nationwide, the prime "lightning season" extends from May through September, although lightning has been known to occur in winter snowstorms. Worldwide, Central Africa, parts of Southeast Asia, and mountain regions of Latin America attract double or triple the amount of lightning as central Florida *[Fig. 3]*.

The top of a large thunderstorm, roughly 20 km across, is illuminated by a full moon and frequent bursts of lightning. These two images were taken nine seconds apart as the STS-97 Space Shuttle flew over equatorial Africa east of Lake Volta on December 11, 2000. Because the shuttle traveled at seven km/sec, the astronaut's perspective on this storm system became more oblique over the interval between photographs. The images were taken with a Nikon 35mm camera equipped with a 400mm lens and high-speed (800 ISO) color negative film.

"You and Roxana are unbelievably lucky that you weren't hurt or killed and that your house wasn't set on fire!" exclaimed a friend upon hearing my account. Were we ever. My house has two chimneys; the one the lightning struck runs down the wall at the head of my bed, because my bedroom is directly above my office.

National Weather Service statistics kept for more than half a century reveal that on an annual average more people are killed by lightning than by tornadoes, floods, or hurricanes *[Table 1]*. (The single largest category of victims is golfers, because they are often the tallest beings in wide, flat terrain or they huddle for shelter under lone trees that may draw lightning; golfers alone account for more than six percent of victims.) But fatalities comprise only 10 percent of people actually struck by lightning. About 1,000 a year across the United States live through the experience but suffer burns, cataracts, or more debilitating neurological injuries; one common injury is hearing loss from the acoustic shock of accompanying thunder, which can reach a pressure of 10 atmospheres—enough to burst eardrums.

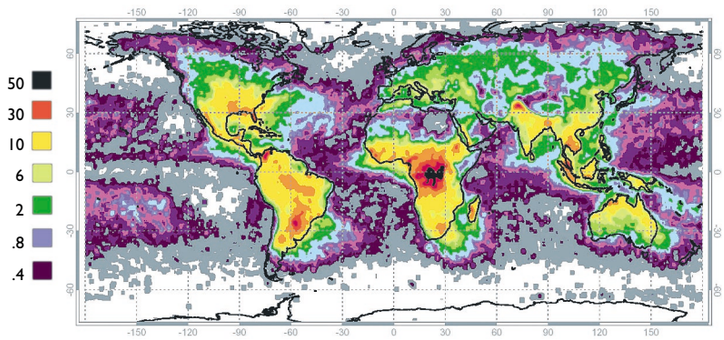


Figure 3 Data from space-based optical sensors (April 1995 to November 2000) reveal the uneven distribution of worldwide lightning strikes, with color variations indicating the average annual number of lightning flashes per square kilometer. Central Africa is the lightning capital of the world.

INSURING THE RISK

Far more common than deaths or injuries from lightning is property damage. According to Richard Kithil, founder and CEO of the National Lightning Safety Institute, Louisville, CO, about one house in 200 is struck per year. As nearly as I can calculate, that means that over a lifetime of home ownership the odds of a house being struck by lightning exceed the lifetime odds of a woman's getting breast cancer. According to various insurance sources, lightning damage amounts to nearly *five percent* of all paid insurance claims nationwide each year, with residential claims alone exceeding a billion dollars. The average residential payout per lightning claim exceeds $5,000. Mine topped $16,000, which included rebuilding the chimney and fireplace and replacing both circuit-breaker boxes plus every switch and socket in the house—this latter "a routine fire-prevention precaution after a lightning strike, especially one documented to have traveled through the wiring of the entire house, because you can't guarantee that the breakers will function in the future," explained the electrician. Good precaution: he later found charring in several sockets and switches not connected to appliances that failed.

Commercial costs are even greater, even not counting indirect costs (such as payroll for a workforce idled by not being able to use the premises). According to the electric utility companies' research group EPRI, lightning accounts for *30 percent* of all power outages, and losses to the industry exceed $1 billion annually.

