CHAPTER *1*

Withstanding . . .

I was reading late and doing research for this book during the early morning hours of September 11. I fell asleep with the TV on and a book on my face. I fell asleep feeling safe and lulled into REM by TV images of Valley icon Jamis MacNiven riding his neighbor's camel Omar during the Sand Hill Soap Box Derby Race, an event he created for corporate sponsors to donate money for schools to design some of the most efficient and sci-fi-looking cars to compete in an annual race. The documentary took place a year or so back when times were better, and I probably had a smile on my face when the sandman visited.

I awoke to something very surreal that I was only subliminally listening to as I emerged from a troubled sleep, removed the book from my face, and reached around blindly on my bed for my glasses. I soon understood that 9/11, 2001 marked the end of the world as we knew it.

I watched live from Silicon Valley as the second plane crashed into the World Trade Center. For a moment it didn't register; for one naïve moment I thought they were playing a replay of the first crash, which I was still only barely comprehending. I started doing the math in my head . . . what were the odds of two planes crashing into The Towers by accident?

It was impossible. *Surely, it was impossible.* And then there was the news of the crash at the Pentagon. We soon knew the truth. I immediately booted up my computer; e-mail had already started to fly in: people wondering if I was in NYC that week, people wanting to know I was safe. People in NYC who couldn't get through on their phones. What I soon found out as I tried to make a number of phone calls around the country, most all were answered by that annoying recording: *All circuits are busy, please try your call again.* Strangely enough, I continue to hear that recording more often today as circuits continue to be overloaded. Alas, my e-mail worked, so I began the task of answering the mail I received and shooting even more off. I watched a CNN feed on my local network, turned on NPR, and listened as my fingers flew on the keyboard.

Although my long-distance phone carrier had failed me, the Internet kept right on rerouting. Packets swam confidently, speeding their way to predetermined destinations. Maybe it seems ghoulish to say it, but the e-mails being sent to most of the servers involved in the terrorist attacks would be routed to mirrored sites, many messages never to be read by the people they were intended for. The messages survived when most of the recipients did not. Messages that are probably still sitting on a mirrored site, some sys admin still having the task of deciding what to do with them. Encapsulated messages floating aimlessly. *Messages in bottles,* as Len Kleinrock would later comment when I mentioned this to him.

While I was sitting here on the West Coast trying to figure all of this out on 9/11, on the East Coast, Kim Polese, chairman of Marimba, was two blocks away from the World Trade Center in the Marimba NYC offices, about to head out to the WTC for a meeting. A meeting that not only would never happen, but one with people she has not been able to contact since.

"The World Trade Center didn't exist when it was time for my appointment," says Polese of that day's plans. "I was in midtown headed downtown; it was definitely a close call." Her offices have only recently (in late October) been able to receive power and water. Her only means of communicating with anyone that day, and those that would follow as airplanes were grounded, was her Blackberry PDA. "That's how I communicated. I asked my office to contact my family and let them know I was okay, because some of them aren't on e-mail. In a sense, it was a communication lifeline.

"My perspective is that the Internet has proven itself to be an incredible tool of communications for people around the world, so just the use of it as a utility of instant communication was underscored on 9/11," says Polese about her perspective of the Internet after the WTC incident. "I experienced a dramatic change in people's perception of the Internet; now it's clear that it's a standard part of where we turn to get information. One thing that's unique now is there's constantly breaking news. Almost every couple of hours you find yourself asking, *What's the latest?* because, unfortunately, it's still building and happening in real time. Even CNN can't have the speed immediacy that the Internet does by definition. It's not the novelty it was five years ago, or even less; it's a common part of our everyday life and where we turn to get the latest news."

The Internet, although put together with the idea of transferring technology data, was quite a humanistic element on that fateful day. And although a madman named bin Laden brought the United States to its knees for a brief time, I do have a feeling that it will be our technology that finds him and brings him to justice. Our technology will play a huge part in this war we're currently fighting. And even as I make these changes to this manuscript to update it due to 9/11, lobbyists are trying to push encryption laws through because they don't understand the technology and feel these applications are a threat to national security; a knee-jerk reaction made by politicians who don't understand technology and thus fear it.

But you know what? When the smoke cleared the Internet had survived, and the world was brought together as a village against a common enemy. It took a disaster of heartbreaking proportions to prove a theory thought out loud many times since its inception.

Scientists have always been the unsung heroes of wars; it may be brute force we first attack with, but innovations such as the Varian brother's Klystron, and the splitting of the atom are what really won wars. The geeks—and this word is not a slight, this is a moniker that technologists wear with pride (didn't you know the *ee* in geek stands for *electrical engineer?*)—are who won the war. It was brains over brawn (or should I say, science that aids brawn) that wins our fights in the end. It will be scientists who come up with vaccinations and early-warning detection aids for anthrax, the Ebola virus, and other biological threats that will keep us safe in the future.

In the years since those scientists got together in Los Alamos to work on the end-all solution of World War II, we've been developing an even greater tool; one of freedom, one that allows the free transfer of ideas—even if one lives in a communist country. After all, the Internet is U.S. democracy incarnate (or what we used to know as democracy). It offers us a one-stop shop for just about every amendment in our Constitution. The ability to publish anything we want anytime, anywhere, 24/7, in color, streaming, or just in plain simple text. The right to deliver that message completely naked (see www.nakednews.com, if you don't believe me), or even copulating while saying it. Has the world ever known such freedoms? Doubtful.

Knowledge can bring down governments; the Internet just happens to be the medium of this messenger. There is no greater power than knowledge. There's a reason why China's government is closing down cyber cafés (by the thousands) that offer software Chinese citizens use to surf the Web and post messages anonymously. This Internet of ours is helping to spread human rights; making our world a global village where exchanges of ideas are a right, not a privilege. Yes, this war has been waging for a while and now our Western World is being streamed into the computers of people who will see there is another way—but frankly, not everyone is happy about this. Even some people in the good ol' U.S. of A. have a problem with allowing this much freedom.

Meanwhile, technology never sleeps, and we continue to make the Internet more of a ubiquitous part of our lives. I long for the day when a scientist splits my head open and places a beautiful little chip inside and the Internet becomes part of my biology; relatively speaking, that day is not far off. Not too long ago the writers of science fiction pulp fiction paperbacks imagined all kinds of things that were thought unbelievable science (thus, science *fiction*), but we've seen a whole lot of it come about. Who would have thought we would have videophones bringing the war live-time into our own TVs? Soon videophones will be no big thing; the prices will come down, and you'll be able to stream video 24/7 wherever you are, whatever you're doing, live to your web site, or phone to phone, to your glasses—or whatever that tool with an IP address may be.

The future is here; and it was *so* influenced by the imaginings of fertile, creative minds. Ask just about any developer or scientist what they read as a kid under the covers via flashlight and they'll tell you Isaac Asimov, they'll tell you comic books with guys with mutant powers, and they'll probably tell you they watched Gene Roddenberry's *Star Trek.* I'll never forget the day I was hanging out at Ask Jeeves in Emeryville when William Shatner dropped by the engineering department and all those geek code jockeys flipped out their butterfly cell phones and looked like they were about to ask to be beamed up. Tell me this was not a generation inspired by being amazed by speculative science fiction thought up by brilliant writers inspired by scientists with big dreams and a clear vision. Or was that the other way around? Regardless, someone had vision; someone had the science; and somehow they meshed.

And now, here I am talking about a chip being put in my head so that I can gain access to the Internet via some kind of bio/nano technology and wireless communication. Just remember where you read it.

But all of this is in the future; and I think before we can fully understand what will happen in *that* future, we need to get a strong grasp of what synergy of events and people happened in the past to make the vision of the Internet a reality. They were envisioning something grand—something that hasn't quite been realized. They didn't bring this network about so that we can sit here now with our PDAs and our computers and clog the pipes with annoying hoax petitions and sales spam. What could they have possibly been thinking when they imagined this future for us?

PARALLELS

There was a war to be won, and America was determined to win it. December 7, 1941, was a day that will live in infamy—and the day Japan made a fatal mistake; it gave America a reason to rally around a common cause with a single focal point—revenge.