Because a lightning bolt can reach temperatures exceeding 30,000°C—five times hotter than the surface of the sun—lightning ignites half of all forest or range fires and some 15,000 home fires each year. It can rip the bark off trees from canopy to roots [Fig. 6]. It can cause masonry to explode, as its current instantaneously superheats moisture within the material into steam, whose rapid localized expansion creates pressure that violently fractures the material (likely what happened to the masonry atop my chimney). Lightning-induced arcs can ignite volatile compounds or explosives at industrial or military sites. Lightning that finds ground through plumbing may explode pipes and hot water heaters. Myth notwithstanding, lightning can and does strike twice—or more times—in the same place; the Empire State Building is struck about two dozen times a year, and in one storm was struck 15 times in as many minutes. And yes, as the *Plain Dealer* essayist discovered, lightning literally can punch holes through walls as it seeks the lowest-resistance path to ground, usually wiring or plumbing.

Especially susceptible are computers, other electronics, and even media. In an office building, lightning may travel to earth along reinforcing steel inside concrete walls or columns. What appears to be a single strike usually consists of several rapid strokes; these create momentary

Table 1: Severe Weather Fatalities

YEARS	LIGHTNING	FLOOD	TORNADO	HURRICANE	LIGHTNING %
1940-49	3,293	619	1,788	216	55.4
1950-59	1,841	791	1,409	877	37.4
1960-69	1,332	1,297	935	587	32.1
1970-79	978	1,819	986	217	24.6
1980-89	726	1,097	521	118	29.5
1990-99	570	992	580	140	24.5
2000-03	189	221	190	91	27.4
TOTAL FATALITIES	**8,929**	**6,836**	**6,409**	**2,246**	
AVERAGES					
64-yr avg	140	107	100	35	
34-yr avg	72	121	67	17	
14-yr avg	54	87	55	17	

During the 64 years that the National Weather Service has kept statistics on severe weather fatalities in the U.S., lightning has killed more people than tornadoes and hurricanes combined. But that raw number obscures some significant trends. During the first decade (1940-49), lightning killed a total of 3,293 people—55 percent of all victims of severe weather. In a later decade (1990-99), lightning killed only 570 people, accounting for less than 25 percent of severe-weather deaths. Every year since 1975, lightning has killed fewer than 100 people annually, down from peaks topping 400 deaths per year in the early 1940s. That dramatic decline is because of improved building codes for lightning protection, as well as public education about lightning's dangers. Yet, every year lightning regularly claims the lives of 40 to 100 people nationwide.

UNIVERSITY OF FLORIDA LIGHTNING LABORATORY

Figure 4 Lightning's temperature—several times hotter than the surface of the sun—is enough to melt sand and rock along the strike's path when lightning travels through the earth, leaving tracks called fulgurites. This excavated section of a fulgurite was formed by lightning deliberately generated at the Camp Blanding rocket-triggered lightning site in Florida operated by the University of Florida.

TIME (EDT)	LATITUDE	LONGITUDE	KA	BEARING	RANGE(KM)
02:43:03 .875	41.490	-81.805	-20.3	300.7	0.2
04.223	41.490	-81.804	-9.8	322.0	0.1
.323	41.489	-81.806	-14.0	291.2	0.2
.347	41.488	-81.809	-7.9	261.4	0.4
.395	41.489	-81.805	-8.3	287.6	0.2

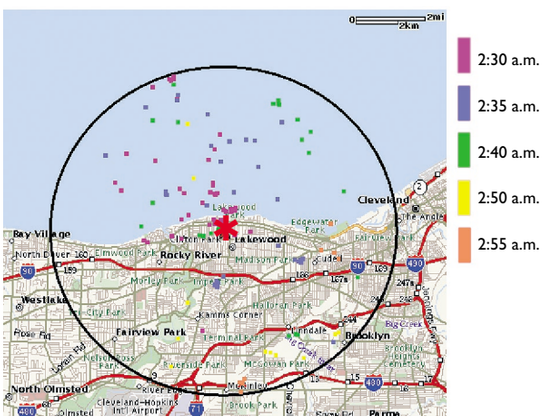


Figure 5 Map of lightning over Lakewood, OH, on 26 August, 2003, between 2:30 and 3:00 a.m. was generated by Vaisala Inc. in Tucson, AZ, which has operated the continental U.S. National Lightning Detection Network since 1989, providing data to the National Weather Service, Federal Aviation Administration, and other agencies and firms. The map shows that in that half hour, lightning and accompanying thunder crashed more than 135 times within five miles of my house (red star), much of it less than a mile north over Lake Erie. In the half-second between 2:43:03.875 and 2:43:04.395, five bolts flashed within 1,200 feet of my house, two likely within 300 feet because the measurement error is about 1,500 feet; likely one of those is the bolt that struck my house. All five had negative polarity (by far the most common situation) and, fortunately for me, ranged below average in magnitude with a "mere" 7,900 to 20,300 amperes of current.

high-strength oscillating magnetic fields, which have been known to erase floppy disks or computer tapes inside a nearby storage cabinet, even inducing power surges in machinery that is switched *off*. So powerful is lightning's electromagnetic pulse that computer equipment has been damaged even inside a building that has *not* suffered a direct hit. Indeed, lightning strikes within 200 yards of power lines or telephone lines can cause a transient over-voltage pulse to be transmitted for *miles*. Overall, lightning zaps an estimated 100,000 desktops and laptops around the country each year, with some estimates of damage both to hardware and data loss running as high as $2 billion, although exact numbers are tough to verify.

By the way, don't feel safer if power and phone cables enter your home or office underground. When lightning strikes the earth, its energy doesn't simply vanish. The lightning current travels surprising distances through the ground (especially wet soil)—sometimes melting sand along its path *[Fig. 4]*—to seek the lowest-resistance path, which may be buried water or gas pipes or coax cables. Even optical fibers, although insulators themselves, may not be immune if they are reinforced by and jacketed in conducting metal.

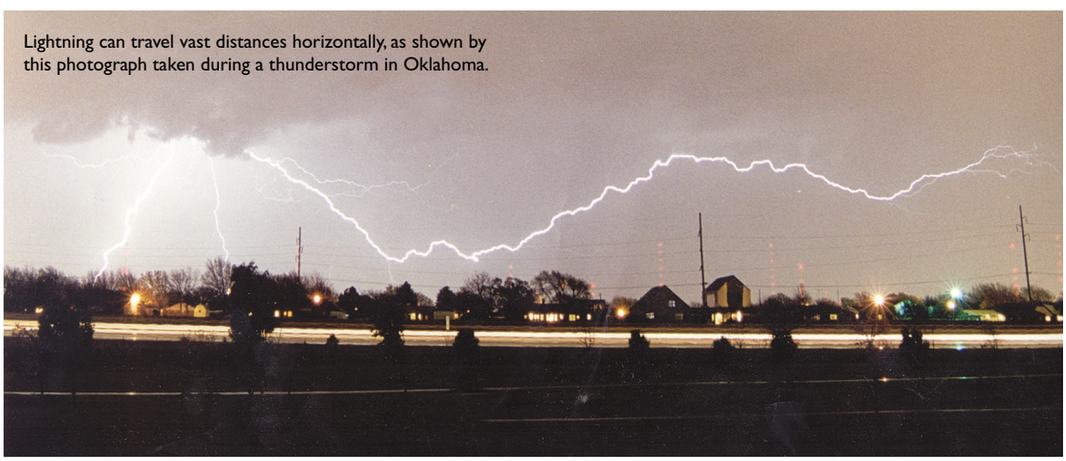
HOW BIG A BOLT?

"The instant lightning hit your chimney, my bedroom lit up orange and I could *feel the hairs rise* on the backs of my arms!" recounted my next-door neighbor. We eyed the distance across her drive and figured it was 30 feet between my chimney and her bed. "That's some electric field," I whistled, having felt such hair-raising only once before in my life, when standing several feet away from the klystrons that power the Stanford Linear Accelerator *[Fig. 5]*.

But there's more. Days later and black with soot from having inspected the inside of my chimney, the bricklayer approached me. In his hand was the fireplace damper handle; attached to it was a short chain and about eight inches of 1/16th-inch twisted wire cable, resembling nothing so much as a thicker version of a bicycle's brake cable. "This cable should have been attached to the damper atop your chimney," he explained. On the driveway amidst the rubble, we found the ruined square metal damper, dangling a similar short length of twisted cable. The free ends of both short cables were blackened and fused. "You're missing 15 or 20 feet of cable, which is nowhere inside the chimney," he asserted. Could the lightning have struck the

damper and simply vaporized two stories of cable?