President Roosevelt knew trouble was on its way after receiving several reports from intelligence regarding intercepted encrypted messages from Tokyo to Japan's ambassador to the United States. The message was decrypted and Roosevelt anticipated backlash from Japan's Admiral Isoruku Yamamoto for America's firm stance to not reverse economic sanctions and embargoes against Japan. Roosevelt remained clear in his demand that the Japanese first withdraw from China which it had invaded in 1937, get out of French Indochina, which it captured in 1941, and pull out of its alliance with Germany and Italy.

Although negotiations went down to the wire, the two countries did not come to an agreement. Roosevelt, via the decrypted messages, was in the know about the secret November 25 deadline that Yamamoto had established to attack the United States if its demands were not met.

Soon thereafter, Yamamoto gave the word and 360 Japanese warplanes, many on kamikaze missions, were launched from six aircraft carriers escorted by battleships, cruisers, and destroyers. It was a tropical, somewhat balmy Sunday morning just before 8:00 AM when the first Zero was seen above by somewhat unbelieving eyes in Pearl Harbor. Many military personnel were sleeping in; none were expecting the attack. Although Roosevelt knew of the threat; none of the Pacific military had been put on Delta Alert.

The roaring engine of a single lead aircraft was soon followed by the thunder of 200 others, and the planes ripped Paradise apart—bombing and torpedoing the ships in the clear-blue waters below. Nearly 200 U.S. planes were destroyed on the ground and another 150 were damaged, leaving the defenders with only 43 operational aircraft. Even before the fires were put out and the billowing smoke began to clear, the somewhat futile rescue efforts to free the Americans sealed in capsized and sunken warships began. U.S. casualties totaled more than 3,400; the Japanese losses were fewer than 100 men, many of those giving their own lives as kamikazes—quite a coveted honor in Japanese culture at that time.

Yeah, America was pretty pissed off, and boy did the surprise attack serve to unify a country that was having its own economic problems. So why do I even bring this up? Because it was the war that birthed the Cold War, that in turn created the Internet. It's also because I need to dispel a myth. I've been told by many founders of the Internet, *Don't go there, it's a myth that the Internet was born from the concept that we needed a communications system that would withstand a nuclear holocaust.*

I start this story at Pearl Harbor because of the eerie similarities that make 9/11/2001 and 12/7/1941 seem like they're in parallel universes. In both cases another entity declared war against the United States; both were sneak attacks; and both were carried out by pilots willing to sacrifice their lives. In both instances there was some kind of connection to encrypted messages (in our current case it was only that encryption technology exists and was suspected, not that it was used). In both cases the American people came together to fight a common enemy. And, unfortunately, in both cases some of that zealous fervor was turned against American citizens and people who just happened to *look* like the enemy. Again, in both cases this thing now called the Internet became involved.

I contend that just as technology was funded and blossomed in the United States after the treaties were signed by all parties, so it shall be again. Okay, so maybe there won't be any treaty signed this time around, but there will be an end, at least for a period of time. And we will see this recession go away just as quickly as the Great Depression did after the United States entered WWII. I'm sure that the aerospace industry will be the first to experience the upswing from government purchases; actually, I've already seen stock go up at what are commonly called *war companies.*

Today I heard a report that someone in government is trying to pass legislation that will put electronic palm scanners into every airport in the United States, and possibly retinal scanners, and I saw another story about a company that is developing *black box* technology that will download a live streaming media of airline cockpit conversations via wireless technology to assure that a pilot's last words will always be heard no matter the circumstances. This is a very difficult time for the bad guys; we're pissed, we have motivation, and we have the technology. The technology will grow due to our need for stricter security, but it has also tempted many key government figures with the idea that our technology needs to be overseen, restrained, and boundaries drawn.

So picture, if you will, for the sake of my scenario, a much younger United States, one that before the war was barely making it through a depression. Then, unified as one, waving flags in the streets. Our soldiers are greeted, much worse for wear, with ticker tape parades; something our next generation of soldiers would not know.

Now picture a more sophisticated United States, one that is so technologically savvy that perhaps it's grown arrogant, fat, and lazy with the ability to rely on technology not aided by the human mind; a society lulled into complacency with automation. Every night her people come home from work to eat prepackaged, precooked, supposedly well-balanced meals directly from a box straight into microwaves to be heated and consumed. Four remotes per entertainment center as content of every kind is available and output at gluttonous rates. Our stomachs and minds are fed and satiated. Our kids play with some of the most amazing 3-D technology that exists: electronic video games where they see endless acts of violence in an evening's worth of entertainment. Game over until our next morning's commute.

A country where radar is so sophisticated it can detect and identify planes deviating ever so slightly from their set flight pattern—but one missing the vital policies and wherewithal to do anything about it until it's too late. Four planes were hijacked that September day, and probably others targeted for takeover but detoured because of the immediate orders for grounding of planes in the air.

So there we were with all of this technology, including the ability to have stricter policies in place to identify people who are a threat to national security, a way to identify objects such as box cutters through archaic X-ray machines; but really, no thought of putting all these technologies to use with the intelligent human aspect needed to temper technology and identify a bad situation. So many countries I have visited or lived in, including the United Kingdom and Germany, have stricter policies in place because they have so often been the victims of terrorism.

We're learning, we'll survive as a whole, and we'll thrive despite our lazy tendency to rely on automated technology manned by the complacent and governed by the clueless. We'll glean, we'll modify, we'll evolve. We won't be an easy target *next* time. I wonder if someone, somewhere said those same words after December 7, 1941?

DIGGING IN

Getting back to the past . . . Dr. Vannevar Bush, no relation to our current man at the helm, is where this story of Internet innovation really begins. Born in the late 1800s in Massachusetts, he would later teach at Tufts University until 1917. He developed the first submarine-detection research for the Navy, and before the age of 30 he became a faculty member at the Massachusetts Institute of Technology. He was one of the MIT research team members who built an automated network analyzer, a computer used to solve mathematical differential equations. It was no surprise to his colleagues when he was involved in building the first analog computers in the 1930s.

President Roosevelt saw Bush's genius and rewarded it by appointing him chairman of the National Defense Research Committee in 1940, to help win the war that America was about to engage in. In 1941, Bush was appointed director of the newly created Office of Scientific Research and Development, established to coordinate weapons development research, where he led nearly 6,000 leading scientists in the application of science to warfare; Bush oversaw Los Alamos and the Manhattan Project.

"This has not been a scientist's war; it has been a war in which all have had a part. The scientists, burying their old professional competition in the demand of a common cause, have shared greatly and learned much. It has been exhilarating to work in effective partnership. Now, for many, this appears to be approaching an end. What are the scientists to do next?"

—Vannevar Bush, in "As We May Think," published in the *Atlantic Monthly* in 1945

With World War II won, Bush served as chairman of the Joint Research and Development Board. Coming from academia, he knew the power of university research and brought together the U.S. military and universities via a commitment of research funding not previously seen in any administration. His unbridled enthusiasm for creating a techno-future would provide universities and think tanks with generous contributions to their coffers that would cover the costs of labs and hardware where the best and the brightest would conduct serious research without scrambling for funding. The only thing Bush asked in return? That the military would benefit from the research brought about by the funding. Bush, a true techno-Jeffersonian type, would become cofounder of Raytheon, one of the US's most prolific defense contractors, and then settle into a position as president of the Carnegie Institute of Washington research organization.

Bush's most remembered influence on the development of the Internet comes from his visionary description of *memex* referred to in "As We May Think," published in the *Atlantic Monthly* in 1945. This was where our visionary, Vannevar Bush, would reach across the world and touch fertile minds willing and ready to create the future by the sheer power of his words and clear thought when he wrote the first description of the potential uses for IT (Information Technology), that many technologists credit to inspiring the creation of the Internet.

Memex was the visionary's view of technology not yet delved into by the technologists of that era. With his visionary pennings, he spurred J.C.R. Licklider and Douglas Engelbart into action:

> Consider a future device for individual use, which is a sort of mechanized private file and library. It needs a name, and to coin one at random, "memex" will do. A "memex" is a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility. It is an enlarged intimate supplement to his memory.