A typical lightning flash unleashes hundreds of millions of volts with currents of tens or hundreds of thousands of amperes, all within microseconds. Each stroke consists of a very rapid rise (typically less than half a microsecond) to a high peak current (typically 20,000 to 30,000 amps), followed by a much slower decay (typically 500 microseconds) to near zero current. In up to half of lightning strikes, each successive stroke has a lower peak current and a slower decay, with a lower and slower continuing current—100 to 500 amps (what an arc welder uses to join heavy structural steel) for several hundred milliseconds. Extreme lightning, accounting for one percent of strikes, can peak at currents topping 200,000 amps with a rate-of-rise of current greater than 400 kiloamps per microsecond. Different parts of the stroke are responsible for different types of damage. The high-frequency energy in the fast rise time and initial peak current is responsible for most of lightning's over-voltage, high electric fields, and arcing. The low-frequency energy in the continuing current during the decay is the dominant cause of fires and spalling.



Lightning can travel vast distances horizontally, as shown by this photograph taken during a thunderstorm in Oklahoma.

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COSMIC CURRENTS

Lightning is the planet's way of maintaining its electrical neutrality. Far from being unique to the earth, spacecraft have detected it raging on Jupiter, Saturn, Uranus, and possibly Venus. It may have been the prehistoric energy source fueling the formation of early organic compounds on the earth that eventually led to life; it is still important to biology because its ionization of the air is estimated to produce more than half the usable nitrogen in the atmosphere and soil.

Lightning is essentially a gargantuan static discharge. Most of us are familiar with the winter annoyance of walking across a carpet and then reaching for a metal doorknob or bending toward a drinking fountain and *ZAP!* feeling the tingle and hearing the snap of a spark. In a dark room, such sparks can be seen to jump up to two or three inches. That's lightning writ small.

During a thunderstorm, the friction of feet on carpet is replaced by the friction—yes, friction—of water droplets repeatedly rising and soft hail pellets (graupel) falling in the circulating winds inside thunderheads three or four miles overhead. Electrons are stripped from the droplets so that positive ions usually collect near the top of the storm cloud, while the heavier hail transfers the negative charges along the bottom. Air is a good insulator, so the charge built up can be stupendous—up to 20 coulombs. Eventually, the charge becomes so great that a leader, or small stream of charges, migrates downward in 50-yard steps, to be met by a similar leader reaching upward from the ground toward the electrified cloud. The leaders ionize the air enough to give a conductive path, and, when they meet, *ZAP!* In less than a microsecond, charge flows from cloud to ground to neutralize the difference in electrical potential in an enormous spark discharge (lightning), which causes the very air molecules to explode in a pressure wave (thunder), and recombine into other molecules and atoms (giving rise to the ozone scent after a thunderstorm).

In nine bolts out of 10, the discharge leaps from cloud to cloud—a major reason that commercial airliners are diverted around thunderstorms. It's that tenth discharge from cloud to ground that can threaten people and structures on the earth. Indeed, the bottom of a thunderhead can have enough charge to induce a "shadow" of positive charges to build up on the ground immediately below the traveling cloud. Skyscrapers, trees, and chimneys are prime targets as they are tall, minimizing the distance a leader must travel; they also can readily build up charge if they are not grounded.

One of the most dangerous forms of cloud-to-ground lightning, because it is so unexpected, is literally the "bolt from the blue." It's a lightning flash that comes out of the side of a thunderstorm's updraft, travels a relatively large distance horizontally in clear air away from the storm cloud, and then angles down and strikes the ground. Bolts from the blue have been documented to travel more than *25 miles* from the storm updraft *[Fig. 7]*. To a person on the ground

several towns away from a thunderstorm that's on the distant horizon, the lightning literally appears to come from the clear blue sky.

LIGHTNING PROTECTION

Okay, so given lightning's caprice and ubiquity, what can be done to protect your home and office?

First, there's no such thing as lightning prevention. Anyone who tells you there is, is trying to sell you a product—one that won't work. Nor do scientists and engineers fully understand all the conditions under which lightning can arise or the damage it can wreak. All that being said, there are proven ways to mitigate at least some of its effects and lessen the odds of damage or death to you or your property.

My electrician was right. For modern homes and office buildings, you definitely do not want a lightning rod, now called an "air terminal." They do attract lightning, deliberately. Air terminals provide a preferential low-resistance path straight to ground and are useful only for protecting all-masonry or all-wooden buildings (such as barns) without conductors; indeed, their inventor Benjamin Franklin recommended that anyone inside the building should lie in a silk hammock slung from wooden poles in the center of a room (could that have been one factor that saved Roxana and me—the fact that we were huddled on an insulating cotton futon on an all-wooden platform bed?) Air terminals will not protect modern structures, which are riddled with conducting plumbing and wiring, metal door and window frames, baths and showers, metal studs, and steel-reinforced concrete.

For commercial premises, consider installing a high-energy surge arrester at the main circuit-breaker panel for every electrical and electronic conductor that enters the building.

While nothing can protect equipment from a direct hit, a surge suppressor (often optimistically mislabeled a surge "protector") at each computer or other sensitive piece of equipment can minimize damage from distant or even nearby lightning strikes by quickly diverting large voltage spikes to ground. The surge suppressor must be located at least three wire feet away from the device being protected, so that the wire's own resistance can help dissipate the energy from the spike's leading edge. Obviously, to do its work, the surge suppressor must be directly connected to a verified nearby earth-ground, such as an AC power ground, a 10-foot copper ground stake, or a building ground—so it must be plugged into a properly grounded three-wire socket. If you don't have genuine grounded three-wire sockets—a condition still prevalent in older homes such as my own 1914-vintage house—have one installed by an electrician. *Do not* use a two-prong socket by cutting off the third prong or using a "cheater" 3/2 adapter; the surge suppressor, no matter how expensive, will be rendered useless.

Better yet, connect each computer to an uninterruptible power supply. Not only does a UPS come with extra sockets protected by surge suppressors for all your peripherals; it also has a battery that provides power for a short time (10 minutes to more than an hour, depending on the model) during a power outage, allowing you enough time to save files and exit applications gracefully or actually performing those functions automatically. Make sure the UPS is one that comes with a warranty against lightning, with a response time of 10 nanoseconds or less, a clamping voltage of 400 volts or less, and an Underwriters Laboratory test rating of UL 1440 or higher. Don't be cheap. The cost of a UPS may be 10 percent of the cost of the computer and peripherals, but ask yourself: how valuable are your data and your time if unexpectedly you were faced with replacing it all?

Make sure your modem connection also goes through the jack provided on the UPS. Power spikes are more common through telephone lines than power lines.

Make regular backups of your data part of your daily routine. Just do it. Moreover, store the backups in fireproof safes (small ones can be purchased at office-supply stores) in the lowest room of the building or even off the premises.

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Figure 6 Lightning neatly removed a strip of bark from this tree on a hillside in Owings Mills, MD, during a 1985 storm. The tree stood at the edge of a typical mid-Atlantic deciduous forest grove and was not the highest tree in the grove, nor was it at the top of the hill.

Especially during the peak lightning months of May through September, unplug everything you value whenever you leave, even if just overnight. I used to make fun of my mother, a child of the Midwest, who routinely disconnected every toaster and lamp from the wall when not in use and who refused to talk on the phone during a thunderstorm. No more. She was right. "How do you get absolute immunity [from a direct strike] for sensitive electronic equipment? Unplug *everything*!" advised Kithil. "No circuit path, no lightning damage." Disconnect equipment *before* lightning strikes—people have been electrocuted while unplugging their electronics during a thunderstorm. And avoid contact with water pipes or running water.

Purchase replacement-value insurance for your premises and contents. The premiums are perhaps 10 to 20 percent higher than standard insurance, but the payout covers the difference between the depreciated value of your equipment and the actual cost of new—and according to IRS schedules, computer equipment depreciates quickly.

Last and most important, how can you protect yourself, your colleagues, and your loved ones from lightning? Recommendations today are far more conservative than in years past. Because of the risk of bolts from the blue, many lightning-safety sources advise following what they call the 30/30 rule: end outdoor activities and seek shelter if there are fewer than 30 seconds between a flash of lightning and resulting thunder (indicating the lightning is less than six miles away), and stay there until at least 30 minutes after the last observed thunder or lightning. Not just any shelter will do: seek a Faraday cage—a metal-topped vehicle, or, better yet, a large permanent building with wiring and plumbing.