> It consists of a desk, and while it can presumably be operated from a distance, it is primarily the piece of furniture at which he works. On the top are slanting translucent screens, on which material can be projected for convenient reading. There is a keyboard, and sets of buttons and levers. Otherwise it looks like an ordinary desk.
>
> In one end is the stored material. The matter of bulk is well taken care of by improved microfilm. Only a small part of the interior of the "memex" is devoted to storage, the rest to mechanism. Yet if the user inserted 5000 pages of material a day it would take him hundreds of years to fill the repository, so he can be profligate and enter material freely.
>
> —Vannevar Bush, in "As We May Think,"
> published in the *Atlantic Monthly* in 1945

Vannevar's description goes on to tell of the ease of use which vast libraries of knowledge are stored and accessed. While Douglas Engelbart was serving in the U.S. military in the Philippines, he read the inspirational words of Bush that would hit home. Engelbart, who now lives in Silicon Valley, is far less well known than the next generation of technologists who would build on his technologies—the computer mouse, windows-style personal computing, hyperlinking, e-mail, and video conferencing, just to name a few.

Engelbart, raised during the Great Depression, had been attending a university to study engineering and then joined the Navy, where he received further technical training.

"I grew up during the Depression, so I mostly worried about keeping a steady job," says Engelbart of his career path. "I had more opportunities when the war came along; I had been working as a welder in a shipyard and also attending college for two years. Then I was drafted and ended up being trained by the Navy as an electronics technician. I spent a year in the Philippines, and I remember being on this island called Leyte at a receivership—that's what the Navy called any place they brought new people into before they were assigned. There were these houses up on stilts on this island that was pure jungle; we just mostly wandered around and did some kind of muster call twice a day and stood in line for chow.

"I looked up one day and saw this hut and it had a sign: Red Cross Library. I climbed up the ladder and it was this clean little room that had about 300 books, magazines, and some chairs; I was pretty much alone up there because most of the sailors and marines who were there didn't read much. But I found a magazine that had an article written by Vannevar Bush; it referred to all kinds of things that captured my imagination, including frames of microfiche and how you could go frame-by-frame and have some code on the top that would automatically refer you to something else. It sounded exciting as hell. So with my two years of pre-engineering school and a year of technical training around all of the oscilloscopes and radar—I could see that all of this electronic stuff was making it happen. You could really see where all of this was going."

Could it be that Bush's concept of the Internet and the vision of what it could become was just as important as Bush handing over the blueprints for this new technology? Probably even more so, because it was a vision that could only be honed with time and the experience of seeing where our society was going.

The end of the war was difficult for some, especially those who were deciding what to do with their lives after returning to a society that had evolved without their presence. For others it was the promise of a new future, a world on the threshold of creating new technologies that would make the United States a strong leader with a unified people and a limitless future.

When Engelbart returned he became an engineer and had a clear mission, one that took only a little prodding on his way to work one clear California morning.

"In 1950, I got engaged," says Engelbart of the promising future that lay ahead. "That next Monday I was driving to work and thinking about my job—I was going to be married and I was going to live happily ever after; that seemed taken care of. Suddenly, I got in to work and as I'm going down this long hallway at what is now NASA, in my job as an electrical engineer, I start to wonder about my professional goals.

"So when I got back to work that first day, I thought about what I was going to do and I proposed to myself—*Why don't I move into a career that benefits mankind?* Perhaps it was a little naïve for a country boy to ask this of himself, but I stuck with it. Month after month I would go into libraries and see the latest on what was being done and I wondered . . . *Should I become a biologist, a scientist, perhaps a teacher?*"

Engelbart began to think again about that article he had read in the Red Cross library kampong in a thick jungle so very far away from home. He hadn't forgotten about that article; he thought of it often as he wondered about where the world was going. That path led him to the Stanford Research Institute (SRI), where he would lend his vision to the future Internet.

Meanwhile, on the other side of the country, young Leonard "Len" Kleinrock had been having similar daydreams about the future. At the age of six he had been inspired by an ad in a *Superman* comic book, from which he ordered the plans to build a crystal radio. Kleinrock acquired all the parts needed to build it, including an earpiece he swiped from a public phone. It would be interesting to know what phone company had "donated" that piece of equipment and to see if Kleinrock's future work had any entanglements with that company. It was from his family's Manhattan apartment, where he spent his childhood hours flipping through futuristic pulp comic books with stories of superheroes armed with cool technology defeating the bad guys, that he amazed himself by getting that crystal radio to work. Music finally did come through the earpiece—no batteries or power required—and all at the hands of a six-year-old with great curiosity and a focused goal. Yes, Kleinrock's destiny was solidified that very day.

Time moved on for Kleinrock, and not being in a position to pay for higher education or having the leisure of not working full-time to earn a paycheck, he attended the tuition-free City College of New York. Ambitious from the start, he went to night school, worked hard, and received a full graduate fellowship from MIT in the Electrical Engineering Department.

At MIT Kleinrock found himself surrounded by peers conducting their Ph.D. research in information theory. Always one to forge his own path, Kleinrock chose instead to venture into the uncharted area of data networks. In 1961 he published the first paper on the subject of packet switching theory: "Information Flow in Large Communication Nets," in the *RLE Quarterly Progress Report.* This work would pave the way for Lawrence "Larry" Roberts to prove that packets could be used for the purpose of networking computers.

Kleinrock completed his research in 1962, and his work was published in 1964 by McGraw-Hill as an MIT book titled *Communication Nets.* His research created the basic principles of packet switching, and it laid the foundation for what we now know as the Internet.

OTHER MINDS AT WORK

In 1962, while Kleinrock was attending school and shaping his idea of the future, and Engelbart was trying to pinpoint which technology would best benefit man's interest, Jack Ruina, director of *ARPA,* appointed Joseph Carl Robnett "Lick"

Licklider as the director of the newly government-established Information Processing Techniques Office (IPTO).

The goal of that department? To carry on the research of SAGE, and specifically develop one of the first wide area computer networks for its U.S. radar warning system, and build a robust electronic network to interconnect the key military sites, the Pentagon being one of them.

In 1963, Licklider funded a research project called MAC, headed by Robert Fano at MIT. The project developed the potential for establishing communities of users on time-sharing computers, and monitored the interactions between its community by measuring communication, and found that the project nurtured the establishment of real human relationships based on long distance electronic interactions. This study had a long-lasting effect on the research community and underscored the benefits of wide area networks.

Licklider's future vision (I love the fact that he was so visionary he even addressed his memos to his colleagues as *Members and Affiliates of the Intergalactic Computer Network*) would greatly influence the creation of a DARPA-sponsored distributed network called ARPANET, that would seven years later become the Internet.

Licklider, like many who would follow his work, had a keen interest in the brain and in finding out how and why it worked. Before joining DARPA he was an experimental psychologist and professor at MIT with a focused interest in psychoacoustics. While at MIT Licklider worked on several projects that would nurture curiosity about how the sciences of human factors and computers of the future would converge.

While doing his research Licklider found that gathering data on psychoacoustics was incredibly cumbersome, and he went one step further from that conclusion to measuring *exactly* how cumbersome it really was. He clocked his own time to determine how much was being spent in gathering, storing, and doing his comparisons, in contrast to the actual time it took him to draw conclusions. His conclusion was that 85 percent of his time was spent gathering and analyzing, and that 15 percent was spent coming to a conclusion. This mental exercise had a way of reminding him every time he went to do research how there must be a better way; a computer technology that could be created to give him back the time he was losing by physically acquiring his research.

Before joining ARPA, Licklider had been looking at a way to solve problems at Bolt, Beranek & Newman (BBN) to carry through his psychoacoustics work, and had been given the thumbs-up on purchasing a PDP-1 from DEC—one of the first minicomputers that was equal in computing power to a mainframe. Even though BBN founder Leo Beranek wasn't quite sure how they would use the $25,000 minicomputer, he agreed to the exorbitant purchase because he had a hunch that it might turn out to be an important machine to the future direction of BBN.

The word *minicomputer* is used quite liberally in this context; although the PDP-1 was smaller than a mainframe, it still took up the space of two large stacked desks. What was great about this computer was that Licklider could be interactive with it; he could program the computer directly, instead of going through the ordeal of submitting punched cards and waiting for the data, and he could review the results via a live-time screen display. He saw where this industry was going.