If caught in a thunderstorm far away from any Faraday cage, avoid picnic shelters, solitary tall trees, high ground, open spaces, water, all metallic objects, and close contact with other people. Spread out away from other people and seek clumps of shrubs or trees of uniform height, ditches, trenches, or low ground. Then remove metal objects from your pockets and crouch down, feet close together, head bowed, hands over ears; do not lie down (you don't want lightning to complete a ground circuit through your heart). And vow to yourself not to take such risks again.

AM I SMARTER NOW?

So why *did* lightning strike my house instead of the nearby taller trees? "Science says lightning is a stochastic, random, unpredictable phenomenon," Kithil replied. Turns out it's fairly common for lightning to strike *below* the highest point on a tall structure; why not my chimney? Indeed, lightning has been known to bypass all protections and even strike a supposedly protected target. For all the gruff unscientific vocabulary, the insurance agent had it exactly right: lightning does what it wants.

What are the odds of being struck by lightning versus winning the lottery? Well, because the population of the United States is about 290 million and maybe 1,000 per year get struck by lightning, the annual statistical odds of your getting struck are about 1 chance in 290,000—about *15 times higher* than the most favorable odds of 1 in 5 million of hitting most state lotteries.

Since August 26, 2003, my betting money has been on the lightning.

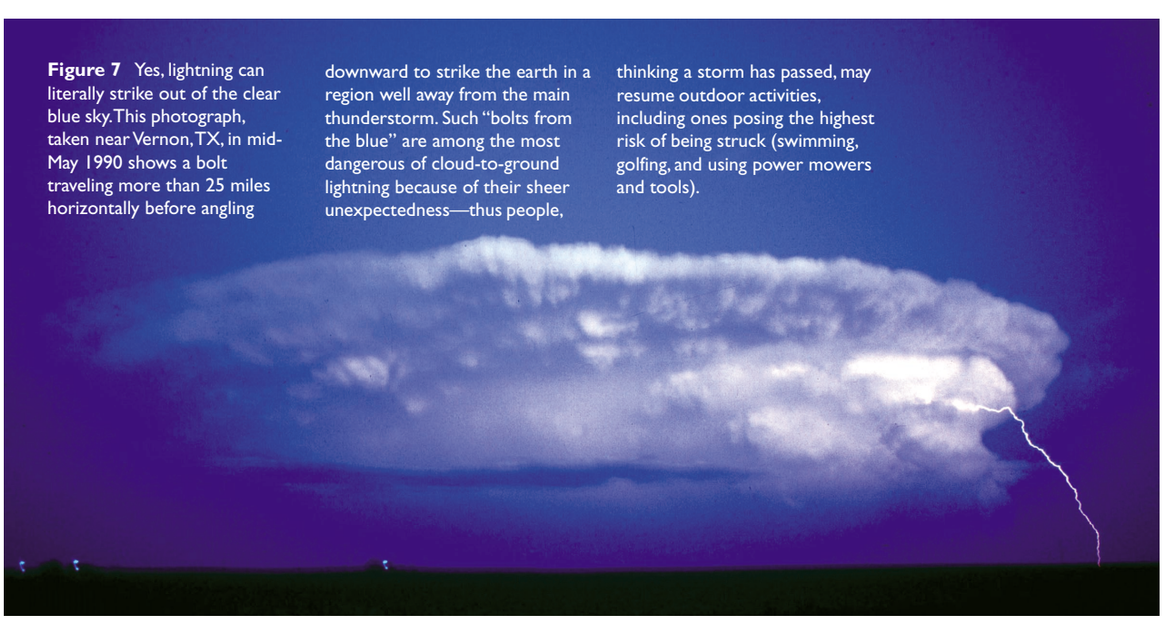

Figure 7 Yes, lightning can literally strike out of the clear blue sky. This photograph, taken near Vernon, TX, in mid-May 1990 shows a bolt traveling more than 25 miles horizontally before angling downward to strike the earth in a region well away from the main thunderstorm. Such "bolts from the blue" are among the most dangerous of cloud-to-ground lightning because of their sheer unexpectedness—thus people, thinking a storm has passed, may resume outdoor activities, including ones posing the highest risk of being struck (swimming, golfing, and using power mowers and tools).