Before he came to IPTO in 1962, Licklider wrote another paper that (like Vannevar's *Atlantic Monthly* article) envisioned the computer/man relationship and how it would be an important part of the future. His 1960 paper titled "Man-Computer Symbiosis" described an assistant within your computer (think of an efficient secretary rather than

Microsoft's annoying, animated paperclip assistant), and predicted simulation modeling, graphical displays, and other tasks and features of today's computers.

Many people in companies and learning institutions were looking into projects that would further network technology. One of them was Paul Baran. It's fairly clear that the purpose of building a computer network that would survive a nuclear holocaust came from Baran, who wrote the first paper on secure packetized voice, titled "On Distributed Communications Networks, IEEE Transactions on Systems." He describes a network created by the military to withstand a nuclear war. Even though Baran's work for RAND was based on this idea, the ARPANET had no relation to his work. So, it's widely believed that this is the paper that somehow bled into the cultural media and the general idea that the Internet was built to withstand a nuclear holocaust.

In 1964 Licklider left the IPTO and went to work for IBM. In 1968 he went back to MIT to lead Project MAC, and in 1973 he returned once again to lead the IPTO for two more years and fittingly enough completed the life cycle of that project. He was one of the founding members of Infocom.

Following Licklider's 1964 departure Ivan Sutherland became the second director of IPTO/ARPA. Sutherland, like many people involved at ARPA, had a great interest in developing the computer graphics industry and created a sketch pad program for storing computer displays in memory where they could be modified. His program enabled the field of computer graphics that built the framework for the graphical displays available today.

Meanwhile at MIT, Lawrence Roberts had been working in the background. It was during a 1964 meeting between Licklider and Roberts that Licklider encouraged Roberts to undertake the creation of the Internet. Roberts claims that this meeting was the critical turning point, where Licklider's Internet concept was transferred to him to implement. In 1965, ARPA contracted its first network experiment, and Ivan Sutherland awarded it to Roberts at MIT's Lincoln Labs.

Sutherland saw the work of Robert Taylor, who was powerfully influenced by Licklider, was very interested in the man/computer relationship, and, like Licklider, was a researcher in psychoacoustics. In 1966, when Sutherland left and Roberts refused the job, Taylor was promoted to directorship of IPTO/ARPA and began the initial work of the ARPANET, but continued to try to lure Roberts onboard.

Roberts was very happy at Lincoln and was dead set against taking over the directorship of ARPA. In order to persuade him, Taylor leveraged the funding that ARPA provided to Roberts' lab at MIT.

"I was kind of blackmailed to go to ARPA," says Roberts with a smile as he thinks back on it. "Ivan was the one who brought it up initially; he had funded my experiments at Lincoln Labs. Ivan asked me to go to ARPA and I said, *No.* Apparently all of the principals at ARPA decided I should be the next person in line; Ivan asked me several times. So Ivan finally left the job to Bob Taylor. The community agreed that Bob Taylor should be in charge for a while, but that they should bring me on as fast as possible.

"Well, Bob called to try and get me to come on board, and I again said *No.* So what he did was go to his boss, Charlie Hertzfeld, and ask, *How much money do you give to Lincoln?* And he answered, *Well, we give them 51 percent of their money.* So Taylor asked, *Can't you do something to get Roberts here?* So, he called up the director of Lincoln and said, *Do something*. The director of Lincoln called me and said *I think it's in your best interest that you go to ARPA, and we'll pay your way and take care of everything—and it'll be good for your career.* I don't regret that I took the job.

"At that point I realized that I was so far ahead in research [Lawrence had been working in virtual reality]—so far beyond where graphics really were that I couldn't get commerciality out of it. We had head-mounted displays and 3-D projections; I did all that in my thesis. But it was way beyond what people were doing. It was going to be 30 years before anyone could use it. So, what I really believed was that it would be good to go out and do something that was closer to commercial reality. So I went to ARPA—and I have Bob to credit for all of that because he got me interested."

In 1966, Roberts joined the IPTO as chief scientist. Roberts began noticing some redundancy in resources to the ARPA-funded projects when he came on board.

"I think about it [the pervasiveness of the Internet] most often when I'm driving down the freeway and see WWW. on a billboard—and no telephone number. I think, 'My god, the only way we're communicating now is through these web addresses.'"

—Lawrence Roberts,
cofather of the Internet

"There were lots of different computers with different databases and different systems that were not transferable," says Roberts. "For instance, if there was data on another computer, you couldn't just get it on all computers, and personally you couldn't store it all. Some of the information was coded in a way where it wasn't compatible and you couldn't move it. And the software at that time was mostly unique to a specific research site because they had developed it. So we had many, many incompatible computers, not at all like it is today, because Microsoft has changed that. We didn't even have word processing compatibility. The ability to get at other people's documents was difficult, and the best way to do that was across the Network. If you put in a standard ASCII communication mechanism someone could send the data and someone else could look at it. I realized that this technology was certainly better than circuit switching."

1967

Wes Clark suggests that instead of using the mainframe computers on the Network, minicomputers be used for Network packet switches. This puts the minds of people on the proposed Network to rest because they don't want any downtime on their mainframes.

On June 3, 1968, Roberts gave a report titled "Resource Sharing Computer Networks," describing the plan to build the ARPANET. A little more than two weeks later, Taylor signed the approval for the project. Taylor had the foresight and the authorization power to begin the wheels turning on the ARPANET project. Without this approval, things might not have gone quite the way they did. Although many individuals have been attributed to fathering the Internet, this first act of giving power (and cash) to the ARPANET project should by no means be underestimated.

In 1968 a call for proposals was raised by Roberts for the design of the ARPANET. He had done much of the overall network design, network economic analysis, line optimization, and the selection of computer sites to be connected. Later that year Roberts evaluated the potential paths, and with the ARPANET staff and a group of its contractors, they made a game plan. That same year, the Network Measurement Center at UCLA, led by Kleinrock, was given the contract to undertake ARPANET measurement. At that same time, the ARPANET packet switch contract was awarded to Frank Heart's group at BBN to create the ARPANET Interface Message Processors (IMPs), and the BBN group proposed using Honeywell 516 minicomputers for the IMPs. The BBN group had such icons as Bob Kahn, Severo Ornstein, Dave Walden, and many other key individuals on board.

1971

Ray Tomlinson, a principal scientist at BBN, popular for his work on early mail and file transfer programs, made a unilateral decision that sticks with us even to this day—many, many times a day. He meshed the file transfer protocols of one program with the send/receive abilities of two other electronic e-mail programs. To address e-mail Tomlinson had to specify both the machine and the particular user for the netizen for whom it was intended. He needed a single keystroke character that would separate the two in the address, but not be found in either the host name or a person's e-mail address. The @ sign fit the job beautifully.

Then, three years after Taylor had taken the baton as director, and well after ARPANET was on its way, he passed directorship of the IPTO on to Roberts. Taylor left to create the computer science lab at Xerox's Palo Alto Research Center (Xerox PARC), and in 1983 he founded DEC's Research Center in Silicon Valley.

The year 1969 was a very busy one for the burgeoning network. A paper written by Steve Crocker covering host-to-host protocol, the first output of the Network Working Group (NWG) was released and the much-awaited first node of ARPANET was installed at UCLA's Network Measurement Center, where under Kleinrock's direction it connected the IMP to their Sigma 7 computer. The second node of ARPANET was installed at SRI, where Engelbart's group connected it to its SDS 940 computer. In September 1969, the first ARPANET messages were sent.

A WHIRLWIND OF ARPANET ACTIVITY MOVES US FORWARD

Many people pushed the Internet technology further to develop it into the commercial Nirvana that it has become. An event took place in 1971 that directly affected the growth of the Internet: the first Terminal Interface Processor (TIP) in ARPANET allowed terminals to dial directly into the network. The next year Roberts created the first e-mail management program allowing responding, forwarding, and filing.

Also in 1972, FTP protocol specification (RFC 354) was released by Jon Postel and Abhay Bhushan. Another accomplishment during that eventful year was the first public demonstration of ARPANET, led by Kahn, a major milestone to showing the world what we could expect from the distributed network. Bob Kahn was hired by Roberts into

ARPANET. Xerox PARC was now moving into the picture, as Bob Metcalf's Ethernet design successfully expanded the ALOHA packet radio concepts and applied them to cable.

In 1973 Roberts left ARPA for commercial interests. That next year, BBN released a revised ARPANET routing after a complete rewrite by John McQuillan; this resolved many issues in the software and brought great improvements forward in the network's routing.

Bob Kahn and Vinton Cerf wrote a paper on Internet protocol, TCP, *A Protocol for Packet Network Interconnection;* and Kahn and Cerf began design in 1973. Two years later, ARPANET was transferred to the Defense Communications Agency. And that next year Vint Cerf joined ARPANET as the manager of the packet radio, packet satellite, and packet research programs, where he stayed until 1982. The next year, in 1977, the first TCP was in operation over ARPANET, Packet Radio Net, and SATNET (satellite network). During that year, Steve Crocker and John Vittal release e-mail specification (RFC 733).

The world was moving quickly in 1978, as Vint Cerf, Jon Postel, and Danny Cohen split TCP into TCP and IP, where TCP was the end-to-end process and IP was the network routing process.

The '80s mark the accomplishment of NSF organizing CSNET and increasing it to 70 sites by 1983 and integrating most computer science sites by 1986. The late Internet pioneer Jon Postel, along with Paul Mockapetris and Craig Partridge, developed the Domain Name System (DNS) to support the e-mail addressing space by creating .com, .edu, .int, .gov, .mil, .net, and .org. About that same time the NSF set up its NSFNET backbone to connect five supercomputing sites and network other Internet sites at 56kb; that next year NSF upgraded NSFNET to T1 speed.

ARPANET turned 20 years old in 1989—and then was shut down. During the following months, node after node was taken off the Net, and the first commercial Internet lines were opened through MCI. By the mid-1990s ARPANET was only a part of a great legacy brought forward and spear-headed by a great many visionaries. In 1991 the floodgate to commercial use of the Internet was opened.

HERE, LOOKING BACK

Many of the founders of the Internet now look back with hindsight and also with the foresight they had when the pieces were beginning to fit together. We'll never know what Vannevar Bush would say about the Internet that embraces his original vision of vast amounts of knowledge available at a click, but I do have an inkling that he would be taking in its *adult* endeavors, one of the most successful segments of the Internet market, with curiosity and humor, chuckling about the nature of man and his computer.

HUMAN(ITY) AND THE COMPUTER

"I think that over the last two decades the Internet has been very important for humanity," says Lawrence Roberts. "Basically the Internet has made it very difficult for dictators and communism, because people get their information from all over the world and they didn't have to depend on restricted news sources. The Internet has changed the world—and I think it's what broke up the communist block, in large part because they couldn't control the news anymore. That's not true in every dictatorship; sometimes people don't have enough good Internet access to receive news, and even China is still trying to control the news. I think it will eventually topple that system because people are getting through and there's too much data—they can't monitor and control everything. I don't think they can live through it and control the news forever. Eventually their system will change—they're struggling against it, as you'd expect, but they can't win.

"As I was creating the Net, I very quickly saw that it could be helpful. What I was trying to do was establish a worldwide ability for people to get at information quickly. I thought that would change the rate of knowledge growth around the world. This was the next evolutionary stage where we could get information quickly and knowledge growth would grow very rapidly. Originally, I wasn't thinking as much about governments and democracy and freedom as I was later on. By the early part of the network operation, I saw the Net would affect that too, and that it would become a serious benefit. If you look at my first submission to Congress, I didn't say it [ARPANET] was going to kill communism, but I found that it would be valuable for the government, humanity, and the military. Later on I started realizing that was going to be one of the big impacts, and that it would in fact change the abilities of people everywhere."

"I went to Congress with the story about how it was going to change the way we communicate and our information transfer. There was nothing in it about military activity. Basically the military would benefit as much as anybody else. It was clear to Congress that if this worked it would work for the military as well as everyone else."

—Lawrence Roberts,
cofather of the Internet

"The first indication of this change was within months of it starting," recalls Roberts. "It was about '71 when we got the Network really working and got Hawaii online; people in Hawaii had very restricted news, and the people in Iowa were the same way. People we were involved with, educated people, were interested in what the gold market was doing, so they would watch over their systems, and for a lot of people that was their primary news source. Now, of course, that's normal, but back then some people didn't have good access to national news and started using the Network to find out what was going on in the world. So people started putting newsfeeds right on the Internet from the start. And people from all over found that tremendously valuable because they wanted to find out what was going on and search for what they were interested in instead of trying to read the local newspaper."

OLD CHALLENGES LINGER TODAY

With some of ARPANET's biggest challenges met and obstacles removed, the future was wide open and people began thinking beyond simply making it work.

"ARPANET had a real commercial advantage over circuit switching as far as moving data," says Lawrence Roberts of the early Net. "I also showed that voice was already economic on packet switching, but it wasn't even possible that it was going to move that fast because there wasn't a big enough benefit to move over to that method. People were going to stick with what they were doing for a period of time [the phone], but I predicted it would take around 20 years."

The greatest minds in the world began to ponder, research, and create what the future of this man and computer network would look like.

"When we started designing the Network the concept was mainly to have high reliability," says Roberts. "The phone network was not sufficient or capable [for our purpose] for a number of reasons. One is that it didn't handle burst traffic, and second, it was too unreliable and slow to make quick connections. For data you need a very quick connection and you need to establish it instantly and be online all of the time. And you have to be able to burst at very high speeds and not pay for it all the rest of the time, so it's very different from the phone network. Getting that technology into place was the first thing for us and reliability was part of that process.

"The Network was a redundant, distributed system; it didn't have anything to do with disasters—that was Paul Baran's concept," stresses Roberts. "I was really worried about the reliability and stability of the Network so that it would do the job—the best design was a distributed design in general and it was reliable and economical. So I always knew it was going to be reliable; and as it grew it would become even more reliable because it would have thousands of nodes and you'd have to kill hundreds of them before it had any significant impact whatsoever. A few of them were actually hit in the World Trade Center; and it was a minor impact to the Network, so minor that the network didn't notice it at all. There were overloaded servers where you couldn't get anything off of CNN because they didn't have enough capacity and that was an individual server problem, not the Network's.

"The Network worked perfectly, in fact all the people I know were getting all of their information that way—especially those in Washington and New York where the phone networks had been affected," says Roberts, analyzing what occurred in the communications networks after 9/11. "The reason was because the phone network has a secondary problem—that we made sure we didn't design into IP networks—the problem is that as the load increases, the performance of the switch declines so that you have a curve that occurs. As load rises, the total capacity of the switch goes up and up and up, and then there's a point where the demand goes back down again. But if the demand becomes too high the switch can't hardly do anything. That's what happens in earthquakes and disasters with the phone network. The software and switching element is basically not capable of handling the call requests, so it can't deny them effectively and it goes into a mode and tells everyone to go away. It is a disaster all in itself because nobody is getting anything done. Whereas, with an IP network, everybody works slower, but it continues to get better and better until you peak out at the maximum capacity of the network and you're still operating and everybody is getting something done.

"In fact, during that disaster [9/11], nobody had any problem with the Network, it worked perfectly," says Roberts of the network that eventually evolved from ARPANET. "And that's exactly proving to people that the Net is a lot more reliable in that kind of environment. But the whole goal of the project was reliability in everyday operation; you don't want the failure of a piece of equipment to affect your net in any way. IP networks have been built with lots of redundancy anyway. I didn't think there was any likelihood of that being a problem and it wasn't. That's not saying that we have to get rid of the phone network, it's worked pretty well. Only in a case of disasters is the phone system a problem; and that's a big problem for the military, so they have to have their own systems. One issue comes up when you're designing a switch, and that issue is if you allow the control traffic, the stuff that is setting up the paths and the calls, to be the same priority as the data, then you can get into the same problem, and that's when you get into an overload and you can't get the control through. Then it gets slowed down until you can't make anything happen, so the network loses connectivity, because it's not keeping in touch with itself fast enough. If you give that a higher priority and dedicate three percent of your bandwidth to control, it works perfectly and there's never a failure and that's essentially what we've done," says a much wiser Roberts, who is now founder and chairman of Caspian Networks, a Silicon Valley Internet infrastructure company developing a new generation of equipment for the networks upon which today's Internet runs.