References

Pictures of lightning damage to my house, plus subsequent reconstruction of my office during the seven-month saga appear at *http://home.att.net/~trudy.bell/lightning_strike.htm*. Dedicated lightning junkies can find daily news reports about lightning strikes around the world at *www.sirlinksalot.net/lightning.html*.

Information about the physics of lightning, current research and monitoring programs, and safety can be found at federal government websites, such as those of the National Oceanic and Atmospheric Administration at *www.lightningsafety.noaa.gov/index.htm*, the National Weather Service forecast office at *www.crh.noaa.gov/pub/ltg.shtml*, and NASA-sponsored global hydrology and climate center at *thunder.msfc.nasa.gov*. Some of NASA's work-in-progress on lightning and thunderstorms is summarized at *science.nasa.gov/headlines/y2003/30oct_lightning.htm?list866505*. For comparison of fatalities, injuries, and damage from lightning compared with other hazardous weather, see *www.nws.noaa.gov/om/hazstats.shtml*.

The National Lightning Safety Institute (NLSI, *www.lightningsafety.com*) is a nonprofit organization advocating lightning safety, and offering educational materials, white papers (including its book *Lightning Protection for Engineers*), and technical consulting (clients have included airports, the armed forces, various departments of transportation, major corporations, and national laboratories).

Information about any lightning strike in the U.S. since 1989 can be obtained from Vaisala at *www.lightningstorm.com/*.

The power engineering society within the Institute of Electrical and Electronics Engineers has several lightning working groups, some of whose work can be accessed at *ewh.ieee.org/soc/pes/lpdl*.

The International European Commission (IEC, *www.iec.ch*) has a designated multi-country lightning protection committee, which maintains lightning-protection standards; see *www.iec.ch/cgi-bin/getsps.pl/81.pdf?file=81.pdf*. It offers the IEC 61024 series of reference documents for lightning protection engineers (in the U.S., there is no single lightning safety code).

The International Conference on Lightning Protection meets every two years; abstracts from September 2004 are at *www.iclp2004.org*.

Victims of lightning strikes can find valuable guidance and information from Lightning Strike and Electric Shock Survivors International at *www.lightning-strike.org*.

For those interested in comparing the odds of being struck by lightning to the odds of winning different kinds of lotteries, check *www.jrwhipple.com/findit/lotto.html* and *www.alllotto.com/lottery_odds_calculator.php*.

Image Sources

Fig. 1: the author
Fig. 2: Flash Density Map (1996-2000) and Fatalities Map: NOAA; Vaisala Inc.
Fig. 3: Lightning Map: NASA Marshall/National Space Science and Technology Center. The map includes data obtained from April 1995 to March 2000 from NASA's optical transient detector and from December 1997 to November 2000 from NASA's lightning imaging sensor. Both are satellite-based sensors that use high-speed cameras capable of detecting brief lightning flashes even under daytime conditions. Compiled by NASA scientists at the global hydrology and climate center at the National Space Science and Technology Center (NSSTC) in Huntsville, AL, this information represents the first time these two instruments have been cross-calibrated to form a composite representation of global lightning patterns. The NSSTC operates through a partnership between NASA's Marshall Space Flight Center in Huntsville and six Alabama universities.
Table 1: Calculations from National Weather Service statistics.
Fig. 4: University of Florida Lightning Research Laboratory
Fig. 5: Vaisala, Inc., Tucson, AZ
Fig. 6: © 1985 Karl Esch
Fig. 7: © 1990 Robert A. Prentice
Space Shuttle, p. 15: NASA. *http://grin.hq.nasa.gov/ABSTRACTS/GPN-2000-001879.html*
Storms from space, p. 16: NASA Earth Science and Image Analyis Laboratory, Johnson Space Center. Additional images taken by astronauts can be viewed at NASA-JSC's Gateway to Astronaut Photography of Earth at *http://eol.jsc.nasa.gov/*
Horizontal thunderbolt, p. 19: © Charles Allison, *www.oklahomalightning.com*
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