THE ORIGINAL VISION

Vannevar Bush and J.C.R. Licklider had a very futuristic world in mind when they went about writing their papers on how the future would shape up; envisioning people finally gaining control over the technology that would empower them. Super-intelligence powered by 24/7 availability to vast libraries of knowledge where one could click from window to window to obtain a deeper understanding of the world around him or her.

"When I sat down with Licklider in '64 he convinced me this [the Network] was important—that language allowed people to communicate, and that the printing press allowed them to communicate much faster," says Roberts about that fated day he had the discussion. "And my original thought was that we need to get to the third generation of information transfer where people can have all the information in the world. What we thought was that anyone in the world could get to a computer anywhere in the world and get any information. At that point we had all mainframes, so we weren't thinking so much in terms of personal computers; we were thinking about people at their terminals who were going to reach out to other people on the Network.

"When I first thought about it I was at MIT and I was thinking, *How do we change the state of the world*?" says Roberts about what was on the minds of a lot of people who would end up working together to build the ARPANET. That question hung in the collective consciousness of a generation of technologists who would reach out to find others with like minds.

"The second thought I had in answering that question was once you do this, the dictatorships, communism, and such couldn't exist with this massive flow of information in the world, not just what's under their control. My feeling was that it was very important for the speed of innovation, the speed of research, the speed of science, and commerce. There was no thought in my mind or anyone else's mind that e-commerce would succeed [as an industry]. E-commerce had failed on every front it had tried—people just didn't seem to want to buy from their TV set. If we had thought seriously about it we would have realized that there were things people could buy electronically with less work than they could go to the store to purchase. If it's something in the store that's really common it might not be attractive to buy online, but if it's something hard to find, and Amazon proved that pretty effectively, then it could be of major benefit.

"That was the first thing we missed," admits Roberts of the overlooked benefit. "The second thing we missed for years was e-mail and personal communication. Although very early on I did the e-mail handler, send mail and read mail, which gave me the basic file transfer, and then I said, *I can't use this,* because it is pouring out like teletype. So I built an e-mail library where I could save them and read them by title only, and choose to save them, read them, and respond to them, and it looked like it looks today; I can hardly tell the difference. That was in '71. After we built the Network and got the thing going, we quickly realized that all the communications benefits were major, and we'd be able to do voice and video later on and be able to virtually take anything on."

While Roberts was talking with Licklider back in 1964, Douglas Engelbart had already been inspired by Vannevar Bush's words that he read two decades earlier in the unlikely setting of a foreign jungle.

> *"The real thing that made the Net more dynamic was the emergence of the World Wide Web. What seemed to get that going was a free browser. If it had been just somebody who was saying, 'I have this product to sell,' then people may not have tried it. Tim Berners-Lee made it easy for everyone to try."*
>
> —Douglas Engelbart,
> founder of the Bootstrap Institute

Engelbart found a home at the Stanford Research Institute (SRI) in Silicon Valley, where he settled into a research position, earning more than a dozen patents in two years while working on magnetic computer components, fundamental digital-device phenomena, and miniaturization scaling potential. In 1959 he'd been given the thumbs-up to pursue his own research. In the back of his mind he still contemplated Bush's words. He spent the next two years formulating a theoretical framework for a new discipline based on his thoughts that *complexity and urgency are increasing exponentially, and that the product of the two will soon challenge our organizations and institutions to change in quantum leaps rather than incremental steps.*

In 1963 Engelbart finally received the backing to start his own research lab at SRI, which he later dubbed the Augmentation Research Center. He began by developing the kind of technology he believed would be required to augment our human intellect.

During the 1960s and 1970s, his team produced a visionary project in hypermedia-groupware system called NLS (for oNLine System). In the spring of 1967, it was arranged that all the ARPA-sponsored computer research labs, including Engelbart's, would be networked to promote resource sharing. Engelbart saw ARPANET as a way to transfer NLS provisions into a wide-area distributed collaboration.

"Before ARPA came along, I was talking to my crew at SRI and saying that we just had to find a community of users for the project we were working on, and just how do we spread that community out? We knew it was going to be a challenge. Then there was this meeting in the spring of '67 at the University of Michigan. Larry Roberts and Bob Taylor were saying how they [ARPA] had this special project they wanted to talk to the group about. It was about computer networking and how they really felt that we ought to tie all the computers together. The way the whole thing was disclosed was that we could share computational resources and data.

"So the general idea was that we had to get it up and working and try it out. Well, we tried to get the Defense Department's computer centers to buy into it and they were all very skittish about doing something that would interfere with their productivity.

"So these prima donnas were talking about it—and one guy says to the other, *What have you got in your computer that I want?* The other guy says, *Don't you get my reports?* Knowing full well that the other guy doesn't. He answers, *Do you send them to me?* Knowing that the other guy probably has no idea who is on his list to receive his reports. So, they know they couldn't get anywhere shooting at each other, so they turn to Roberts and Taylor and say, *You guys are going to have* *to keep a database up that says who has what kinds of processes and who has what kinds of data, and how to access and exchange the information.*

"Apparently Roberts and Taylor had not thought about that, because they almost shriveled—they both had one secretary," says Engelbart, smiling as he remembers the moment. "So I said, *Hey, we are doing that kind of thing, and we could make an online information center that could hold that data and make it available to the Network.* We heard some sighs of relief, and that's when we got the commitment to be the Network Information Center [NIC]."

Because of Engelbart's quick reaction in meeting ARPA's need for a central directory, his site was the second host on the network. He saw NLS as a natural to support an online directory of resources, a project he continued to direct until 1977, when it was spun off.

Engelbart felt that the key to having the man and the future world's computer database, as Bush had described it, work flawlessly together was finally being actualized. While working on these theories, Engelbart became a pioneer in developing the following technologies: the mouse, 2-dimensional display editing, in-file object addressing, linking, hypermedia, multiple windows, cross-file editing, integrated hypermedia e-mail, hypermedia publishing, computer-aided meetings, formatting directives, and distributed client-server architecture, and the list goes on. He successfully garnered many patents, and concepts that would be leveraged into today's technologies, technology that would make today's technology icons rich.

In 1989 Engelbart founded the Bootstrap Institute <www.bootstrap.org>, feeling there was a great need to pursue researching and developing enabling technologies, best practices, and strategies to develop and deploy them. Engelbart now works with members of government, industry, and society to find solutions to the ever-growing difficulties that technology creates.

HAPPENSTANCE?

This book opens with a quote from Branch Rickey, the Brooklyn Dodgers' general manager. It reads, "Luck is the residue of design." Could it be that the Internet is a creation of happenstance? A product of pure luck? A beautiful act of serendipitous chaos that brought the right people together at the right time?

"The technology hadn't been designed, per se," says Leonard Kleinrock, cofather of the Internet, professor of computer science at UCLA, chairman and advisory board member of TTIVanguard <www.TTIVanguard.com>, and chairman of Nomadix <www.Nomadix.com>. "It was very carefully thought out, but there was a lot of development, in the sense, the way software and systems are developed along the way, but it wasn't accidental. It was very purposeful, but it was new technology. *Accidental* says it was serendipitous, not planned, or strategic—and it was very strategic.

"One must never underestimate the proper attitude of ARPA for providing the funding, the flexibility, the freedom, and the testbed for the small number of experimental negatives to shake down the technology to serve the purpose they wanted; which was to share resources. They weren't intending to make a commercial powerhouse out of it. ARPANET had the time to mature in a proper environment of experimentation. The Network couldn't have started from day one because we were busy testing things, crashing things, not giving reliable service, or even intending to do so because we had to try new things all the time. The fact that ARPA made that available was a brilliant move on their part. I'm not sure they planned it to be so brilliant, but it was just the right thing at the right time.

"We had industry and government and academia all working beautifully together and a relatively loose governance on the other hand; ARPANET wasn't driven by milestones, it was driven by creativity and cooperation. It wasn't the hard-nosed sergeant in arms, it was that we all wanted to make it happen, and we did. As a result, it was a wonderful, wonderful experience."

Kleinrock, although a UCLA professor, is an MIT man at heart, and he has a theory about how some of the alchemy came about to make the ARPANET work. "I spent a number of years at MIT; it's a wellspring of new technology created by brilliant strokes of realization and newness. So it was not a new thing to Larry or me who had come out of this environment. Or to Bob Kahn, who also spent some time at MIT. MIT was really unique at the time; it was a Golden Age. Our classmates and our faculty were all coming up with these great results. I was able to prove that large systems dramatically improve performance. For a young kid coming out of graduate school to be thrown into that mix was fantastic; then you contribute, you turn people on, the creative juices start to flow, and you develop technology."

Again, in a mission to set the record straight, I posed the question of whether ARPANET was funded to create a mode of fail-proof communication in the case of a nuclear holocaust.

"There is an issue here," says Kleinrock, pondering the question. "Were there people deep in the Pentagon who were signing the checks who had that as their motivation? Maybe. We don't know. Was that the case presented to the researchers? By the researchers? Or by ARPA itself to the world? To the public? To us? No. Everyone whom I spoke with at ARPA who was involved in the funding process agrees that the idea was about resource sharing. I know what was motivating them—they were funding a bunch of principal investigators, and each time they gave somebody funding they would create a specialized resource out of it. The research resources dealt with the graphics, the databases, the machines . . . and every time the funding was given the researchers said, 'Go buy me a computer and I want that computer to have the same resources as all the other guys have—I want graphics, simulation, databases, etc.' ARPA said that it couldn't afford to give everybody everything, but if you, Mr. Researcher, were in the network and wanted to do graphics, you could log onto Utah, if you want simulation, you log onto UCLA—that was the motivation. That's the story sold to us and by us.

"We were not motivated by a network that would survive military or hostile attack," says Kleinrock of his initial involvement with ARPANET. "My design, which allowed those things [a network that would go undisturbed in an attack] to happen was predicated by very different things; that it should be scalable—and that wouldn't happen if there was centralized control. Once you have distributed control you've got redundancy, adoptability, flexibility, and all those other things that suit damage control because you don't put all of your eggs in one basket.

"If you look at the statistics of the Internet growth, it has been growing exponentially since day one, except it had to get really big before everyone else noticed it. A few events happened for it to accelerate some, like the Web."

Did Kleinrock expect the unprecedented growth of the Internet of recent years? In a press release from UCLA dated July 3, 1969, he gives glimpses of the challenge his department was then about to take on:

RELEASE: UCLA TO BE FIRST STATION IN NATIONWIDE COMPUTER NETWORK*

UCLA will become the first station in a nationwide computer network which, for the first time, will link

*UCLA Office of Public Information, "UCLA To Be First Station In Nationwide Computer Network," July 3, 1969, www.lk.cs.ucla.edu/LK/Bib/REPORT/press.html.

together computers of different makes and using different machine languages into one time-sharing system.

Creation of the network represents a major forward step in computer technology and may serve as the forerunner of large computer networks of the future.

The ambitious project is supported by the Defense Department's Advanced Research Project Agency (ARPA), which has pioneered many advances in computer research, technology and applications during the past decade. The network project was proposed and is headed by ARPA's Dr. Lawrence G. Roberts.

The system will, in effect, pool the computer power, programs and specialized know-how of about 15 computer research centers, stretching from UCLA to M.I.T. Other California network stations (or nodes) will be located at the Rand Corp. and System Development Corp., both of Santa Monica; the Santa Barbara and Berkeley campuses of the University of California; Stanford University and the Stanford Research Institute.

The first stage of the network will go into operation this fall as a subnet joining UCLA, Stanford Research Institute, UC Santa Barbara, and the University of Utah. The entire network is expected to be operational in late 1970.

Engineering professor Leonard Kleinrock, who heads the UCLA project, describes how the network might handle a sample problem:

Programmers at Computer A have a blurred photo which they want to bring into focus. Their program transmits the photo to Computer B, which specializes in computer graphics, and instructs B's program to remove the blur and enhance the contrast. If B requires specialized computational assistance, it may call on Computer C for help.

The processed work is shuttled back and forth

until B is satisfied with the photo, and then sends it back to Computer A. The messages, ranging across the country, can flash between computers in a matter of seconds, Dr. Kleinrock says.

UCLA's part of the project will involve about 20 people, including some 15 graduate students. The group will play a key roll as the official network measurement center, analyzing computer interaction and network behavior, comparing performance against anticipated result, and keeping a continuous check on the network's effectiveness. For this job, UCLA will use a highly specialized computer, the Sigma 7, developed by Scientific Data Systems of Los Angeles.

Each computer in the network will be equipped with its own interface message processor (IMP) which will double as a sort of translator among the Babel of computer languages and as a message handler and router.

Computer networks are not an entirely new concept, notes Dr. Kleinrock. The SAGE radar defense system of the Fifties was one of the first, followed by the airlines' SABRE reservation system. At the present time, the nation's electronically switched telephone system is the world's largest computer network.

However, all three are highly specialized and single-purpose systems, in contrast to the planned ARPA system which will link a wide assortment of different computers for a wide range of unclassified research functions.

"As of now, computer networks are still in their infancy," says Dr. Kleinrock. "But as they grow up and become more sophisticated, we will probably see the spread of 'computer utilities', which, like present electric and telephone utilities, will service individual homes and offices across the country."

"What happened in the '60s," says Kleinrock, "was that it [networking] took a while to catch on because none of the researchers wanted to participate in the Network because they didn't want to put their computers on a network for others to share. They didn't want to do it until we went and told them [that] not only can they use yours, you can also use theirs.

"The original architecture of the Internet only had six bits of address. You could have at most 64, and it sort of flattened out until BBN expanded it. For two years it was very minimal growth because we didn't have a very good protocol. Until we developed the host-to-host protocol it was very difficult for you to use another machine; you'd have to learn the command language, get a logon, understand the applications, and they'd probably have a different operating system [than the computer they were trying to network with]. Until we got a transparent host-to-host protocol it was very difficult, but then it took off quickly. There was a blip when we did the first public demonstration of the ARPANET in 1972, a lot of people saw what was going on. That was not a major blip, it was a little blip, and then it just continued on growing.

"There were really three things I anticipated in the press release," says Kleinrock of what he pointed out in the press release. "I'm not counting the initial success of ARPANET where this technology proved that it would work; that was beautiful. In that press release I was basically predicting five things: that the Internet would have five properties. It would be ubiquitous, it would be always available, always on, anyone could connect in with any device, and it would be invisible like electricity. The Internet got the first three right, but it failed on the other two: It's very difficult for anyone with any device to get on—that's what I call Nomadic commuting. It's not invisible because if you call Windows an invisible, easy GUI, than I would agree, but I don't. I failed that part of the prediction. What I didn't predict was that my 93-year-old mother would be on the Internet today, and that it would penetrate so many aspects of our society; our government, our industry, our education, our entertainment.

"When did I see that? Well, in '72 when e-mail was introduced as an ad hoc add-on and it suddenly took over the network and I realized, *Ahhh . . . this is not about computers talking to each other, this is about people communicating*. That was the first insight I had—that's what was going to make this thing grow."

> *"Nobody controls it, nobody can turn it off."*
>
> —Leonard Kleinrock,
> cofather of the Internet, and chairman
> of Nomadix and IITVanguard

"The second time I saw something was a few years later when newsgroups were the rage," says Kleinrock of his next epiphanous moment. "Newsgroups were created around the country by people with similar likes; be it recipes, stamps . . . everything. As a faculty member I was not engaged in any of that, and I remember one day walking into my graduate students' bullpen to ask one of them a question. And I said, *What's that?* [pointing to a screen], and he explained that he was signed onto a newsgroup and explained to me what was going on. I said, *Jesus Christ! There's an underworld of activity here. It's not visible but it's going on all over the place*. And that's what reconfirmed the idea that communities were going to form on their own and take advantage of the Internet infrastructure to grow.

"The third thing was when the Web hit and I began to see the word *Internet* everywhere. I remember one day when I was flying, I counted all of the ads that talked about computers and/or networks in American Airline's magazine. More than half of the ads had something to do with those two things. And that number started growing very quickly. And that was the pervasiveness that I was seeing back in '72. Those were the epiphanies.

"Now, you can't turn the Internet off. The financial system would collapse for example: the transportation systems . . . automatic traffic lights, a whole bevy of things would collapse. Airplanes would not fly, when I say *the Internet,* I mean the automatic computer technologies on board an aircraft, or across the world."

REMINISCING

David J. Farber is one of the most outspoken people on the face of the Earth on the subject of technology and those sensitive areas surrounding it. He has an online newslist, *Interesting People,* where you can read commentary from the world's digerati 24/7 as it happens. He is currently the Alfred Fitler Moore Professor of Telecommunication Systems in the School of Engineering and Applied Sciences and professor of Business and Public Policy at the Wharton School. His latest claim to fame has been serving as the chief technologist at the Federal Communications Commission (FCC). But, going back to his roots, he graduated from the Stevens Institute of Technology in 1956 and began his 11-year career at Bell Laboratories, where he helped design the first electronic switching system (the ESS as well as helping to design the programming language SNOBOL). Then Farber headed west to The RAND Corporation and to Scientific Data Systems.

"While I was at Bell Laboratories in the early '60s until about '67, I had been involved in communications and I saw the beginnings of packet switching. A bunch of us tried to convince AT&T that it should start a research project at Bell Labs on packet switching. We got rejected on the grounds that AT&T held that there was no real business for data," Farber says about the view AT&T took after being advised by some of the best and brightest in the industry. "The interesting thing here, if you talk about Xerox flubbing the future—AT&T outdid them. I then went off and ended up at the University of Irvine, where we were building what I believe was the first fully distributed operating system using a new LAN technology.

"As opposed to most people in the field, we actually built it and it actually ran. So when you read the literature in the field, you find a lot of people who talk about systems they would build if they ever built them. We actually built it and it ran. I was working in the networking area, and I got a call from a friend at UCLA, Jerry Estrin, who said he had a student up there who was interested in this new game—packet switching and real networks. They didn't have anybody up there to work with him, but he was interested in doing a Ph.D. in the area. I said, *I'll help him out.* That student was Jon Postel. That got me in, and it turns out another friend from Bell Lab days got involved in networks; that was Bob Kahn. Suddenly I found myself with a DARPA contract for some interesting stuff and an e-mail address on one of the very early networks.

"The most interesting thing was working with bright, young students at UCLA; at that point Vint Cerf and Steve Crocker were students there. I got involved in research and networking, then I left the University of California at Irvine and went to the University of Delaware, and a friend of mine was trying to start up something which would bring some network technology into the academic arena. At that point there were five universities tied into the baby ARPANET. That was the blossoming of university computer science programs, that was about when Sputnik went up. So then everybody wanted a computer science department [to be on ARPANET], and you had 400 computer science departments with two people in them. We made a proposal to the NSF to put together a network which would focus on bringing e-mail and some overall connectivity to the computer science departments; that was called CSNet. Much to everyone's astonishment the NSF funded it with some interesting caveats attached to it; one of them being that we had to break even in two years, which is not easy."

Farber and his team built the network and got it up and running, and made developments that would make it cheap for universities to connect to the very simple network. "We also went through all of the energy to come up with an agreement with Bob Kahn, who was at DARPA, for letting traffic flow to and from the experimental ARPANET. There were a bunch of big schools on that network and there was some talk about bringing computer science departments together so that the schools could communicate; so we built the first of the peering relationships. The other big thing that happened was that as we grew to maybe 50 to 60 schools we got requests from foreign countries asking if they could join in. We came up with this somewhat strange behavior of saying, *Okay you can join us if you create your own group like us,* because we only wanted to deal with one point per country—we didn't want to deal with 15 schools or 100 schools per country. So we basically sparked the development of national networks. We came up with a connection agreement which was, *You want to connect to us? You pay the bill.* As kids began graduating and having exposure to CSNet, they went off to industry and asked industry, *Can we keep our connection?* And industry said, *Connection to what?* They said, *CSNet,* and industry asked, *What's that?* So pretty soon we had IBM and a large number of companies banging on our door, asking *Can we use this?* and we said, *You can as long as it's for research and you can't use it for commercial traffic.* That was part of our agreement with the DARPA; that we wouldn't pass commercial traffic. They said, *Fine,* because they were trying to attract researchers. And we said, *It's going to cost you,* and then we sat back and thought about the largest amount we could get. So, we charged them an outrageous amount of money—the big companies paid about $50k a year—and we used it to subsidize the schools. The vast majority of the schools paid a small amount of money; industry paid a lot; and the big schools paid a lot. Everyone was happy. We knew if they were using it over and above just the research, but we closed our eyes. I chaired the NSF advisory board at that point, and it was clear that CSNet was a success, but what was happening was that other departments on the campuses kept coming to the computer science departments, asking, *Can we also use the network?* And we kept being bombarded with questions, *Is it okay to use it?* We always told them what we don't know won't hurt us.

"We went into the NSF with a proposal to expand the capability of NSnet into what was known as the National NSF Net NREN (National Research and Education Network). The proposal was accepted and we had the capability to expand the capability of the network to make it look more like the current network, so we started off down that track. But it was pretty clear that no amount of money or no management team we could bring together was going to give us the richness of the structure we needed for what was beginning to be an increasingly large network. So we came up with this brilliant idea of authorizing regional networks . . . northeast region, southeast region, California . . . which would run the network in their region for the universities. So you started getting things which rapidly evolved into ISPs—PSI Network, came out of New York's network. It was a rational thing. And part of the NREN activity was opened up to industry and made it much more of a commercial orientation; again trying to support the universities on the cheap supported by the commercial side. It just kept growing and growing and basically escaped the research control and you have basically the current network."

Farber is constantly on the speaker's circuit, and because he was able to make a viable business from his research, he is asked if he saw the trend coming.

"I'll show you an example of the industrial collaboration; about eight years ago, Bob Kahn and me observed that we were dealing with relatively small networks and yet inside the research labs there were really high-speed capabilities. But it didn't look like there was any way for that technology to get out of the research lab and into the hands of those who wanted to use it because there was no commercial driver. The whole thing was, *We can give you a lot of bandwidth but there is no market for it, so why should we give it to you?* So we started an activity called the Gigabit Test Beds. What that did was identify five test beds for operating at gigabit level. A very expensive game back then. We worked together with industry with this deal; industry will fund us on their own nickel, the NSF will fund the universities, and they'll fund themselves and give us the infrastructure. And that was a big, big win. We handled all the major corporations involved, all of the major universities, and some small ones, and we ran the first gigabit networks on the East Coast.

"Cisco came directly out of that network; as a direct result out of that effort we were looking for high-speed routers. A couple of other companies spun out of it; more important, the big carriers got a jump on when they normally would have deployed this technology. Again, it was a marvelous use of industrial/university collaboration because each one had something to gain."

So when asked again about the beginning—did Farber know a good value when he saw one? "One thing I observed out of this whole process was that none of us knew where this whole thing was going. I gave a talk at Microsoft a couple of months ago and commented that had we known where it was going at that time, we'd all be worth as much as Bill Gates. Anyone in the game from the start is worth nowhere as much as Bill Gates. People can say, *We knew it was going this way,* then you have to ask, *What happened . . . how come you're not rich?* Nobody knew it would explode like this. It took a couple of serendipities; the Web was a serendipity no one expected. The popularity of e-mail was something nobody expected. All those things that nobody could predict—it just took off.

"I knew the technology was valuable, there was no question about that; I knew it would replace things like the U.S. mail. We were swapping documents around through e-mail, and it was clear it was going to change the complexion of the way people carried on their research and their business. What we couldn't predict was the transfer over to a wildly growing popularization. We knew we would use it and that companies would use it; that wasn't an issue. But the explosion that took place with the Web was unpredictable, but of course that wouldn't have taken place if it didn't have a network to run on. So it's one of those serendipities. About four or five years ago the ACM [Association for Computing Machinery] asked me to write the predictions for its fiftieth anniversary—a projection of the next 25 years in networking and communication. I told them they were out of their mind; to do a five-year projection would maybe be accurate, I can reach for 10 with maybe some daydreaming, but this field is much too impacted by serendipity and it's very hard to predict."